Household Behaviour and the Environment

REVIEWING THE EVIDENCE

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**ORGANISATION FOR ECONOMIC CO-OPERATION
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1. Introduction

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1. Objective

This volume is based on the proceedings of the OECD Workshop on "Household Behaviour and Environmental Policy: Review of Empirical Evidence and Policy Issues" organised by the Environment Directorate, 15th-16th June 2006, in Paris.

The objectives of this volume are twofold:

- To review empirical evidence to better understand the determinants of household environmental behaviour in five key areas of environmental policy: waste generation and recycling, personal transport choices, residential energy use, food consumption and domestic water use.

- To provide further insight into how to improve the effectiveness and efficiency of environmental policies that affect households, while addressing social concerns.

2. Background

Environmental pressure from households is projected to significantly increase by 2030 (OECD, 2008a). One of the key determinants of household consumption patterns is economic growth, with the relative economic importance of countries such as China and India increasing. Steep growth in the world population (from approximately 6 billion in 2000 to over 8.2 billion in 2030) will also be an important driver of consumption. The trend towards ageing of the population, urbanisation and changing lifestyles will influence the structure of consumption as well.

Concerns about the environmental impacts of consumption and production, such as loss of natural resources, climate change and other environmental damage caused by emissions and waste, have been addressed at the global level by the United Nations since the 1992 Earth Summit, in Rio de Janeiro. The 2002 Johannesburg World Summit on Sustainable Development called for the development of a 10-year framework of programmes to promote sustainable consumption and production patterns. This challenging task is co-ordinated under the UN-led Marrakech process.

In response to the increasing environmental impacts of consumption, governments introduce policies to affect households' patterns of consumption and influence their decisions (OECD, 2008b). Some recent national initiatives include: the phasing out of incandescent bulbs (*e.g.* Australia, EU Directive), tighter minimum energy performance standards for residential buildings (*e.g.* Australia, Canada, Japan, EU Directive), fuel consumption labels (*e.g.* Canada, Korea, EU Directive), incentives to buy alternative-fuel vehicles (*e.g.* Canada, Norway, Sweden), congestion charges (*e.g.* UK, Sweden), grants for residential energy conservation projects (*e.g.* France, Germany), differentiated vehicle taxation (*e.g.* Korea, the Netherlands), rebates for investment in water efficient equipments (*e.g.* Australia) and organic food labelling (*e.g.* Canada).

Previous work has highlighted the need to have more insights on household environmental behaviour and consumption patterns (OECD, 2002; EEA, 2005). How do households respond to the various types of policies implemented by governments to promote more sustainable consumption patterns? How does environmental behaviour vary across households?

In this context, a project on Household Behaviour and Environmental Policy was initiated at the OECD Environment Directorate, in 2005, to provide guidance on the design of environmental policies targeted at households. This work aims at better understanding household environmental behaviour and how policies implemented by governments may affect household decisions in order to guide policy makers in their search for effective and efficient environmental policies, while addressing social concerns. Five areas in which environmental impacts arising from household consumption are significant were selected for analysis: energy and water use, food consumption, transport choices, and waste generation and recycling.

This activity consists of two main phases carried out over the period 2005-2008, under the guidance of the Working Party on National Environmental Policies (WPNEP). As part of the first stage, existing empirical evidence on the main drivers of household behaviour in these five policy areas were reviewed and the results were presented at the 2006 OECD Workshop on "Household Behaviour and Environmental Policy: Review of Empirical Evidence and Policy Issues". More than sixty participants, attended the Workshop, including representatives from governments, academia, international organizations involved in the Marrakech Process (UNEP) and non-governmental organisations (NGO's). The background papers commissioned by the OECD for the Workshop, as well as a review of the literature on the determinants of residential water use, served as inputs to the preparation of this volume.

This stocktaking exercise provided guidance for the next phase of the project, by identifying issues which could be usefully addressed with this OECD activity. Specifically, the second stage of the project involves the implementation of an OECD international household survey on environmental behaviour, in 2008, which covers the same five key policy areas (energy, organic food, transport, waste generation and recycling, water). The collected data will be analyzed with the objective of formulating policy recommendations.

This activity builds on earlier work undertaken by the OECD on household consumption[1] (OECD, 2003, 2002, 1999), while aiming at widening the scope of the previous analysis.

3. Approach

This volume seeks to bring new light to decision-makers on environmental policies targeting residential energy use, organic food consumption, water consumption, personal transport choices and waste generation and recycling in a number of ways:

- *By covering key areas where households exert pressure on the environment*

The volume examines five key areas where households exert pressures on the environment: waste generation and recycling activities, personal transport choices, residential energy use and food consumption and domestic water use. In particular, households' choices concerning energy and transport modes have direct implications for the challenging issue of climate change.

Total residential energy use in OECD countries is expected to increase by an average of 1.4% per year from 2003 to 2030. This increase will be more rapid in non-OECD countries than in OECD countries and forecasts indicate that non-OECD residential energy use will be nearly 30% higher than the OECD total in 2030. Residential energy demand grows with income, as households increase their stock of electrical appliances. This results in a rise in energy consumption overall, despite energy efficiency gains (OECD, 2008a).

Passenger kilometres travelled (on rail, air, buses and light duty vehicles) are projected to expand by 1.6% per year worldwide to 2030. Transport-related greenhouse gas (GHG) emissions are also expected to grow significantly. Improvements in the energy efficiency of transport vehicles will be more than offset by increases in the number of vehicles owned and in average vehicle use (OECD, 2008a).

Current waste management policies have been successful in diverting increasing amounts of valuable materials from landfill for further use, thereby reducing the associated environmental impacts. However, municipal waste generation is still rapidly increasing, in particular in non-OECD countries, and waste management will be a major challenge in the coming decade. The generation of municipal waste is projected to increase from 2005 to 2030 within the OECD region by 38% (1.3% per year) (OECD, 2008a).

Significant water scarcities already exist in some regions of the OECD and in many non-OECD countries. Even though many OECD countries in recent years have successfully reduced water use per capita and in total, it is projected that approximately 47% of the world's population will be living in areas with high water stress by 2030, mostly in non-OECD countries (OECD, 2008a).

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1. Assessing the environmental impacts from household activities was one of the objectives of a previous publication (see OECD, 2002) but it is largely outside the scope of this report.

A common feature of these four areas is that households tend to ignore the adverse effects of their decisions on the environment. Addressing this over-use by internalising the "environmental externalities" is a case for public policy intervention. The context is somewhat different for organic food, because if consumption proves to have less negative impacts on the environment, government intervention can encourage households to consume more organic products.

- *By examining various types of environmental policy instruments that target household behaviour*

The objective of the project is to assess the effect of different types of policy measures on household decision-making with respect to these five key environmental issues. This volume therefore considers households' responses to a broad variety of instruments including: economic instruments (*e.g.* taxes, pricing structure), labelling and information campaigns, direct regulation (*e.g.* water use restrictions, technical standards of appliances), as well as the provision of environment-related public services (*e.g.* recycling schemes, public transport).

Different environmental policy measures provide different incentives for "environmentally responsive" consumer choices and behavioural responses. Economic instruments, such as environmentally-related taxes, are often advocated to be the most cost-effective manner to meet environmental objectives. Taxes and subsidies will have a direct effect on the relative prices and will provide incentives for polluters and resource users to reflect environmental impacts in their decisions (*i.e.* to internalise externalities). Direct regulation, which is the most frequently used approach in OECD countries, can also be quite effective, by constraining the choice set available to consumers. However, it may create rigidities that might limit their environmental effectiveness and/or their economic efficiency. Policy makers can also rely on labelling and information campaigns which will affect the knowledge based upon which choices are made (OECD, 2008c).

More specifically, this volume reviews available evidence on the effects of a broad range of policies targeting changes in household consumption patterns and behavioural adjustments in the five areas examined. These measures include:

- For waste generation and recycling**:** *waste collection and management charges (flat fees vs. volume- or weight-based charges), deposit-refund systems, door-to-door vs. drop-off, recycling schemes, labelling schemes (e.g. recycled content), etc…*

- For residential energy use: *energy taxes, energy efficiency labelling of appliances and buildings, grants to invest in energy efficient equipments, technical standards of appliances, provision of differentiated 'green' energy, etc…*

- For organic food consumption[2]: *product labelling, information campaigns on organic food products, organic standards, etc...*

- For personal transport choices: *fuel taxes, congestion charges, subsidies for alternative-fuel vehicles, parking restrictions, emissions standards, quality of public transport, etc...*

- For residential water use: *pricing structure (fixed rate vs. increasing block tariff), grants for using water-efficient technologies, water efficiency labelling, etc...*

- *By considering differences in environmental behaviour among households*

Household consumption is generally considered at the aggregate level. By contrast, this project examines how environmental behaviour and consumption patterns may vary across households. This provides important insights on sources of environmental pressure. While important in itself, an accurate assessment of the role of these factors is also key in determining the actual influence of policy variables.

The project looks at how socio-demographic characteristics of households may influence their behaviour with respect to waste generation and recycling, personal transport choices, residential water and energy use and organic food consumption. It examines the role of socio-economic factors, such as income or education level. The demographic characteristics considered include: age, household size and composition, urban/rural. The role of attitudinal characteristics is also examined (*e.g.* environmental concerns, norms and values), because they can be important determinants of environment-related household behaviour.

4. Theoretical insights

This project also intends to bring new insights to policy makers for the design of environmental policies, with the objective of changing individual behaviour, by applying a theoretical framework which allows: (1) to analyse people's response to environmental policy and environmental behaviour in a extended approach of individuals' consumption choices and behaviour which includes "irrational" behaviour; (2) to consider differences in environmental behaviour among household groups; (3) to take into account both "private" and "public" motivations in household decisions.

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2. The work focuses on instruments directly targeting consumer choice concerning organic food consumption, such as the provision of information (*e.g.* organic labelling). The impact of government subsidies provided to agriculture to favour organic food production is outside the scope of this study.

Benefits of broadening the framework of standard economics to analyse household behaviour

In standard economic models, individual decision-making is based on the assumptions of rational behaviour and self-interest, according to which individuals make choices that maximize their well-being or utility under the constraints they face. These assumptions are often supported by empirical evidence: people facing policy incentives will respond generally in a manner consistent with welfare maximisation. Pricing will induce a change in consumption decisions, standards will also affect decision-making. Because of the existence of search costs, the provision of information to individuals will also allow them to express their demand for environmental quality.

However, there are areas where households' actual responses to environmental policies might differ from that predicted by standard economic theory.

In some cases, household responsiveness to economic incentives may be limited because of the existence of non-economic motivations. For example, evidence suggests that households have strong personal motivations to sort waste, and that relying on economic incentives may undermine such motivations (Frey, 1999; Frey and Oberholzer-Gee, 1997). Another possible "inconsistency" is the apparent gap between long-run and short-run preferences of agents, reflecting extremely high discount rates. This is of particular relevance for policies targeting residential energy use, where agents fail to adopt energy-efficient technologies that are cost-effective.

Better understanding existing differences in responsiveness, and the factors that can explain these "anomalies", is therefore of value to provide guidance to policy makers for the design of environmental policies. The framework adopted in this volume to analyse household consumption decisions and environmental behaviour, accordingly, includes the role of attitudinal and contextual elements.

Insights from economics as well as from other disciplines of social sciences, including sociology and psychology, complement each other to provide a more comprehensive picture of household behaviour and response to environmental policies. The approach used here draws on behavioural economics and recognises that society can shape individual preferences and beliefs, in particular through institutions and social norms, and socialization processes.[3]

Different models can be applied to explain environmental behaviour - such as the theory of planned behavior[4] and the value-norm-belief model.[5] Individuals' behaviour in these models is considered to be influenced by the perception of what others think about their behaviour (*e.g.* "social norms", "normative believes") and

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3. See Boudon, 1988; Burt, 1992; Coleman, 1990; Granovetter, 1985; Hedström, 2005; Raub and Weesie, 1990.

4. See Fishbein and Ajzen, 1975; Ajzen, 1991; Sparks and Shepherd, 1992; Kaiser *et al.*, 1999, Kalafatis *et al.*, 1999.

5. See Stern *et al.*, 1995 and Stern, 2000.

personal beliefs, such as the moral obligation to contribute to a better environment.[6] These models prove to be particularly relevant in the analysis of travel mode choices[7], organic food purchases[8] and recycling activities.[9]

Better understanding of how norms and values can affect the environmental behaviour of individuals can provide useful insights to policy makers for choosing (and combining) instruments to improve the effectiveness and efficiency of policies. Government can also influence norms (Nyborg, 2003), in particular, through information-based instruments such as communication campaigns; this may also contribute to increasing the acceptability of policies.

Benefits of considering differences in environmental behaviour among household groups

Why not consider households as a homogenous group? Better understanding of how environmental behaviour may differ among households is likely to bring useful insights to policy makers to better target policies. The fact that households respond differently to similar policy measures is not sufficient justification to target policies, but there are some conditions and good reasons why it can be important to target policy instruments at specific groups. However, targeting measures may entail important administrative costs that need to be taken into account by policy makers.

To target policies that need to be targeted by nature

Individuals tend to underestimate the negative effects of their decisions on the environment. Internalising environmental externalities and inducing individuals to take into account these effects in their decision-making process is a case for public intervention.

In some instances, the existence of environmental externalities may not be the only source of market inefficiencies. Policy makers may need to use complementary measures to remove other failures in addition to the instruments more directly targeting the environmental externality (*e.g.* energy tax to reduce CO_2 emissions from residential energy use). These other sources of market barriers and failures include: information asymmetries, failures on the capital market and split incentives ("landlord/tenant" failure). Some of these measures need to be targeted at specific household groups to improve the effectiveness and efficiency of the policy. Considering differences in environmental behaviour among household groups may facilitate this process.

The provision of information to consumers so they can make informed choices is a common motivation for government intervention. The slow adoption of

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6. See Poortinga *et al.*, 2004.

7. See Bamberg and Schmidt, 2003; Harland *et al.*, 1999; Heath and Gifford, 2002.

8. See Grunert and Juhl, 1995; Stern *et al.*, 1999; Makatouni, 2002; Zanoli and Naspetti, 2002; Tanner and Kast, 2003.

9. See Berglund and Matti, 2006; Thørgesen, 2003.

environmentally preferable goods may, for instance, be primarily due to information failures and search costs. Information-based instruments, such as energy labels for appliances and building certificates are, for instance, introduced in combination with energy taxes. There may be differences in access to information across households which prevent some household groups from expressing their underlying demand for environmental quality.

Some households (*e.g.* low-income households) may face constraints to access the credit market, preventing them from making investments in environmentally preferable goods (*e.g.* alternative fuel vehicles, water/energy efficient equipments) which would appear to be cost effective for them to undertake. Policy makers may therefore need to adopt complementary measures to address these barriers in the capital market. These measures include grants or preferential loans targeted at vulnerable households.

Some households may face few incentives to invest in environmentally preferable goods or to adopt environmental behaviour. For instance, the landlord has little incentive to choose the most water/energy-efficient equipment (*e.g.* space heaters, lighting system) and/or to invest in isolation, when the tenant benefits from these choices though reduced energy/water bills. Government may need to introduce targeted measures to address this source of market failure.

To address distributional effects of environmental policies on households[10]

Besides looking at the environmental effectiveness and economic efficiency of measures, governments generally consider the social effects of environmental policies. The implementation of policy instruments may raise distributional issues and government concerns about the distributional effects of environmental policies generally arise when it is felt that a policy instrument is regressive, in the sense that its financial burden falls disproportionately on vulnerable households (*e.g.* low-income households). It may also arise if the environmental benefits of policies accrue disproportionately to higher-income households. All public policies are likely to have distributional effects of some kind and the need to tackle them arises when the effects are significant or if the perception of the distributional impacts represents a significant barrier to the introduction of the policy.

Better understanding differences in behaviour according to individual characteristics is required in order to address distributional concerns, while still ensuring that the economic efficiency and environmental effectiveness of the policy remains intact. Distribution according to economic status (*e.g.* across household income) is only one criterion by which to examine distributional issues. The approach used in this project allows for the examination of other possible criteria, including distribution across age, ethnicity or geographical areas.

The distributional impacts of a wide range of instruments are considered here. Evidence on the distributional issues related to the use of environmental policies generally focuses on the possible regressive impacts of economic instruments, in

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10. See Serret and Johnstone (2006).

particular taxes. This may be attributed to the relative transparency of financial impacts compared to other measures. However, the relatively few studies available suggest that other policy instruments, such as direct regulation, also have distributional implications, even if these implications are often less transparent.

Insights gained from distinguishing between "private" and "public" benefits

A mixture of "public" and "private" considerations is likely to enter into households' decision-making processes. Individuals' actions can bring about benefits that will be enjoyed by individuals collectively (*e.g.* improved air quality), in addition to private interests (*e.g.* considered best for themselves).

In the scope of this volume, individual choices where both "public" and "private" benefits can be considered include the following types of decision: to recycle or not; to buy a fuel-efficient vehicle or not; to consume organic foods or not. For instance, by recycling, households may reduce waste-related environmental impacts (public benefits) and reduce their expenditures on waste collection (private benefits) at the same time. In a similar way, purchasing organic food products may result in lower use of pesticides (public benefits) and improved personal health (private benefits); purchasing of a fuel-efficient vehicle may reduce emissions of greenhouse gases (public benefits) and reduce life-cycle vehicle costs (private benefits). The purchase of energy and/or water efficiency appliances may as well reduce pressure on the environment (public benefits) and expenditures and water and/or energy use (private benefit).

The relative importance of private and public considerations may vary from one environmental policy area to the other. For instance, among labels relating to environmental issues, energy-efficiency labels are characterized by the fact that energy users receive a direct private benefit from using energy-efficient products (*e.g.* reduced utilization costs), which is not normally the case with recycling-related logos (*e.g.* for recycled materials).

Taking into account the existence of "public "and "private" objectives in individual decision-making can help improve the design of environmental policies by finding the right balance between incentives targeting "public" and "private" motivations. However, it can be sometimes difficult to 'unbundle' private and public motivations in household decisions.

The co-existence of private and public motivations can have implications for the design of public measures aiming at providing information (*e.g.* labels, information campaigns), so that consumers can make informed choices. For example, as organic food consumption is believed to provide both public (environmental) and private (health) benefits, the effectiveness of information campaigns to promote organic food consumption might benefit from making reference to both types of expected benefits.

5. Main messages

In light of the outcome of the first phase of the project, as summarized in this report, a better understanding of the determinants of household behaviour provides useful insights to policy makers on how to best influence residential energy and water

use, household waste generation and recycling levels, personal transport choices, and organic food consumption. In particular, the report addresses questions about:

- households' responsiveness to different types of policy measures;
- the effects of socio-demographic, attitudinal, and contextual factors;
- the presence of interaction effects between policy instruments and socio-demographic, attitudinal, and contextual factors;
- the presence of complementary (versus substitution) effects among different types of policy measures;
- the distributional effects of different types of policy instruments.

The results suggest that finding the right balance among environmental, economic, and social policy objectives requires careful policy design.

6. Road map

The remainder of the volume consists of five papers reviewing the literature on the determinants of household behaviour in the five key environment-related areas addressed. The last paper discusses the main policy implications. **Paper 2** presents the empirical literature on the determinants of domestic waste generation and recycling activities[11]; **Paper 3** gives an overview of recent empirical studies on the determinants of personal transport choice which takes into account the factors influencing car use and car choice as well as demand for public transport[12]; **Paper 4** provides a review of the empirical literature on the drivers of residential energy demand[13]; **Paper 5** sums up the findings of studies which examine the factors affecting the demand for environmentally responsible products (ERPs), including organic products[14]; **Paper 6** summarizes the empirical findings on the determinants of residential water use.[15] Finally, **Paper 7** concludes by examining key areas in which empirical work is likely to inform policy makers for the design of effective and efficient policies while addressing social issues like distributional concerns.

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11. This paper is based on "Empirical Evidence in the Area of Waste Management and Recycling" prepared for the OECD and discussed at the Workshop by Ida Ferrara, Atkinson Faculty of Liberal and Professional Studies, York University, Canada.

12. This paper is based on "Review of Empirical Studies on Personal Transport Choice" prepared for the OECD and discussed at the Workshop by Joyce Dargay, Institute for Transport Studies, University of Leeds, U.K.

13. This paper is based on "Empirics of Residential Energy Demand" prepared for the OECD and discussed at the Workshop by Bengt Kriström, University of Agricultural Sciences, SLU-Umea, Sweden.

14. This paper is based on "Review of Empirical Studies on Environmentally Responsive Food Choice" prepared for the OECD and discussed at the Workshop by Stefano Boccaletti, Università Cattolica del S. Cuore, Italy.

15. This paper is based on "Residential Water Use: A Literature Review" prepared for the OECD by Ida Ferrara, Atkinson Faculty of Liberal and Professional Studies, York University, Canada.

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2. Waste Generation and Recycling

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1. Introduction

There are two serious failures that arise in the management of solid waste. The first relates to the existence of negative externalities in the individual decision-making over waste generation and disposal. When individuals decide on how much to consume and what to consume, they do not take into account how much waste they produce. Because the external costs of waste generation (such as air and water pollution) are ignored by individuals, more waste is produced and disposed of than is socially optimal. The second serious failure relates to the ways in which waste collection services are typically financed. More often than not, individuals pay for waste disposal in lump sums through general taxes or flat payments to local governments or private collectors. Hence, waste disposal costs are not fully reflected in the prices households face at the margin. Even if these flat charges included both the private and external costs of waste production and disposal, individuals would still face zero prices for additional waste produced, and would thus tend to produce (and dispose of) more waste than if they were to pay for the additional garbage according to its social marginal cost.

Addressing the issue of municipal solid waste is an important policy objective and one which is becoming increasingly challenging to address. On the one hand, while the awareness of the external effects of waste generation is increasing, there is resistance by society to the development of new landfills and incineration facilities. On the other hand, municipal solid waste generation has grown significantly over the last decades as a result of higher incomes, more intensive use of packaging materials and disposable goods, and increased purchases of durable material goods. This problem is projected to continue to grow, despite current efforts to reduce the material content of products and to stimulate the reuse of products and packaging and the recycling of materials and substances.

It is then not surprising that many countries actively seek to reduce and dispose of waste more effectively. In particular, governments have become increasingly concerned with their waste disposal financing options, and have become interested in experimenting with unit charges for garbage collection services to induce people to produce less waste by consuming more environment-friendly goods and by engaging in recycling activities. In addition to quantity-based fees, which represent a market incentive approach, governments have also turned their attention to recycling programs or regulatory approaches as a means of diverting waste from landfills. With residential solid waste becoming a more important issue to policy makers, many theoretical and empirical papers

have been produced by economists to understand how (and to what extent) household waste management decisions are affected by government policies and socio-economic variables. A review of the theoretical literature on the economics of household waste management can be found in Choe and Fraser (1998), Fullerton and Kinnaman (2002), and, more recently, in OECD (2004). Most of the models support the use of a deposit/refund type scheme: that is, a system consisting of an advanced disposal fee applied either at the production or the purchase point and a recycling subsidy to households that recycle or firms that purchase recycled materials. Other models support the use of a virgin material tax or a direct tax on households' disposal choices. Unfortunately, deposit/refund systems are very complex to administer, and are thus subject to high transaction costs; they may therefore be inappropriate for certain waste types, such as food and some types of plastic. Hence, in spite of there being theoretical consensus among economists that deposit/refund mechanisms are efficient, advanced fees and recycling subsidies are not very common and deposit/refund systems are only implemented for beverage containers.

The empirical literature is also quite extensive, flourishing over the past ten years in response to the increased interest on the subject among policy makers. Key issues that are addressed in this literature are whether unit-based pricing programs have significant effects on household garbage and recycling behavior, whether recycling programs are effective, and whether user fees work better if used in isolation or when combined with a recycling program. Furthermore, empirical studies look at the impact of socio-economic or demographic variables on household decisions over waste disposal and recycling; some of these studies, although very few, also allow for attitudinal and contextual characteristics as potential determinants of waste management practices.

Understanding how these variables affect households' waste generation and recycling choices enables policy makers to take more informed decisions about where and when to implement a particular policy. For example, if attitudes towards recycling matter, investing in educating households about the environmental impact of waste generation and recycling may be attractive. If households living in multi-family dwellings tend to recycle less than those in single-family dwellings, implementing recycling programs uniformly across a community may not be advisable. If old households tend to recycle more because of the lower opportunity cost of time they face, policy initiatives intended to reduce the time intensity of recycling activities may be appealing. If age matters, in that it has a negative effect on waste disposal but a positive effect on recycling, recycling programs (as opposed to unit pricing systems) may be a better policy option in communities with a larger proportion of elderly people. If home-owners recycle more, a unit pricing system (as opposed to a recycling program) may be more effective in communities with high rental rates. If population density has a negative effect on recycling, a unit pricing system may provide better incentives for more environmentally responsible waste management activities in denser communities. These are just some of the many considerations that policy makers must account for when deciding on whether and how to target a particular group or community to provide the necessary incentives or mechanisms for a more socially optimal management of waste *vis-à-vis* a reduction in waste generation and disposal and an increase in recycling.

In Section 2, a review of the empirical literature on waste management and recycling is provided. The review is structured in terms of the relevant variables analyzed in the studies discussed, that is, waste generation, recycling, waste prevention, and willingness

to pay for waste collection services[1]. In Section 3, the policy implications that arise from the discussion of the empirical literature are elaborated upon and concluding remarks highlighting existing gaps in the literature and pointing to areas where additional insights would be valuable for the formulation of policy recommendations are given.

2. Literature review

In this review of the empirical literature on household solid waste management, results are presented according to four themes: waste generation, recycling, waste prevention, and willingness to pay. In most cases, the studies reviewed cover more than just one theme as the four areas (and especially the first three) are inevitably linked. In a conceptual framework, disposal activities are in fact related at two different levels: *i)* by a waste constraint according to which total garbage, which depends on consumption, is equal to the amounts of recycled, composted, legally discarded, and illegally disposed of waste; *ii)* by a time constraint according to which the time investments in the four disposal options must add to some fixed amount of time allocated to waste management. Hence, for a given consumption pattern and level, any policy affecting any of the four disposal options would inadvertently have an impact on at least one of the other options. Conversely, any change in one of the activities that is not accompanied by much of a change in the other alternatives would have to be coupled with changes in consumption level and/or pattern. In terms of time, as disposal activities are time-consuming, although the marginal effect of time is not necessarily uniform across the four options, any policy affecting the amount of time devoted to one activity would influence the (time) resources spent on at least one of the other disposal options. Naturally, any change in time devoted to any of the four activities that is not accompanied by changes in the time devoted to the other activities would have to be coupled with changes in resource allocation to leisure, which, ultimately, would result in changes in consumption levels and/or patterns.

2.1 Waste generation

Of the seventeen empirical studies reviewed here that are concerned with waste generation, five rely on community-level data, eight on household-level data, and the remaining four are either based on municipal data obtained by aggregation of household data or rely on model simulation using parameters obtained by calibration of the model employed to actual values of the relevant variables. At the community level, the studies are those by Jenkins (1993), Strathman *et al.* (1995), Podolsky and Spiegel (1998), Kinnaman and Fullerton (2000), and Dijkgraaf and Gradus (2004). At the household level, the studies are those by Hong *et al.* (1993), Fullerton and Kinnaman (1996), Nestor and Podolsky (1998), Hong (1999), Hong and Adams (1999), Sterner and Bartelings (1999), Van Houtven and Morris (1999), and Linderhof *et al.* (2001). The authors of the remaining four studies are Richardson and Havlicek (1978), Morris and Holthausen (1994), Palmer *et al.* (1997), and Miranda and Aldy (1998).

In Richardson and Havlicek (1978), an analysis of economic and social factors affecting the quantity and composition of household solid wastes is provided, based on

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1. The results of the studies are summarized in the three tables presented in the related online report, "Household Waste Generation and Recycling: Summary of Empirical Results", at *http://dx.doi.org/10.1787/482400015020.*

data from a stratified random sample of 24 municipal waste collection areas in Indianapolis. For each area, the quantities of eleven selected household solid waste components (*e.g.* clear glass, brown glass, green glass, aluminum, other metals, textiles, newspaper, all other paper, plastics, garbage/other) are obtained during July and August 1972 by aggregation of the wastes in the various categories generated by 60 to 90 households without their knowledge of being studied before or after the project. Additional data on the variables included in the analysis as determinants of waste (*e.g.* household income based on house and property values, household size, percentage of people between 18 and 61 years old) come from the 1970 census. Each of the eleven equations estimated but the brown glass equation, which is dropped from consideration, is found to be statistically significant. Household income has a positive effect on green glass, aluminum, newspaper, and total garbage, but a negative effect on textiles, plastics, grass, and garbage/other, which includes food wastes, dirt, ashes, ceramics, and miscellaneous items not suitable for any other category. The positive effect on newspaper could be attributed to the fact that higher-income households tend to purchase more newspapers and have thus larger quantities of newsprint that could be potentially recycled; the negative effect on textiles could be explained by the fact that higher-income households tend to dispose of clothing through charitable institutions; the negative impact on garbage/other may be the result of fewer meals being consumed at home as higher-income households tend to eat away from home more often than lower-income households. Household size has a consistently positive effect on every waste component but newspaper and grass. The percentage of people in the 18 to 61 age group has also a consistently positive effect on every waste component but newspaper, textiles, grass, and garbage/other; hence, there is a tendency for households in the middle of their life cycle to produce more garbage.

In Hong *et al.* (1993), a data set of 2 298 households in the three-county Portland metropolitan area (in Oregon, USA) surveyed through a multi-stage stratified sampling method during 1990 is utilized to estimate the demand for solid waste collection services as a function of household attributes (size, education, race, tenure status, income, and value of time) and the fee for disposing of an additional 32-gallon can.[2] The value of time is computed from the woman's wage or, in households without a female adult, from the man's wage; for households headed by a retired person, the opportunity cost of time is presumed to be zero. The estimation procedure employed involves two stages: in the first stage, as collection service charges depend on the level of service contracted, the disposal fee variable is regressed on one-can, two-can, and three-can disposal charges and household attributes (income, value of time, education, race, and house ownership); in the second stage, a linear (two-stage least squares) equation for trash disposal services is estimated upon substitution of the predicted values for disposal charges from the first stage for the actual disposal charges. Hence, the estimation results suggest that households that are non-white or have higher incomes (although the demand is income-inelastic) or that rent their homes or have larger families tend to demand more garbage

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2. Trash disposal fees are based on a block (32-gallon can) payment schedule that specifies the volume of garbage to pick up over a given time interval and the frequency of collection. Disposal fees are based on competition among waste collection firms. The incremental disposal fee for a 32-gallon can is then computed for each household based on quoted price schedules and the household's quantity of solid waste (non-recyclable) produced.

collection services. The disposal charge does not, however, seem to play any role in households' decisions about how much garbage to dispose of at the curb.

In Jenkins (1993), monthly data from nine US communities, covering a period of at least one year during the 1980s for each community, are pooled to construct a panel data set for the estimation of the residential and commercial demand functions for solid waste collection services. Five of the communities rely on user charges and have minimum service requirements which, although differing across the communities, have the common purpose of reducing the chance that individuals respond to a user fee by illegally discarding their waste. The remaining four communities either have flat fees or finance their disposal services out of property tax revenues. Furthermore, as many of the nine communities do not have separate records on the quantity of commercial versus residential solid waste, the empirical model consists of three different equations: one representing residential demand (using data from four communities, only one of which with a user fee system), another representing commercial demand (using data from one community), and a third representing the sum of residential demand and commercial demand (using data from five communities). Of the residential sector regressors considered in the analysis, average household income, mean temperature, average precipitation, age distribution of the population as captured by the proportion of the population aged between 18 and 49, and population density as a proxy for urbanization are found to positively affect waste disposal.

The effect of *income* is somewhat unexpected as, although high-income families consume more and thus produce more waste, they tend to have a consumption pattern that does not favour waste-intensive goods (starchy and sugary goods and beverages), to dine in restaurants more often, and to donate their old clothing to charities as opposed to discarding it, thus producing less waste; in theory, it is not clear that income would have a positive influence on waste disposal.

The effects of the *weather* variables are expected as, during the growing season when there are warmer temperatures and greater precipitation, yard waste increases; furthermore, rain augments the weight of all types of absorptive waste.

The effect of *population density* is for the most part explainable: as urbanization increases, consumers have easier access to retail outlets so that they tend to buy smaller quantities more frequently, which leads to a lot of packaging waste; as urbanization increases, households also have less storage and avoid storing easily replaceable items such as gift boxes, choosing to throw them away and repurchase them later when needed. However, as urban populations have small yards and little yard waste, the overall effect of urbanization on waste disposal does depend on the relative strengths of the two effects.

As the young adults are the greatest consumers of material goods within a society, they are expected to have high waste quantities as the positive estimate of the coefficient of the population age distribution suggests. Of the three remaining variables to discuss, price received for old newspapers, which is used to proxy the price households receive for *recycling* in view of the fact that a great portion of the refuse recycled is paper and most of the paper recycled is newspaper, is statistically insignificant. The other two, *average household size* and *user fee*, have a negative impact on waste disposal. The negative effect of the former suggests that there exist economies of scale within the household, that is, the average refuse per family member declines as the number of members increases.

There are various reasons why this is the case: consumption of certain goods, such as newspaper, is not increasing with household size; the consumption of family-sized food and personal care items reduces packaging waste per capita; certain items, such as clothing and toys are used for longer periods of time as they are passed down from one child to another. Finally, the user fee is found to be quite effective; the price elasticity of demand is in fact -0.12 which implies that a 10% increase in the user charge results in a 1.2% decline in waste per person.

In Morris and Holthausen (1994) a household production model of waste management is developed to illustrate key relationships among consumption, waste reduction, recycling, and disposal. The model is then simulated based on parameters obtained by calibration of the model to actual waste flows, prices, and expenditures observed in Perkasie, a small suburban community in Bucks County, Pennsylvania, under two very different economic and institutional regimes: one, in place before 1988, with fixed fees for garbage collection, no curbside recycling, and a twice-a-week mixed waste collection; the other, instituted in 1988, with per-unit (bag-based) charges, curbside recycling, and once-a-week collection. Specifically, simulations are provided for various scenarios: fixed fee and no recycling (F1), fixed fee and recycling (F2), variable fee of USD 0.50 and recycling (U12), variable fee of USD 0.75 and recycling (U22), and variable fee of USD 1.00 and recycling (U32). Upon comparison of the results in the various scenarios, U12 versus F1, U12 versus U22, and U22 versus U32, unit pricing is found to provide households with incentives to reduce curbside waste disposal, incentives which do not seem to dissipate as the user fee is increased, although the source of reduction shifts from an increase in recycling to a decrease in waste production.

In Strathman *et al.* (1995), monthly data from the Portland, Oregon, metropolitan area covering the period from January 1984 to December 1991, are used to estimate the demand for landfill disposal services (in terms of tons of landfilled waste per thousand residents), which is specified as a function of tipping fees, average weekly income of manufacturing workers (as a proxy for income), and construction employment (as a proxy for the local business cycle and also because substantial amounts of waste result from construction activities). Under some simplifying assumptions, namely, that the elasticity of substitution between landfill services and other inputs like incinerating and recycling services is zero, as pointed out in Nestor and Podolsky (1996) and emphasized in Strathman *et al.* (1996), that all the waste disposed of is landfilled (there is no illegal disposal), and that landfilling charges are fully passed on in collection fees (there is marginal cost pricing or the nature of collection services is competitive), the price elasticity of demand for collection services is computed as the product of the price elasticity of demand for landfill disposal services and the inverse of the disposal's share of total cost. The calculations then yield a waste collection services elasticity of -0.45, which is three times larger than the elasticities estimated in previous studies, suggesting that the pricing of waste collection is more effective at reducing waste volume than previously thought.

In Fullerton and Kinnaman (1996), the effect of the bag-based unit pricing system introduced in Charlottesville, Virginia, in 1992, is studied in the basis of a sample of 75 households, whose bags or cans of garbage and recyclable materials are counted and weighed over two four-week periods before and after the implementation of the program and whose income and demographic characteristics are collected by means of a questionnaire. Per-capita garbage weight, garbage volume, and garbage density are thus

estimated as functions of the number of newspapers delivered daily per person, the fraction of the household consisting of children under three years old, the presence of at least one member with some college education, income groups, the presence of at least an adult married couple, and whether the household is white. Other variables, such as home ownership, employment, age, and household size, are initially included in the analysis but eventually omitted as they are found to be insignificant. Hence, changes in garbage weight, volume, and density are computed and found to be statistically significant. In response to the implementation of the program, the average household reduces garbage weight by 14% and garbage volume by 37%; at the same time, however, the average household increases garbage density (weight per can) by 43%, which suggests stomping activities. The ordinary least squares estimation procedure is then employed to determine how the changes in the various waste measures are affected by demographic variables. For both garbage weight and garbage volume, the decrease is smaller for households that subscribe to more daily newspapers, for those with infants, and for married couples; it is greater for households with more income. For garbage density, the increase is larger (and thus more stomping occurs) among married couples but lower (and thus less stomping occurs) for households with more income.

In Palmer *et al.* (1997), a partial equilibrium model of waste generation and recycling is developed to evaluate the cost-effectiveness of various policies for reducing solid waste disposal, namely, refundable deposits, which are equivalent to disposal charges, advance disposal fees, and recycling subsidies. The model is then calibrated with elasticity estimates from previous empirical studies and with 1990 price and quantity data for each type of the five materials considered (paper, glass, plastic, aluminum, and steel) which account for 56% of all municipal solid waste discarded. Within the calibrated model, the three policies are compared and contrasted in relation to a 10% reduction in total waste. The results suggest that the waste disposal reduction target is achievable either with a USD 45 per ton deposit/refund, or with an USD 85 per ton advance disposal fee, or with a USD 98 per ton recycling subsidy. The lower intervention level of the refundable deposit is attributed to the greater incentives that exist under a deposit/refund system as it relies on both source reduction and recycling; on the other hand, the other two policies take advantage of opportunities for either only recycling or only source reduction. The recycling subsidy encourages recycling but also consumption by lowering the effective price of the final material for those users who recycle. The advance disposal fee discourages consumption, thus decreasing the amount of material available for recycling and reducing recycling. The results also suggest that there exist significant cost implications if common waste reduction targets are set for specific materials as opposed to for all of the wastes; for example, a USD 70 (as opposed to a USD 45) per ton deposit/refund is required to achieve a 10% reduction in the disposal of each of the five materials. Hence, if the social marginal cost of disposal is the same across different waste types, it may be more costly to set policy goals for individual materials as opposed to implementing a single disposal price for all materials.

In Miranda and Aldy (1998), a case study involving four California, three Illinois, and two Michigan communities with unit pricing programs for residential waste collection (five urban and four suburban communities varying significantly in terms of population size and density, and median household income and housing value) is conducted to ascertain how the various characteristics of the nine unit pricing programs affect program outcomes. Of the nine communities, five have a bag-based pricing system and the remaining four have a cart-based subscription system, with fees per gallon ranging from 2

to 10 cents. All nine communities operate a curbside recycling program, which is freely provided only in seven of the communities, with mandatory participation in one case, voluntary participation in six cases, and provision of recycling containers and service upon request in two cases. Also, all communities but one provide yard waste collection and, of the six communities with yard waste collection data, three charge yard waste collection fees. Finally, all communities have various rules and ordinances to ensure residential compliance with their waste management systems and special collection programs for items such as appliances and holiday greenery. In general, following the implementation of a unit pricing system, communities are found to experience decreases[3] in annual residential waste landfilled and incinerated, in addition to growth in recycling and yard waste collection, some source reduction, and undesirable diversion activities such as dumping in commercial dumpsters and burning of refuse.

In Nestor and Podolsky (1998), the effects of two basic approaches to unit pricing practiced in the United States, namely, a bag/sticker program and a subscription can program, are compared and contrasted. Under the former, households purchase official program bags or stickers to attach to a standard size garbage bag. Under the latter, households subscribe to a level of service per period of time in advance and pay accordingly: the more cans per week they subscribe to for pick-up, the more they pay. In order to evaluate the relative performance of the two systems, an experiment is conducted in the City of Marietta, Georgia, in 1994, which involves randomly assigning the two program variations to collection routes in the community. The data are collected by means of a phone survey, which is administered twice, before the experiment, when garbage collection services are financed through a flat fee system, and after the experiment, when some households (121) face a bag-based pricing system and others (163) a can-based subscription pricing system. With the phone survey, information on households' socio-economic characteristics and waste management practices in terms of number of full and partial 30-gallon bags of trash and recyclables set out for curbside collection, managed on-site, and transported off-site, is gathered at two points in time.[4] Additionally, the charge per unit of waste (bag or can) is included into the analysis. While the per-bag fee is readily available, the per-can fee under the subscription program is computed as the difference between the monthly cost of a one-can per collection service and the monthly cost of a two-can per collection service, divided by the number of additional cans collected during the month. The tobit[5] estimation procedure is then applied to estimate the waste in each of the six alternatives mentioned above as well as

3. Decreases tend to be larger in communities with higher user fees and smaller minimum container size.

4. Hence, households decide whether to dispose of or recycle the waste they produce and, for each type (trash versus recyclable), whether to pay for curbside collection, or manage it on-site, or transport it off-site. In essence, households face six waste management alternatives. On-site management would, for example, include composting of trash and reuse of recyclables. Off-site transportation would include commercial dumpsters or public receptacles for trash and drop-off or donation centres for recyclables.

5. The tobit specification is based on a maximum likelihood estimation procedure that treats the zero values of the dependent variable differently from the other values. When a continuous dependent variable is censored at zero and a large number of zeros are observed, the usual least-squares estimates are biased, even in large samples, whether all of the zeros are included in the estimation and treated same as the other values or they are omitted from the analysis.

the total waste produced, which is equal to the sum of the waste managed by the six methods, as functions of the price per 30-gallon container, whether the unit pricing system for garbage disposal is based on bags, annual household income, fraction of members under the age of 18, fraction of members working full-time, fraction of members who are 65 or older, number of individuals in the household, whether the home is owner-occupied, whether the household is non-minority, and whether garbage disposal is available in the household.

Based on the results about trash or garbage management, *income* appears to be a significant and positve determinant of on-site disposal; however, the estimated coefficient and corresponding marginal effect are extremely low. The fraction of *individuals in the household working full time* has a negative influence on off-site disposal, while the fraction of *individuals who are 65 or older* has a significant and negative effect on every management alternative but on-site disposal. *Large households* tend to have higher levels of curbside trash while *home-owners* tend to have lower levels of curbside and off-site trash but higher levels of on-site trash. Finally, *non-minority households* seem to have less curbside and on-site garbage. As for the estimated *price effects* of the bag-based and subscription systems, the findings suggest that both programs lead to a decrease in curbside trash, although the latter is less effective at decreasing trash. The bag-based system has no other significant effect while the can-based (or subscription) system increases on-site and off-site disposal. The availability of garbage disposal in a household increases garbage generation.

In the empirical section of Podolsky and Spiegel (1998), a cross-sectional data set involving 149 municipalities from five New Jersey counties is utilized to estimate by the ordinary least-squares procedure the relationship between quantity of municipal solid waste disposal, unit pricing, and the quantity of municipal recycling. Of the 149 communities examined, 12 have unit pricing (bag- or tag-based) during some portion of the year of analysis (1992) and the remaining 137 finance waste disposal either through general tax revenues or flat fees. For all of the 149 municipalities, however, recycling programs are mandatory. To capture the influence of unit pricing on the demand for municipal solid waste disposal services, the price per ton of waste (computed upon adjustment of the different prices of bags or tags across the communities by the permitted weight per unit volume of a disposal container under the assumption that the weight limits are binding) and an interaction variable between tons of recycling per household and an indicator for the presence of unit pricing are employed.

The estimation results confirm, as theory suggests, that households respond to an increase in the unit disposal fee by reducing their demand for waste disposal services, with a demand elasticity (as measured at the mean values of the user fee and per-capita tons of garbage in communities with unit pricing) of -0.39; however, the indirect effect of unit pricing through an increase in recycling is insignificant, although negative. In other words, the effect of recycled level on waste disposal, which is significant and negative implying that households view waste disposal and recycling as substitutable waste management activities, is the same independently of whether a unit pricing system is in place. To isolate the effects of policies and to explicitly identify factors contributing to the demand for municipal solid waste disposal which are not under the control of government officials, various socio-economic variables are also included in the analysis. Of these variables, *income* per household increases waste disposal, with an income elasticity as measured about the sample means of 0.55 implying that waste disposal is a

normal, non-luxury good; *number of employees* per household, which accounts for non-residential waste disposal in the data, also increases waste disposal but at a decreasing rate; median *age* and *number of persons* per household decrease waste disposal, although the effect of the latter is declining. Finally, *population density* and *snow* have a negative impact on waste disposal while *rainfall* has a positive effect. Population density increases as the cost of occupied space increases; hence, the negative relationship between waste disposal and density suggests that households' waste management is sensitive to changes in the cost of occupied space. As for the weather variables, rain naturally causes the weight of bags/containers to increase while snow may reduce the provision of municipal waste disposal services.

In the final section of the study, the welfare implications of unit pricing are computed for two types of municipalities, the average and largest communities, from the data without unit pricing, and two levels of the unit price, a low price of USD 1.00 per ton and a higher price of USD 1.60 per ton. The calculations show that the reduction in waste disposal expenditures and the social welfare gain (the difference between the dollar value of the resources needed for the provision of waste disposal services over and above their optimal level and the total willingness to pay for this additional supply) is significant. Even when illegal disposal is accounted for on the basis of the largest estimate of incremental illegal waste disposal found in Fullerton and Kinnaman (1996) of 0.42 pounds per person per week and the reduction in waste disposal expenditure is assumed to be utilized for the provision of other services, the net social welfare gain (social welfare gain minus social cost of illegal disposal) is sufficiently large to potentially more than offset any additional administrative cost associated with unit pricing. Under the conditions of the smallest unit price (USD 1.00) and smallest average household size (2.06), the incremental administrative cost would have to be more than USD 6.90 per household for unit pricing to actually entail a social welfare loss.

In Hong (1999), a sample consisting of 3 017 Korean household survey data is employed in a simultaneous equation model that considers the feedback effects between total waste generation and recycling to examine the impact of the price incentives that arise under a unit pricing system on household waste generation and recycling in Korea. Data are collected in December 1995, following the adoption by the Korean government of a bag-based unit pricing system on household solid waste in 1995, and comprise quantities of non-recyclables and recyclables in terms of number of bags per week and household characteristics, including age, income, education level, residential location, and household size. The results for the system of structural equations estimated by three-stage least squares show that, with the exception of the user fee which is insignificant, the variables included in the total waste generation function have positive effects; specifically, households with higher incomes, more members, and higher recycling rates tend to produce more garbage.

In Hong and Adams (1999), the effects of the block payment system adopted by the Portland (Oregon) metropolitan area consisting of four counties with a population of 1.4 million are studied. The block payment system differs from the per-bag payment system in that households must contract with haulers for the collection of a specified volume of garbage at a given interval (usually once a week). The specified volume is based on standardized cans (one or more 32-gallon size) or carts (20-gallon, 40-gallon, 60-gallon, and 90-gallon sizes). Under such a system, households contract for a volume that is less than the expected amount of total solid waste generated if the opportunity cost of

recycling and/or composting is less than the savings from avoiding the next largest container size. The disposal fee is thus computed as the incremental collection fee between the contracted size and the next largest size of can or cart.[6] The analysis involves a sample of 944 households for which the amount of discarded non-recyclables is weighed 8 times (twice per season) on collection days between August 1992 and July 1993 and the amount of recyclables is weighed twice (on two days when non-recyclables are measured) and to which a face-to-face survey is administered following the waste measurements. The panel data set is then used to estimate two models: a can/cart choice model to determine the factors affecting households' decisions over the volume to contract and the demand equations for waste disposal, recyclable collection, and recycling rate.

The first model is based on the face-to-face household survey data and consists of an ordered probit estimation of the probability of contracting for a larger can/cart as a function of the payment difference, income, household size, education level, home ownership, the presence of a garage, and the presence of children under 3 years of age.[7] The results of this model reveal that *household size* and the *presence of small children* are the only two factors affecting households' choice of volume contracted; specifically, size has a positive effect on the probability of choosing a larger container while the presence of small children has a negative effect.

The second model is based on the entire panel comprising the survey data and the waste measurements over time and thus includes (time) fixed effects captured by seasonal dummy variables. The results of the two-stage least-squares estimation of the demand for waste collection services suggest that households with *more occupants* and/or with a *child under 3* years old generate more waste while households living in a house equipped with a *garag*e generate less. As for the *seasonal effects*, the demand for non-recyclables collection services tends to be highest in the spring and lowest in the winter. Of the remaining variables included in the estimation, the payment difference is the only variable with a significant negative effect on non-recyclables. Even though the payment difference does not seem to influence households' decision about the can/cart size to contract, the block system is successful at providing them with the incentive of disposing of less waste in order to avoid being moved into a higher (more expensive) block if the amount of non-recyclable waste exceeds the contracted volume.

In Sterner and Bartelings (1999), an attempt is made to investigate the importance of attitudinal variables on households' waste management decisions. The data employed come from a Swedish municipality, Varberg, where a weight-based billing system is

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6. For example, the additional cost (or price of waste disposal) for a household using a 32-gallon can is the difference between the cost of a 40-gallon can and that of a 32-gallon can; for a household using a 20-gallon cart, it is the difference between the cost of a 32-gallon cart and that of a 20-gallon cart. This difference is used as a proxy for the unit price of waste collection services.

7. As in Hong *et al.* (1993), the predicted payment differences are used instead of the actual payment differences. Hence, in the first stage of the estimation, the price variable is regressed on 32-gallon can and 40-gallon cart service fees, income, household size, home ownership, education level, garage status, and the presence of small children. The results are used to compute the predicted values of the payment differences which are, in turn, used in the second stage to estimate the can/cart choice model and the demand equations.

introduced in 1994. Unfortunately, the data available, which are based on a mail survey and post-reform measurements of waste flows for about 450 households in a single residential area, do not cover the period before the implementation of the program so that price effects are omitted from the analysis. The data are thus used to estimate the demand for waste disposal services and study households' composting behaviour and willingness to pay for sound waste management. The demand for waste disposal model includes personal characteristics (gender, marital status, education, age, household members, and people staying at home), economic characteristics (living area, garden area, and income), variables related to waste management (time spent on waste management and distance to recycling center), behavioural variables (recycling of different materials, such as paper, glass, batteries, and hazardous waste, and composting of garden and kitchen waste), and attitudinal variables (importance of waste problem, composting, change in buying habits, change in attitude towards waste problem, difficulties in recycling paper and glass, batteries, and hazardous waste, and importance of fee structures). The results show that *attitudes* do play an important role in waste disposal decisions. In particular, the more difficult households perceive recycling to be (especially of paper/glass and hazardous waste), the more garbage they dispose of at the curb; a positive attitude towards composting leads instead to a lower demand for garbage collection services. Among the *behavioural* variables, the composting of kitchen waste is the only variable with a significant (and negative) effect. As for the *personal* and *economic* characteristics, age and the number of people staying at home have a negative impact on waste disposal demand while living area has a positive influence.

In evaluating the determinants of composting behaviour based on the survey data, the percentage of composted kitchen waste is regressed on attitudes, personal and economic characteristics, and whether waste management is perceived to have significant time requirements. The results show that the composting of garden waste is the variable that is most relevant in the decision over kitchen waste composting: households with access to garden waste are more likely to compost kitchen waste as they have the habits and equipment. If households perceive waste management to be time-consuming, they are less likely to compost. To some extent (at a lower significance level), households with larger living areas compost less while households that believe in the importance of fee structures for waste management compost more.

In Van Houtven and Morris (1999), the impacts of two unit-based pricing programs (a bag program and a subscription can program) introduced in Marietta, Georgia, in January 1994 as part of a pay-as-you-throw solid waste demonstration project are investigated at both the community (or route) and the household levels. The route-level analysis relies on a panel data set consisting of monthly tons of mixed waste collected on 16 sanitation routes from August 1991 to October 1994 and involves separating the impacts of the two unit pricing systems from seasonal variations in waste generation as well as determining whether the two programs differ in terms of effectiveness at reducing waste and whether this difference varies across months. Based on the estimation results of the route-level study, both programs are found to have significant negative impacts on waste generation in each of the ten months of the demonstration period (January to October 1994), with the bag program however producing a larger reduction and with larger effects (in terms of waste reduction) witnessed in months during which households tend to have larger amounts of waste (April, June and July). In the household-level analysis, information on the economic and demographic characteristics of 398 households, the attributes of their homes and yards, and their attitudes on solid waste issues is collected by means of a

telephone survey conducted prior to the demonstration project. Furthermore, for each of the 398 households, mixed waste and recyclables are measured four times over a two-week period before the implementation of the unit pricing program and, similarly, four times over a two-week period during the demonstration period.

Of the 398 households, 230 (58%) participate in the subscription can program and the remainder participate in the bag program. The data set is then employed to analyze mixed waste, recycling, and total (mixed waste plus recyclables) waste. The amounts of mixed and total waste per household are estimated with a tobit model; the probability of recycling is estimated with a probit model. Based on the estimation results pertaining to the effects on waste disposal, mixed waste increases with the *number of residents* but is lower for more *educated* and for *urban* households and for households that consider waste reduction to be important. Both the can and the bag programs reduce mixed waste, although the former is not as effective as the latter (a 20% versus a 51% reduction under the bag program over a two-week period); furthermore, the effect of unit pricing is larger in households with many residents and lower among home owners. Other variables included in the study, but found to be insignificant, are whether the household's residents are white and home ownership.

In Kinnaman and Fullerton (2000), data on 114 US communities with user fee programs (from the US Environmental Protection Agency and phone inquiries) and 845 communities without user fees but with and without curbside recycling (from the International City Managers Association) are used to estimate both the demand for garbage collection and the demand for recycling collection. Secifically, the per-capita quantities of collected residential garbage and recyclable material are estimated as comparable functions of the price of garbage, the presence of a curbside recycling program, per-capita income, average household size, the percentage of the population consisting of people who are 65 or older, the percentage of those 25 or older with a bachelor's degree or higher, the percentage of households that own their home, density, and dummies to account for the possible effects of state laws prohibiting yard waste from landfills, deposit/refund systems for bottles, and mandatory recycling. Data on demographic characteristics come from the US Census. To control for the possibility of endogenous local government decisions about the price per bag of garbage collected and whether to implement curbside recycling, the price per bag of garbage and the probability of implementing free curbside recycling are first estimated as functions of observable exogenous variables such as the regional tipping fee, the population density, several state policy variables, and demographic characteristics.[8] The predicted values of the policy variables are then used in the garbage and recycling demand equations to correct for endogeneity.

The results of the second stage estimation of the demand for garbage collection on the exogenous variables listed above and the predicted values of the curbside recycling and

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8. The probability of implementing free curbside recycling is found to increase with the regional tipping fee, density, and education, and to decrease with household size and whether a refundable deposit system is in place. The user fee is found to increase with education, regional tipping fee, whether a yard waste ban is in place, and whether municipal resources are used for garbage collection; the user fee instead decreases with income. The effects of all the other variables included in the probit (for probability of recycling) and tobit (for user fee) estimations are found to be (statistically) insignificant.

user fee variables reveal that *income* has a positive effect while *education, mandatory recycling,* and *unit-based pricing* have a negative effect. When compared to the estimation results in the absence of correction for endogeneity in local policy choices, the *user fee* and the *mandatory recycling* are found to be more effective at reducing garbage,[9] suggesting a community self-selection bias, that is, communities with larger per-capita waste are more likely to implement a user fee system, or the presence of unobserved variables that affect both the quantity of garbage and the probability that a community implements unit pricing. The inclusion of communities with subscription programs whereby households pre-commit to a certain number of bags for which they pay independently of whether they use them serves to reduce the overall impact of the user fee.

In Linderhof *et al. (*2001), the effects of a weight-based pricing system are analyzed for Oostzaan, a countryside village north of Amsterdam and the first municipality in the Netherlands to introduce a weight-based pricing program (in October 1993). Households (3 437 in total) are surveyed between 2 and 42 times, starting in July 1993, that is, before the implementation of the unit pricing system, and ending in September 1997. Observing households for such a prolonged period of time allows for the possibility of differentiating between short-run and long-run price effects through the inclusion of the lagged dependent variable (weight of waste) as an explanatory variable. Hence, the weight of compostable waste and the weight of non-recyclable waste are estimated as functions of the marginal price of waste, household composition (percentage of women), size, age of household head, indicators for children's age, temperature, seasonal and annual indicators, and the lagged weight of waste. In both regressions, the disposal fee is found to be effective at decreasing waste; the reduction in compostable waste is however much larger than the reduction in non-recyclable waste, possibly because of the existence of an easy alternative to curbside collection for compostable waste, namely, home waste composting, but not for non-recyclable waste. Furthermore, in both instances, the long-run effects are larger than the short-run effects (the estimated coefficient of the lagged dependent variable, when used as an explanatory variable, is significant and positive), implying that the effects of the weight-based pricing system continue in future periods. The amounts of compostable and non-recyclable waste also depend positively on the *number of people* in the household, the *share of women* in the household (as women tend to have lower labour force participation rates than men in the Netherlands and thus spend more time at home), on *temperature*, and whether there are *infants* (between zero and 2 years old) in the household. The presence of children 2 or more years old increases compostable waste but reduces non-recyclable waste. *Age* has no impact on compostable waste but reduces non-recyclable waste although at a decreasing rate. The estimated coefficients of the annual indicators (for 1994, 1995 and 1996) are, in general, significant and negative, implying lower amounts of waste in the years following the implementation of the user fee system; these effects strengthen the conclusion that the program is

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9. In particular, a user charge of one US dollar per bag would reduce annual per-capita garbage by 412 pounds when endogeneity is accounted for and by 275 pounds in the absence of correction. Mandatory recycling, instead, reduces garbage by 89 pounds in the former case but has no significant effect in the latter.

effective at reducing waste, especially compostable waste.[10] The significant *seasonal* effects in the third and fourth quarters (relative to the first quarter) are negative for both types of waste and those in the second quarter are negative only for non-recyclable waste; the strongest impacts are however in the third quarter, possibly because of a holiday effect as the third quarter includes the summer school holidays.

In Dijkgraaf and Gradus (2004), a cross-section of Dutch municipalities over a three-year period, from 1998 to 2000, is used to estimate the effects of four different unit-pricing systems (weight -, bag-, frequency- and volume-based systems)[11] on total waste, unsorted waste, compostable waste (such as vegetable, food and garden waste), and recyclable waste (such as glass, paper and textiles). For each waste stream (total, unsorted, recyclable and compostable), the quantity of waste is estimated as a function of dummies for the presence and type of unit-pricing system, socio-economic characteristics (area of a municipality per inhabitant, average family size, number of non-western foreigners per inhabitant, percentage of total inhabitants earning a median income, number of houses sold per inhabitant, number of flats sold per inhabitant, dummies for small and large municipalities, and percentage of inhabitants older than 65), time-invariant regional fixed effects, and time fixed effects. Data on the quantities of waste collected come from studies by the Dutch Waste Management Council (AOO) while data on the socio-economic characteristics come from the Dutch Central Bureau of Statistics (CBS).

In general, the results for unsorted waste suggest that unit-based pricing is effective; specifically, unsorted waste decreases by nearly 50% under a weight- or a bag-based system, 27% under a frequency-based system, and 6% under a volume-based system. As for the socio-economic characteristics, *income* has a positive effect and *family size* has a negative effect. Communities with a larger *population of elderly* people and/or a smaller *population of foreign* people tend to have larger quantities of waste per capita. Lastly, *density* has a significant and negative effect. Once the possibility of influential environmental activism (that is, the possibility that households in municipalities with unit-based pricing systems are more concerned about the waste problem than households in municipalities without such systems) is accounted for through the inclusion of a dummy that separates municipalities with a unit-based pricing system throughout the sample period from those with a unit-based pricing system only in later years (1999 or 2000), the findings indicate that municipalities with a high level of environmental activism have 13% less unsorted waste. The larger effects of unit-based pricing systems typically found in studies that rely on community-level data, as opposed to household-level data, may therefore result from a lack of correction for environmental activism.

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10. Non-recyclable waste is lower in 1994, statistically the same in 1995 as in 1993, and higher in 1996. The increase in 1996 is actually found to be higher than the reduction in 1994. Compostable waste is lower in each of the three years, with a larger decrease in latter years, providing additional evidence that the long-run effects of the user fee program are stronger than the short-run effects.

11. Under the volume-based pricing system, households decide on their waste supply at the beginning of the contract period and at annual review times, and choose between different volumes of collection can. This is effectively a subscription-based program.

2.2 Recycling

Among the empirical studies concerned specifically with recycling, Callan and Thomas (1997), Kinnaman and Fullerton (2000), and Dijkgraaf and Gradus (2004) employ community-level data, and Hong *et al. (*1993), Judge and Becker (1993), Reschovsky and Stone (1994), Fullerton and Kinnaman (1996), Nestor and Podolsky (1998), Hong (1999), Hong and Adams (1999), Sterner and Bartelings (1999), Van Houtven and Morris (1999), Jenkins *et al.* (2003), Ando and Gosselin (2005), and Ferrara and Missios (2005) rely on household-level data. Other studies that fall neither under the community-level nor the household-level categories include Morris and Holthausen (1994), Hornik *et al.* (1995), and Miranda and Aldy (1998).

In Hong *et al.* (1993), a household-level data set from a 1990 survey conducted in the three-county Portland metropolitan area (Oregon, USA) is utilized to investigate whether, how, and the extent to which the frequency of recycling participation is influenced by household attributes (size, education, race, tenure status, income, and value of time) and by the fee for disposing of an additional 32-gallon can. Upon substitution of the predicted values of disposal charges for the actual disposal charges, which are obtained by estimation of the disposal fee variable as a function of one-can, two-can, and three-can disposal charges and household attributes (income, value of time, education, race, and house ownership), an ordered probit model is used to estimate the frequency of recycling with results that suggest that all of the variables listed above (including the disposal fee) but income have a significant impact on recycling participation. In particular, the disposal fee, the number of people in the household, and the level of education contribute to more frequent recycling; the opportunity cost of time, renting, and being non-white contribute to less frequent recycling.

In Judge and Becker (1993), a controlled field experiment involving 1 000 homes in Rice County (Minnesota) is conducted to investigate the relationship between recycling convenience, solid waste diversion, and program costs. In particular, the 1 000 households participate in a variety of voluntary house-to-house recycling programs differing in frequency of recyclable pick-up, sorting requirements, pick-up location, and the amount of recycling educational material distributed. The weekly recycling volume of each participating household is monitored over a six-month period, from November 1989 through April 1990. A random sample of 20% of the participating households is thus selected and additionally (door-to-door) surveyed to obtain demographic information on household size, age, education, and home ownership. Hence, the extent of diversion, captured by the number of recycling bins per household per week is estimated by tobit procedure as a function of convenience factors, efforts to educate residents about recycling, and household demographic characteristics. Not surprisingly, convenience factors are found to increase recycling; specifically, more frequent collection (from biweekly to weekly), lower sorting requirements (from sorting recyclables into separate containers for glass, plastics, newspaper, and metal to commingling recyclables in one large bin), and more convenient pick-up location (from curbside to any location on the property) contribute to increasing diversion. Educational efforts aiming at promoting interest in recycling have no effect on recycling behaviour. Of the demographic variables, only *size* and graduate *school/college education* seem to have a significant and positive impact on the quantity of recyclables. The regression results are then shown to be helpful in determining the type of recycling program to implement, or the efficient level of

convenience, on the basis of marginal analysis, that is, by a comparison of the marginal benefit and marginal cost of increasing convenience.

In Morris and Holthausen (1993), a household production model of waste management is simulated based on parameters obtained by calibration of the model to actual waste flows, prices, and expenditures to analyze the effects of introducing a variable fee for waste disposal in the absence or presence of recycling, of introducing a recycling program in the absence or presence of a variable fee system, and of increasing the variable fee when a recycling program is already in place. Upon comparison of the results of the various scenarios, particularly when household decisions under a fixed fee and no recycling regime are compared with those under a variable fee and recycling regime, implementing a variable fee in combination with a recycling program serves to induce households to recycle more, in addition to producing and disposing of less waste. However, when a recycling program is already in place, that is, when the results of the fixed fee and recycling regime are compared to those of the variable fee and recycling regime, introducing a user fee system does not lead to an increase in recycling; on the contrary, households are found to respond to the system by recycling less, although households do produce and dispose of less waste.

In Reschovsky and Stone (1994), data from a 1990 mail survey of 1 422 households in Tompkins County in the Finger Lakes region of upstate New York are employed to study the factors affecting the decision of recycling several recyclable materials (newspaper, glass, plastic, cardboard, metal cans, and food/yard waste). The presence of a number of different waste management policies (drop-off centers, curbside recycling, mandatory recycling, and bag-based user fee) within a somewhat small geographical region provides the opportunity to examine household responses to various approaches, in terms of individual policies as well as combinations of policies, to solid waste reduction. In addition to the policy variables, which are constructed on perceived rather than actual policies because of the many households misperceiving the set of policies applying to them, the analysis allows for the inclusion of income, education, age, household size, number of hours per week in paid employment, marital status, gender, and storage space at home.

Based on the probit estimation results, the only two demographic variables that consistently affect the probability of recycling (or, more correctly, whether households recycle) are the marital status and *education;* specifically, married households and more highly-educated households tend to have higher recycling (being married has however no effect on the recycling of plastic and cardboard). *Household size* has a negative effect on the recycling of newspaper but a positive effect on the recycling of food/yard waste or composting. Women tend to recycle more glass and plastic. *Age* seems to matter only for cardboard recycling and composting, with older persons recycling less cardboard but composting more. The weekly number of *paid labour hours* has a negative impact only on newspaper recycling while *income* has a negative impact on glass and plastic recycling. *Knowledge* of a drop-off center within 5 miles of the home and adequate *storage space* as assessed subjectively by households are positive determinants of recycling for all materials but newspaper. The effect of the variable capturing how well informed about the recycling programs households feel they are is significant and positive

for all the materials but food/yard waste.[12] As for the policy instruments, the bag-based fee seems to have no impact on recycling, although it increases composting. For newspaper and glass recycling, three combinations of policies are found to be effective but to different extents: mandatory recycling with curbside pick-up; bag-based fee and curbside pick-up (least effective); mandatory recycling with curbside pick-up and bag-based system (most effective). Curbside pick-up coupled with the bag-based program also increases the probability of recycling plastic and cardboard. Finally, curbside pick-up by itself has a positive effect only on cardboard recycling.

In Hornik *et al.* (1995), variables affecting consumer recycling behaviour, taken from 67 empirical studies and classified into four theoretical groups depending on whether they are motivators for or facilitators of recycling and whether they are internal or external to the consumer, are meta-analyzed. Demographic variables are also included but grouped into a separate category. Based on mean correlations between each of the independent variables included in the analysis and the propensity to recycle, internal facilitators (knowledge of and commitment to recycling) are the strongest predictors of recycling, followed by external incentives (monetary incentives and perceived social influence) and internal incentives (locus of control, ecological concern, and personal satisfaction). Of the external facilitators (proximity of containers, frequency of collections, and distribution of materials), frequency of collections is quite significant while the other two facilitators, along with the demographic variables (age, education, income and type of housing), have the least predictive power.

In Fullerton and Kinnaman (1996), households are found to respond to the 1992 implementation of a bag-based unit pricing system in Charlottesville, Virginia, by increasing recycling weight by 16%. This increase, which tends to be smaller for white households and larger for households that subscribe to more daily newspapers, is however concluded to be insufficient to cover the cost of administering the program, even if the increase in illegal disposal that is detected in the study, accounting for 28 to 43% of the weight reduction in curbside garbage, is completely ignored.

In Callan and Thomas (1997), a study involving 324 Massachusetts communities is conducted to estimate the ordinary least-squares coefficients of the determinants of recycling efforts, which include State and local policies as well as socio-economic characteristics. Data for each town's recycling activity and the policy instruments are obtained from the Massachusetts Department of Environmental Protection for fiscal year 1995; data on the socio-economic variables come from the 1990 Census. Hence, the recycling rate is estimated as a function of local initiatives (use of unit pricing and availability of curbside recycling and disposal services), state initiatives (access to the state's materials recycling facility and state-awarded grants for recycling education and equipment), residents' characteristics (median income and educational attainment), and towns' attributes (median housing value, housing age, density, population, and

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12. The effects of the indicators about adequate storage, about not knowing the location of the nearest drop-off center (which is significant and negative only for metal recycling), and whether households feel they are well informed about the recycling programs should be viewed with caution because of the possibility of measurement errors and endogeneity. For example, households least interested in recycling are also least likely to seek out information about recycling programs; households that do not recycle are also more likely to attribute their failure to recycle to inadequate storage space.

community classifications). Additionally, squared terms for population and education are included to capture non-linearities in the effects of these variables on recycling efforts as well as interactive terms between policy instruments to determine whether the effectiveness of any policy is influenced by the complementary use of other policies.

Of the local initiatives, unit pricing and curbside recycling are effective policy tools for stimulating a community's recycling efforts, especially if they are both implemented. Unit pricing contributes to a 24.7% increase in the average recycling rate if used alone and to a 45.4% increase if used in combination with curbside recycling; similarly, curbside recycling leads to a 15.6% increase if implemented alone and to a 36.2% increase if implemented in combination with unit pricing. On the other hand, the provision of curbside trash disposal has no effect on recycling when compared to the provision of drop-off disposal.

Of the State policies, provision of free recycling at the State's materials recycling facility increases the average recycling rate by 35.8% but has no additional effect if combined with unit pricing or curbside recycling; equipment grants have no explanatory power while each additional dollar awarded per household for recycling education contributes to a 9.6% increase in the average recycling rate.[13] As for the remaining variables, income, education, and housing value have a positive effect on recycling efforts while housing, age and population lower the recycling rate; for both education and population, the effects are non-linear and tend to mellow down. Finally, towns classified as resort, retirement, or small rural communities tend to have higher levels of recycling than urbanized centers; in contrast, there is no evidence that the recycling rate in economically developed suburbs, growth communities, residential suburbs, and rural economic centers differs from the recycling rate in urbanized centers.

In Miranda and Aldy (1998), the impact of implementing a user fee system is examined in the context of a case study involving nine US communities differing in demographics and waste management policies. In terms of recycling, the results of the analysis point to more recycling activities in response to user charges for waste disposal, with larger increases witnessed in communities using smaller minimum container sizes.

In Nestor and Podolsky (1998), the estimated price effects on curbside, on-site, and off-site recycling of the bag-based and subscription systems introduced experimentally in the City of Marietta, Georgia, in 1994, suggest that both programs lead to an increase in curbside reycling but the latter is more effective. The bag-based system has no other significant effect while the can-based (or subscription) system increases on-site and off-site recycling. Among the other variables included in the analysis, namely, annual household income, fraction of members under the age of 18, fraction of members working full-time, fraction of members who are 65 or older, number of individuals in the household, whether the home is owner-occupied, whether the household is non-minority, and whether garbage disposal is available in the household, *income* appears to be a significant and positive determinant of recycling, although the estimated coefficient and corresponding marginal effect are extremely low, the fraction of individuals who are

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13. The link between grant awards and a measurable effect on recycling may be time-dependent; in other words, it may take time for a community receiving a grant to purchase equipment or educational materials and even more time for such expenditure to affect behaviour.

under the age of 18 has a positive impact on on-site and off-site recycling, the fraction of individuals who are *65 or older* has a significant and negative effect also on on-site and off-site recycling, *large households* tend to have higher levels of curbside recycling but lower levels of on-site recycling, and *home owners* tend to have lower levels of on-site recycling.

In Podolsky and Spiegel (1998), although recycling behaviour is not studied, some conclusions about the effect of unit pricing on recycling arise out of the estimation of waste disposal as a function of, among other variables, the level of recycling and an interaction variable between recycling and unit pricing. The effect of the recycling level on waste disposal, which is significant and negative implying that households view waste disposal and recycling as substitutable waste management activities, is found to be the same independently of whether a unit pricing system is in place. Hence, the unit price is not effective at increasing recycling and thus decreasing municipal waste disposal or, participation to the recycling programs being mandatory in all of the communities included in the study, there is no room for the user fee to further increase recycling, as instead found in Callan and Thomas (1997).

In Hong (1999), survey data collected in 1995 from 3 017 Korean households are utilised to estimate the system of equations relating total solid waste generation to the recycling rate, the user fee, household income, and household size, and recycling efforts to total waste generation, the user fee, the opportunity cost of time, and the education level. As Korean housewives are those who, for the most part, look after waste disposal, the housewife's value of time, which is derived from her wage equation, is estimated as a function of age, education, and area of residence. The results show that all the variables included in the recyclable supply function are significant and have positive effects, with the exception of the opportunity cost of time which has a negative effect. Specifically, households with more education, higher waste production, lower opportunity cost of time, and living in communities with higher user fees tend to recycle more.

In Hong and Adams (1999), the demand for recyclables collection and the recycling rate are estimated based on a panel data set pertaining to 944 households from the Portland (Oregon) metropolitan area whose recycling practices under a block system are observed and recorded on two different occasions during 1992. The findings of the estimation suggest that households with more occupants and/or with a child under 3 years old have lower recycling rates and that households' recycling rate and demand for recyclables collection services tend to be higher in the autumn and lower in the winter. Of the remaining variables included in the estimation (income, home ownership, education level, presence of garage, and disposal fee), the payment difference or disposal fee (that is, the incremental collection fee between the contracted size and the next largest size of can or cart) is the only variable with a significant and positive effect on recyclables and recycling rate. Although the payment difference does not seem to influence households' decision about the can/cart size to contract, the block system is successful at providing them with the incentive of recycling more, in addition to disposing of less waste, in order to avoid being moved into a higher (more expensive) block if the amount of non-recyclable waste exceeds the contracted volume.

In Sterner and Bartelings (1999), the results of a special study of recycling and waste disposal attitudes and habits carried out in three Swedish communities with different fee structures (weight-based fee, frequency-based fee, and a flat fee) and based on a mail

questionnaire are presented and discussed. Of all the recyclable materials considered (glass, paper, refundables, batteries, hazardous waste, household machines, and textiles), only for glass recycling there seem to be significant differences among the three municipalities; specifically, the two municipalities with unit-based pricing systems tend to have higher percentages of recycling. The estimation results also reveal that previous experience with recycling (the degree to which households are accustomed to recycling, which is naturally influenced by individual characteristics) does have a positive impact on the recycling of any material; information about waste problems and change in buying behaviour have a positive impact on paper recycling; household size has a positive effect on paper recycling but a negative effect on the recycling of textiles, possibly because families with many children tend to recycle clothes internally so that they have fewer textiles to recycle; ease of recycling has a positive effect on the recycling of glass, paper, and batteries; the average age of adults in the household has a positive effect only on the recycling of refundables; attitude about the importance of waste seems to be a positive contributing factor only for the recycling of textiles.

In Van Houtven and Morris (1999), household-level data are collected in 1994 before and after the experimental implemention of a unit pricing program (either subscription or bag-based) in Marietta, Georgia. Additional information about the households' economic and demographic characteristics, the attributes of their homes and yards, and their attitudes on solid waste issues is collected by means of a telephone survey conducted prior to the demonstration project. The analysis of recycling activities confirms that both unit pricing systems are successful at increasing the probability of recycling, especially in households with a higher percentage of full-time workers; however, there seems to be no evidence that the bag program performs better and, according to the results of separate regressions involving the amount of recycling, that either of the two programs increases the quantity of recyclables. Furthermore, white and owner-occupied households, households that believe in the importance of waste reduction, and households with more residents in the 25-to-64 age group tend to recycle more; urban households and households with more members working full-time tend to recycle less.

In Kinnaman and Fullerton (2000), data from 959 US communities, of which only 114 have a user fee system in place, are employed to estimate the demand for recycling collection as a function of policy variables (user fee, recycling program, mandatory recycling, deposit/refund system for bottles, and ban on yard waste) and socio-demographic characteristics (income, size, age, education, home ownership, and density). Controlling for the possibility of endogenous local government decisions about the user fee level and whether to implement a recycling program does not yield statistically significant differences in results, with the effect of curbside recycling being the only exception. Specifically, the implementation of a curbside recycling program is more effective in the endogenous choice model, suggesting that there is either a community self-selection bias or that there are unobserved variables that decrease recycling but make communities more likely to adopt curbside recycling. In light of the similarity, the uncorrected estimation results are used to conclude that more recycling occurs in communities where there are more elderly people, larger households, more educated people, more people owning their homes, and where a user fee system is in place. Income, on the other hand, seems to have no impact on recycling, possibly because of offsetting effects: a wage increase leads to a consumption increase, which translates into higher waste production and therefore greater demand for garbage collection and recycling; a wage increase leads also to an increase in the opportunity cost of time, so that

we expect a decrease in time-intensive disposal options such as burning, dumping, and recycling. As the effect of a one US dollar user fee on garbage is not comparable to that on recycling (a 412 pounds reduction in garbage versus a 30 pounds increase in recycling), the study points to the importance of further research to determine whether and the extent to which a user fee reduces consumption, shifts consumption patterns in favour of less waste-intensive goods, increases composting, and/or induces households to resort to less attractive disposal alternatives such as burning and dumping.

In Jenkins *et al.* (2003), household survey data from 20 US metropolitan areas[14] are used to estimate (with an ordered logit regression) the intensity of recycling activities by material (glass bottles, plastic bottles, newspaper, aluminum, and yard waste) as a function of socio-economic (population density, income indicators, household size, age of household head, detached home indicator, home ownership indicator, and education indicators) and policy variables (disposal price, curbside indicator, drop-off indicator, number of materials for curbside collection, indicator for mandatory curbside recycling, indicators for age of recycling programs). The results show that both the availability of drop-off recycling and curbside recycling have a positive effect on the intensity of recycling efforts for the five different materials. Drop-off and curbside recycling programs can be viewed as proxy measures for how convenient recycling is; they are expected to reduce the time and storage costs of recycling, thus making recycling a more appealing disposal alternative.

Because of the lower transportation cost involved in curbside recycling, it affects recycling to a larger extent than the drop-off program. Clearly, in both cases (drop-off and curbside), the effects vary across the five types of recyclables, with the probability of recycling heavier materials such as glass and plastic bottles being more responsive because of larger transportation and storage costs the management of these materials involves. However, making a curbside recycling program mandatory does not have any effect on households' decisions about recycling for any of the five recyclable materials. This is consistent with the finding in Kinnaman and Fullerton (2000) that mandatory recycling has a positive impact only on garbage but not on recycling.

In Jenkins *et al.*, unlike in other studies, including Kinnaman and Fullerton (2000), the disposal price plays no role in households' decisions about recycling. This could be the result of communities with unit-based pricing systems being poorly represented in the data set (only 116) and, furthermore, of many communities with unit-based pricing systems having subscription programs, under which households pre-commit to a certain number of bags so that, at the margin, they face zero cost for having additional garbage. In Kinnaman and Fullerton, the effect of a user fee is smaller when communities with subscription programs are included and disappears when only communities with subscription programs are considered. As for the socio-economic variables included in the study, household *income* has a significant and positive effect on the recycling of newspaper; *education* has a significant but small effect on the recycling of all materials except plastic bottles and yard waste (surprisingly, however, the impact of college education on the recycling of glass bottles is lower than that of high school education);

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14. Of the 1 049 observations available, 116 come from communities with unit-based pricing systems; out of these 116 households, 104 live in communities with subscription programs and the remaining 12 live in communities with bag/tag/sticker programs.

age has a positive but small effect on the recycling of all materials except glass bottles; *household size* matters only for the recycling of glass bottles and yard waste (possibly because they are more time-intensive than the other materials as bottles must be cleaned and yard waste must be bagged); living in a *single-family dwelling* matters only for the recycling of plastic bottles and yard waste (possibly because of the higher storage requirements than the other materials, especially for yard waste); *home ownership* has an impact only on the recycling of glass bottles and aluminum; as population becomes denser and outdoor storage space becomes scarcer, households tend to recycle less yard waste.

In Dijkgraaf and Gradus (2004), the effect on recycling of four unit-based pricing systems are compared and contrasted based on data from a cross-section of Dutch municipalities over a three-year period. In general, unit-based pricing is found to be effective at encouraging recycling. Specifically, a weight-based system serves to increase recyclable waste by 21% while a frequency-based system increases it by 10%; a volume-based system has instead no significant effect. A bag-based system that prices both unsorted and compostable waste has an effect comparable to that of the weight-based system; however, a bag-based system that applies only to unsorted waste with a free collection container provided for compostable waste tends to have a smaller positive effect on recyclable waste. This difference, coupled with the increase in compostable waste experienced under a bag-based system with a free collection container for compostable waste, suggests that part of the recyclable waste is dumped in the free compostable waste can, presumably because of the lower time cost associated with using the can, which is located in the direct vicinity of the house, as opposed to the facility for recyclables, which is farther away. As for the socio-economic characteristics included in the study, *income* and *size* have no effect; communities with a larger population of *elderly people* and/or a smaller population of *foreign people* tend to recycle more; municipalities with many flats tend to have less recyclable waste while municipalities with many houses tend to have no significantly different recyclable waste; *density* has no significant effect. When the possibility that households in municipalities with unit-based pricing systems are more concerned about the waste problem than households in municipalities without such systems is accounted for, municipalities with a high level of environmental activism are found to have 4% more recyclable waste.

In Ando and Gosselin (2005), survey data from 214 households in Urbana, Illinois, are employed to analyze recycling efforts of single- and multi-family dwellings (SFDs and MFDs). Overall, recycling rates tend to be higher in SFD, older, more educated but not MFD, and single-gendered households, among newspaper subscribers, and in MFD households with adequate interior storage space. The lateral distance that recyclers, independently of whether they live in apartments or houses, must walk to put out their recyclables has a significantly negative impact only on container recycling, possibly because containers are bulky, messy, heavy, and fragile, and thus more costly (in terms of time and efforts) to carry. In general, households that tend to engage in recycling when they are not at home have higher paper and container recycling rates; for MFD households that recycle when out in public, the higher rates apply only to paper recycling. Households with two adults or with just women seem to have higher recycling rates for containers while MFD households with work and study responsibilities that sum to less than a full-time commitment tend to recycle more paper.

In Ferrara and Missios (2005), a relatively large household survey data set from 12 municipalities across Ontario, Canada, is collected in 2002 and used to estimate a model similar to that employed in Jenkins *et al.* (2003). Of the 1 409 observations included in the study, approximately 40% pertain to households facing a positive marginal price of garbage disposal, that is, households living in communities with unit pricing systems (bag/tag programs to be more precise). As in Jenkins *et al.*, a material-specific ordered probit analysis is carried out and the probability of recycling each of the recyclable materials considered (newspaper, glass, plastic, aluminum, tin cans, cardboard, and toxic chemicals) is regressed on five household demographics, namely, home ownership, income, education, household size, and age of household head, and five policy variables, namely, user fee, indicator for weekly (as opposed to biweekly) recyclables collection, indicator for free units under the unit pricing system, unit disposal limit indicator, and mandatory recycling indicator. Unlike in Jenkins *et al.*, the *user fee* is found to effectively increase the intensity of recycling for all the seven materials but toxic chemicals, which are excluded from the unit pricing system. Increasing the frequency of recycling collection from every two weeks to once a week (thus reducing the storage cost of recyclables and making recycling more appealing) results in more recycling of glass, aluminum, and toxic chemicals. Providing free units under a user fee system does however induce households to recycle less while mandating curbside recycling leads them to recycle more of every material but glass. Unit limits (limits on the number of units of garbage that can be placed at the curb or bag limits) have a significant and negative effect only on the recycling of plastic and toxic chemicals. Interestingly, even though toxic chemicals are not included in the weekly collections (they are banned from normal garbage collection in all of the communities included in the survey), their recycling is affected by recycling frequency, mandatory recycling, and bag limits; this suggests that there may be indirect spillover effects of curbside recycling into depot recycling: policies that promote more curbside recycling also promote the recycling of non-curbside items.

Household characteristics have substantially different impacts, in both size and significance, depending on the material under consideration. For most materials, the highest *education level* attained is not a major factor in recycling decisions, except in terms of university undergraduate and/or post-graduate education which increases the recycling of newspaper, aluminum, tin cans, and toxic chemicals. Glass is an exception as its recycling is positively affected by any level of education above a high school degree. In general, recycling decreases with *income* for newspaper (at all income levels), plastic (at low income levels), and toxic chemicals (high income levels). As income increases, the *value of time* increases making recycling more costly. *Household size* and *age* do not have any impact on recycling. *Home ownership* does instead have a strong and positive effect on recycling, which implies that home-owners are more attached to their community and/or are more concerned with the perceptions of their neighbors and recycle more as a result.

2.3 Waste prevention

Empirical studies that address the impact of waste management policies on waste prevention or source reduction include Kinnaman and Fullerton (2000) and Dijkgraaf and Gradus (2004) at the community level; Nestor and Podolsky (1998), Hong (1999), and Van Houtven and Morris (1999) at the household level; Morris and Holthausen (1994),

which is based on a simulation exercise, and Miranda and Aldy (1998), which is a case study.

In Morris and Holthausen, household consumption and waste management practices are simulated in various scenarios differing in the disposal fee (fixed versus variable), presence of recycling, and variable fee level. When the results of the fixed fee and no recycling case are compared with those of the USD 0.50 variable fee and recycling case, households are found to respond to the implementation of a user fee for garbage disposal by producing less waste, in addition to recycling more and disposing of less. Furthermore, as the user fee is increased (upon comparison of the results of the scenarios with recycling and three different user fee levels), households keep reducing curbside waste by increasing the reduction in waste production and not by increasing recycling; they in fact recycle less. Hence, at some user fee level, source reduction dominates households' waste management. Finally, when the results of the fixed fee and recycling regime are compared with those of the user fee and recycling regime, households respond to the introduction of a user fee by producing less garbage and thus disposing of less garbage without altering their recycling activities; in essence, when households are already engaged in recycling, it may be easier to reduce the amount of garbage they dispose of by generating less waste through a reduction in consumption and/or a shift in consumption patterns in favour of less waste-intensive goods.

In Miranda and Aldy (1998), the results of a case study involving nine communities with various waste management systems (bag-based or cart-based subscription program, mandatory or voluntary recycling, and yard waste collection with or without a fee) and significantly different demographic characteristics (population size, density, median household income, and housing value) show that, following the implementation of a unit pricing system, communities experience some source reduction, in addition to decreases in annual residential waste landfilled and incinerated, growth in recycling and yard waste collection, and undesirable diversion activities such as dumping in commercial and school dumpsters, burning of refuse, and leaving household garbage at charitable organizations' drop-off locations. Overall, the findings suggest that households modify their waste behaviour in response to a user fee system in two stages: in the first stage, they divert waste through recycling and yard waste collection; in the second stage, after reaching some maximum level of waste diversion, with undesirable diversion rates decreasing as households become more accustomed to their communities' unit pricing programs, they begin to source reduce.

In Nestor and Podolsky (1998), where the effects of a bag/sticker program and a subscription can program are compared and contrasted with data from an experiment conducted in the City of Marietta, Georgia, in 1994, neither of the two programs seems to encourage source reduction. In the estimation of the total waste generation, with total waste measured as the sum of the quantities of trash and recyclables managed by each of the three available methods (at the curb, on-site, and off-site), the can program is found to increase total waste while the bag program is found to decrease total waste but the negative effect is statistically insignificant. Source reduction is however found to be more likely in older, non-minority, and owner-occupied households but less likely in larger households and when curbside disposal is available.

In Hong (1999), a 1995 sample of 3 017 Korean households is used to capture the interactions between household waste generation and recycling. As theory suggests, an

increase in waste collection fees reduces the demand for solid waste collection services but does not necessarily decrease total waste generation or increase recycling. The positive relationship between waste generation and recycling suggests that there exist feedback effects between the two activities: as their recycling rate increases, households generate more waste; on the other hand, as their waste generation increases, they recycle more. After accounting for these feedback effects, the results of the study suggest that the positive effect of the user fee on recycling efforts is partially offset by a fall in source-reduction effort through the feedback effects, ultimately resulting in a small decrease in the demand for garbage collection services.

In Van Houtven and Morris (1999), the impacts of two unit-based pricing programs (a bag program and a subscription can program) introduced in Marietta, Georgia, in 1994, on total waste (mixed waste plus recyclable) are examined. The results suggest that, both the bag and the can programs are effective, although the latter has a weaker effect. Furthermore, in general, the effect of unit pricing is larger in households with many residents and lower among home owners. Total waste increases with household size and income while source-reduction decreases with education, the percentage of members working full-time, and living in an urban area.

In Kinnaman and Fullerton (2000), a cross-section of 959 US communities (114 with a unit pricing system and 845 without such a system) is used to estimate the effects of a one US dollar user fee on garbage disposal and recycling. The study suggests that a unit pricing system may have significant impacts on consumption level and pattern, and thus on waste production, and/or may induce households to resort to illegal forms of disposal. Hence, the study points to the importance of further research to determine whether and the extent to which a user fee reduces consumption, shifts consumption patterns in favour of less waste-intensive goods, increases composting, and/or induces households to shift to less environmentally attractive disposal alternatives such as burning and dumping.

In Dijkgraaf and Gradus (2004), each of the four unit-pricing systems examined (weight-, bag-, frequency- and volume-based systems) is found to have a negative and significant effect on total waste, which is calculated as the sum of unsorted, recyclable, and compostable waste. In particular, total waste decreases by 38% with a weight-based system, 36% with a bag-based system that applies to both unsorted and compostable wastes, 21%, with a frequency-based system, and 6% with a volume-based system. Municipalities that implement a bag-based system only for unsorted waste and collect compostable waste by using a free collection can experience however only a 14% reduction in total waste.[15] As for other interesting findings pertaining to total waste, *income* has a positive effect (but no effect on composting); *household size* has a negative effect implying economies of scale (but a positive effect on composting, possibly because households with more than three members are more likely to have a garden); communities with larger populations of *elderly people* or smaller populations of *foreign people* have more waste, while communities with many flats or smaller areas per inhabitant have less; living in a city has a negative effect, and municipalities with a high

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15. Compostable waste decreases by more than 60% under weight- and bag-based systems (the latter applies to both unsorted and compostable wastes) and by 37% under a frequency-based system. Compostable waste does not change under a volume-based system, and increases by 36% under a bag-based system only for unsorted waste with a free collection can for compostable waste.

level of environmental activism have 7% less total waste (and 10% less compostable waste). As unit-based pricing systems may have adverse behavioural effects by inducing households to take their waste to family and/or friends living in surrounding municipalities without unit-based pricing systems, a test is provided to determine whether waste migration occurs through the inclusion of impact factors, that is, variables measuring how many inhabitants in surrounding municipalities have an incentive to take their waste to another municipality. The impact factor for a given municipality without a unit-based pricing system is a function of the distance to and the size of municipalities with unit-based pricing systems. The smaller the distance and/or the larger the number of surrounding municipalities with unit-based pricing systems and/or the larger a surrounding municipality with unit-based pricing system, the larger the impact factor is. With the impact factors incorporated into the analysis, the estimations suggest that waste tourism is not a significant side effect of unit-based pricing systems so that the total waste variable as computed (that is, unsorted waste plus recyclables plus compostable waste) is a very reasonable measure of waste generation and any decrease in total waste can be attributed to source-reduction activity.

2.4 Willingness to pay

Very few studies are concerned with willingness to pay for waste disposal. In fact, of all the household waste management studies reviewed, only three consider the question: Sterner and Bartelings (1999), Caplan *et al.* (2002), and Berglund (2006), all of which rely on household-level data obtained by means of a mail survey in the first and third cases and a phone survey in the second case.

In Sterner and Bartelings (1999), data from about 450 households in the Swedish municipality of Varberg are employed to estimate the demand for waste disposal and study households' composting behaviour and willingness to pay for sound waste management. Information about willingness to pay (WTP) comes from a question in the mail survey about WTP to have an organization look after the waste and recycling problem. Notwithstanding the limitations of the data on WTP,[16] the estimation results point out that women, less educated people, and younger people are willing to pay more for waste collection (less educated and younger people also tend to produce more waste so that it seems reasonable that they would have a higher willingness to pay).

In Caplan *et al.* (2002), a contingent ranking study, which is based on a telephone survey of 350 households conducted by the city of Ogden, Utha, in July 2000, is carried out to evaluate three options under consideration by the Ogden City's Public Works Department and City Council to divert some of the municipal solid waste stream from landfills. The three options are: *i)* to continue with the existing waste collection system under which waste is placed in one cart without any separation of recyclables and green waste from other garbage; *ii)* households would separate green waste only at a maximum additional cost of USD 2.00 per month; *iii)* household would separate green waste and recyclables from other garbage at a maximum additional cost of USD 3.00 per month.

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16. Many households (about 43%) do not answer the question and 60% of those who answer report a zero willingness to pay as they may find unreasonable to pay someone else to sort their waste. People concerned with waste management are, in fact, likely to view source separation as the most sensible solution to the problem and to believe that individuals should be actively involved in recycling and composting.

The findings of the study reveal that households do support some degree of expansion in curbside disposal services, and that demographic characteristics do influence households' preferences over waste management alternatives. Men, residents more than 45 years old, those with more than 10 years of residence in the city, and low- to mid-income (less than USD 30 000 annually) residents prefer the garbage-only option (option *i)*); women, residents less than 45 years old, those relatively new to the community, and mid- to high-income residents prefer the green waste/recycling option (option *iii*).

In Berglund (2006), households' perceptions of recycling activities in a municipality in northern Sweden with a fairly representative municipal waste management system within Sweden, whereby households sort and clean their waste at source and then transport it to recycling centers, are analyzed in the context of a tobit model that applies when data are censored from below. Specifically, the willingness to pay to have someone else take over the waste sorting activities is estimated as a linear function of income, gender, age, education, type of dwelling, distance to recycling center, whether waste sorting is perceived to be a requirement imposed by the authorities, whether recycling is perceived to be a pleasant activity, and, most importantly, the green moral index (GMI) as a measure of moral motivation for recycling. Based on a 2002 data set consisting of 282 out of 609 received surveys with valid answers to the open-ended contingent valuation question, every statistically significant explanatory variable is found to have the expected effect, with the exception of income, education, and whether recycling is perceived to be a pleasant activity which are found to have no statistical significance. In particular, male or younger individuals, people living in apartments or further away from recycling centers, people who perceive sorting at source to be a requirement imposed by the authorities, and individuals with weaker moral reasons for undertaking recycling activities tend to have a higher willingness to pay. The presence of moral motives for recycling, which translates into a lower willingness to pay to have someone else take over the recycling activities, can then help explain why the real cost associated with recycling efforts, as captured by willingness to pay, is lower than the time cost of recycling which is given by the opportunity cost of lost leisure as measured by net income forgone (more precisely, the average willingness to pay for someone else to recycle per hour is found to be lower than the average hourly wage after tax).

3. Policy implications

In recent years, in view of the significant growth in municipal solid waste, increasing awareness of the external effects of waste generation, and growing resistance by society to the development of new landfills and incineration facilities, the management of municipal solid waste has become an important policy problem and governments have begun experimenting with various approaches to try to reduce the amount of waste landfilled or incinerated, among which quantity-based fees for garbage disposal and recycling programs.

When opting for a unit pricing system, governments have to decide not only on the user fee level but also on the unit of garbage according to which the fee is charged. Although efficiency dictates that the price per unit of garbage disposed of be equal to the marginal social collection and disposal cost, that is, the social cost of collecting and disposing of the last unit, communities adopting unit pricing rely on average cost pricing; furthermore, they tend to ignore the external cost of waste disposal, that is, the dollar value of the air and water pollution caused by the last unit of discarded waste (under

marginal cost pricing) or by the average unit of discarded waste (under average cost pricing). In terms of the unit by which the disposal charge is levied, governments can implement either a weight-based or a volume-based pricing system. Under the former, households pay according to the weight of their garbage; under the latter, they usually pay by the bag so that volume-based programs are often referred to as bag-based programs. Other possible unit pricing systems include frequency-based programs, which involve a fee per pick-up, and subscription programs, also known as block payment systems but referred to as volume-based systems in Dijkgraaf and Gradus (2004), whereby households decide *ex ante* on the number (and often size) of containers to put out for collection and pay according to a fee schedule that is increasing with the number of containers, with provisions existing for occasionally exceeding the subscription level that typically involve households paying the incremental cost of the next level.

In general, the empirical literature on the effects of user fees for waste disposal is uniform about the effectiveness of such charges at reducing waste and/or at increasing recycling. There is very little evidence that unit pricing does not yield the benefits stipulated on theoretical grounds: in Jenkins *et al.* (2003), user fees have no effect on recycling; in Kinnaman and Fullerton (2000), they are ineffective under subscription systems; in Hong (1999), they only affect recycling but not total waste; in Sterner and Bartelings (1999), the presence of a weight- or frequency-based fee structure increases the recycling of glass but not of paper, refundables, batteries, hazardous waste, machines, and textiles; in Hong *et al.* (1993), they only affect recycling but not garbage under subscription or block payment systems; in Reschovsky and Stone (1994), they affect composting but not recycling. In the remaining articles reviewed, Callan and Thomas (1997), Dijkgraaf and Gradus (2004), Ferrara and Missios (2005), Fullerton and Kinnaman (1996), Hong and Adams (1999), Jenkins (1993), Linderhof *et al.* (2001), Nestor and Podolsky (1998), Podolsky and Spiegel (1998), and Van Houtven and Morris (1999), there exists strong evidence supporting the introduction of unit pricing to achieve waste reduction and diversion goals. As economic theory suggests, in the absence of user fees for waste disposal, households perceive the marginal cost of the garbage collection services they receive to be zero and have thus no incentive to reduce the amount of garbage they place at the curb for pick-up by consuming less, and thus producing less garbage, and/or by switching to less waste-intensive consumption goods, and/or by recycling more, and/or by resorting to illegal forms of waste disposal.

While most of the above-mentioned studies examine the impact of unit pricing either on waste disposal or recycling or both, very few of them are interested in source reduction and no study directly considers the effect of the program on consumption patterns. The empirical studies that address the question of source reduction do in fact draw conclusions about the impact of unit pricing on waste production by estimating its effect on a total waste variable which comprises disposed of and recycled wastes, as in Nestor and Podolsky (1998), Hong (1999), and Van Houtven and Morris (1999), or which includes compostable waste in addition to unsorted and recyclable wastes, as in Dijkgraaf and Gradus (2004), or by comparing its effects on waste disposal and recycling, as in Kinnaman and Fullerton (2000). However, as illegal disposal becomes a viable and attractive option under a unit pricing system, ignoring its possibility amounts to a potential overestimation of the effectiveness of user charges at reducing total waste. The studies that focus on the impact of user fees on total waste, all of which but the study by Nestor and Podolsky (1998) conclude that user charges reduce total waste, do not in fact include illegally disposed of garbage in the calculation of total waste and are thus likely

to overestimate source reduction. Hence, research is needed to determine whether and the extent to which user fees for waste disposal reduce consumption and/or shift consumption patterns in favour of less waste-intensive goods.

In terms of the relative performance of the various unit pricing systems, there is some evidence that a bag-based system tends to provide households with stronger incentives to reduce and divert waste than a subscription (or block payment) system. In Kinnaman and Fullerton (2000), for example, the effect of a disposal fee per bag is reduced when communities with subscription programs are added. In Van Houtven and Morris (1999), the bag-based program has stronger effects on waste reduction than a subscription-based program. According to Dijkgraaf and Gradus (2004), a subscription program reduces both unsorted and total waste, although to a lesser extent than a bag-based system, but has no effect on compostable and recyclable waste. In Nestor and Podolsky (1998), however, neither of the two programs encourages source reduction and the subscription program actually increases total waste; furthermore, the two programs have similar effects on waste disposal but the subscription program is more effective at increasing recycling. That there exist differences in terms of their effects on waste disposal and recycling between a bag-based system and a subscription system is not surprising. If, for example, a household that pays by the bag produces an average of 3.5 bags of waste per week, it has the option of storing the half-filled bag for a week and disposing of 4 bags every second week. Under a subscription program, the household does not have the same option: it either subscribes to 3 bags per week or 4, depending on the cost of over-reducing waste relative to the cost of over-producing waste. The waste disposal and recycling levels could thus be lower or larger than under the bag-based system. Hence, because households cannot make instantaneous adjustments to their waste disposal if they happen to fall short of or exceed their subscription level, there exists a "lumpiness" problem, as referred to in Nestor and Podolsky, under a subscription program that is likely to result in inefficient waste management. To reduce the potential differences in waste disposal and recycling efforts between the two systems or the "lumpiness" problem arising under a subscription system, smaller minimum container sizes may be used.

When a block payment system is considered in isolation, results are rather mixed: in Hong *et al.* (1993), the system increases the frequency of recycling participation but has no effect on garbage; in Hong and Adams (1999), it reduces non-recyclable waste and increases recyclable waste and recycling rate but has no effect on the choice of container size; in Kinnaman and Fullerton (2000), the effect of the disposal fee per bag disappears when only communities with subscription programs are considered. In essence, a block payment system provides households with the incentive to stay within the contracted volume: if households exceed this volume, they must pay for the extra volume. While households can adjust their waste volume through either source reduction or waste diversion (or both), they can only rely on waste diversion (increasing recycling) for unexpected adjustments in their waste volume to avoid being moved into the next (more expensive) block. Clearly, households generating waste near breakpoints (for example, 2.1 or 3.1 cans) have the greatest incentive to recycle as they realize savings with a relatively small reduction in non-recyclables and, correspondingly, a small increase in recyclables. If, however, a major effort is required, households are less likely to participate in curbside recycling and may decrease their recycling efforts to take full advantage of the extra can of garbage that they must purchase.

As for the analysis of the effects of other types of unit pricing, particularly weight- and frequency-based, the empirical literature is rather limited. In the only study that considers communities with weight-based disposal fees, that by Dijkgraaf and Gradus (2004), weight- and bag-based programs are found to yield similar results in terms of incentives provided to households to decrease unsorted and compostable waste and increase recycling, performing far better than frequency- and subscription-based programs. In Fullerton and Kinnaman (1996), however, the average household is found to increase garbage density (weight per can) in response to a bag-based user fee by 43% (the increase is estimated to be larger among married couples but lower for households with more income). Further research is then needed to determine whether a weight-based pricing system, whereby households pay according to the weight of their garbage, is more effective at reducing and diverting waste in view of the possibility of stomping under a bag-based pricing system. This is particularly important as there are administrative cost differences between the two programs, with the bag-based system clearly being less expensive to administer. If the weight-based system is indeed superior, governments must decide on which program to implement on the basis of a cost-benefit analysis or by comparing the incremental benefit of a weight-based system to its incremental cost.

Frequency-based pricing is not very common, probably because, among the various types of unit pricing, it is the one that least reflects marginal cost pricing according to which households are charged a fee per unit of waste that is reflective of the costs (both private and external) of collecting and disposing of the marginal unit. A couple of studies examine the effect of frequency-based user charges in relation to other types of fees. Specifically, in Dijkgraaf and Gradus (2004), a frequency-based pricing, which reduces unsorted waste by 27% and increases recycling by 10%, is shown not to be as effective as a weight-based system or a bag-based system that prices only unsorted waste. Furthermore, a frequency-based system has a negative effect on compostable waste comparable to that under a bag-based system that prices both unsorted and compostable wastes, and is more effective than a subscription-based system which reduces unsorted waste only by 6% and has insignificant effects on composting and recycling. In Sterner and Bartelings (1999), communities implementing either a frequency-based fee or a weight-based fee experience a similar reduction in glass recycling; however, neither of the two structures has an impact on the recycling of paper, refundables, batteries, hazardous waste, household machines, and textiles. Hence, it is not clear from the available empirical estimates -- and thus more research is needed -- that a frequency-based program cannot facilitate or contribute to environmentally sound waste management.

As a final note about whether to implement unit pricing and which type of unit pricing to implement, the empirical literature on household solid waste production is rather silent about the cost of administering such a program and how this cost varies across the different types of user charges. Higher administrative costs are indeed alleged to be one of the drawbacks of unit fees when compared to flat fees, and it is therefore possible for the administrative cost advantage of the latter to outweigh the benefit from waste diversion and reduction under the former. In Fullerton and Kinnaman (1996), the cost of administering a bag-based program is estimated to be USD 0.193 per bag when illegal disposal is completely ignored, so that the costs of enforcing dumping laws and cleaning up illegal dumpsites can be omitted; this cost exceeds the threshold level of USD 0.149, or the estimated benefit per bag, which is computed based on a social marginal collection and disposal cost estimate of USD 1.03 per bag from Repetto *et al.* (1992) and a fee per

bag of USD 0.80. In Podolsky and Spiegel (1998), the threshold level is much higher, even if it is measured per household as opposed to per bag, and equal to USD 6.90 per household when the per bag fee is USD 1.00, illegal disposal is accounted for on the basis of the largest estimate of incremental illegal waste disposal found in Fullerton and Kinnaman of 0.42 pounds per person per week, and the reduction in waste disposal expenditures is assumed to be utilized for the provision of other services.

In addition to the possibility of being more expensive to administer, unit pricing is often criticized for a number of other practical difficulties. First, revenues from the fees depend on household responses and are therefore difficult to predict; this is particularly important if the fees are intended to finance garbage collection and disposal. Second, quantity-based pricing creates the incentive for illegal forms of disposal. Third, the incidence of quantity-based pricing may be regressive as the demand for garbage collection services tends to be income-inelastic, implying that poor people spend a larger proportion of their incomes on waste management than rich people. Fourth, a quantity-based fee is equivalent to a uniform tax on all types of garbage and is thus inefficient if materials within the waste stream have different social costs; for example, the social cost of disposing of flashlight batteries is greater than that of old newspaper so that the disposal tax on the former should be greater than that on the latter. Finally, the use of common receptacles in multi-unit dwellings makes it difficult to extend quantity-based pricing to the residents of these dwellings.

Although illegal disposal is often alleged as one of the major adverse behavioural effects of unit pricing for garbage collection, the empirical studies that attempt to measure the impact of implementing a unit pricing system for garbage collection on households' propensity for illegal disposal do not allow for a definitive statement about the presence of illegal activities under unit pricing. Most of these studies conclude that illegal activities, including waste transfers to neighbouring municipalities without unit pricing, are either not a problem, as in Reschovsky and Stone (1994), Van Houtven and Morris (1999), and Dijkgraaf and Gradus (2004), or consist merely of small (about 4% or 5%) waste transfers, as in Linderhof *et al.* (2001), or tend to decrease over time as households become accustomed to their communities' unit pricing programs, as in Miranda and Aldy (1998). In the only study that reports significant increases in improper waste disposal, Fullerton and Kinnaman (1996), illegal dumping is found to account for 28% to 43% of the weight reduction in curbside garbage;[17] hence, when the increase in recycling (16% of the total reduction in garbage) and the true reduction in garbage that accounts for the increase in illegal disposal are taken into consideration, the incremental benefit of unit pricing is found to be rather small and insufficient to cover the cost of administering the system (as a matter of fact, even if the increase in illegal disposal is ignored, the results show that the administrative costs of the bag-based pricing system more than outweigh its benefits).

In order to get a better sense of the implications of unit pricing for illegal forms of disposal, studies are needed that rely on more direct ways of measuring illegal disposal

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17. The extent of illegal disposal is measured indirectly as the difference between the pre-program garbage and the increase in recycling and composting for households setting out no garbage for collection during the post-program four-week period data collection and choosing "other" when asked about means of reducing garbage in response to the user fee over i) did not attempt to reduce garbage, ii) recycled more, iii) composted more, and iv) demanded less packaging at stores.

activities, which are likely to be more accessible at the community level through collection and disposal cost figures, and that address questions such as whether illegal disposal, if it is indeed a problem, can be mitigated through *i)* a centralized policy ensuring that all communities adopt the same system so that waste tourism possibilities are eliminated, although such an arrangement may not be optimal if communities are demographically heterogeneous as the impact of a waste management policy is likely to be tied to demographics, *ii)* reduced accessibility of commercial and municipal dumpsters, and/or *iii)* an effective system of monitoring and fining illegal disposal of the type in place in Oostzaan, the Dutch community studied in Linderhof *et al.* (2001), where households are given opportunities to report misconduct of waste littering and illegal dumping and, in some cases, traced based on the contents of the litter, forced to pay for the waste collection, and fined. In low population density areas, where illegal activities are easier to carry out, monitoring may prove very expensive so that policy makers may consider investing in programs to educate individuals about the environmental dimension of waste management, giving them an opportunity to become more environment-conscious, and about available programs.

The importance of educational programs is supported by the empirical findings in a number of studies that look at the impact of environmental activism or awareness and knowledge about available waste management options, such as those by Dijkgraaf and Gradus (2004), Linderhof *et al.* (2001), Reschovsky and Stone (1994), Jenkins *et al.* (2003), and Hornik *et al.* (1995). Particularly interesting is the conclusion in the last study that knowledge and social influence from neighbours, friends, and family members are the most effective predictors of recycling, implying that, once educated about recycling (importance, availability, and how to recycle quickly and conveniently), individuals tend to recycle more; furthermore, the impact of demographic characteristics on recycling is likely to disappear as recycling becomes more diffused throughout the population and accepted by more types of consumers. Educational programs may also serve to change people's perceptions about the difficulties related to recycling and composting, which, as shown in Sterner and Bartelings (1999), are important determinants of recycling efforts.

For the most part, the empirical literature on unit-based waste collection charges tends to focus on changes in material flows, ignoring, for example, the potentially higher cost of administering a unit pricing system. Needless to say, however, the decision of whether to introduce unit pricing to finance garbage collection services must ultimately rest upon considerations about the private and external costs associated with changes in material flows. An attempt to understand the costs and benefits of unit-based waste collection charges has recently been undertaken in OECD (2006), where three waste management systems (from Torelles de Llobregat in Spain, Landkreis Schweinfurt in Germany, and Ghent and Destelbergen in Belgium) are examined. These systems consist of differential and variable rate (DVR) charges, that is, charges which vary with the amount and characteristics of the waste collected.[18] A key conclusion in the report is that net social

18. A bag-based scheme for municipal waste was implemented in Torrelles de Llobregat in 2003; this is the first example of such a scheme in Spain and may still be the only one. In Landkreis Schweinfurt, a three-part tariff system consisting of a fixed fee, a fee per emptying of any bin, and a weight-based fee was introduced at the end of the 1990s. In Ghent and Destelbergen, a system was adopted in 1998 whereby households living in rural areas would use only wheeled bins, choosing the frequency with which they would set out their bins for collection and paying a fee per bin. In central areas, households would use sacks and pay a fee per sack.

benefits of DVR charging schemes are always positive except when external costs of air pollutants are assumed to be low (so that avoided costs of treatment/disposal are low), with slightly worse results when the costs of time are taken into account. Questions about DVR charging systems raised in the study and necessitating further research include *i)* whether any reduction in collected household waste following the implementation of unit pricing can be attributed to a movement of commercial waste out of the municipal collection system), *ii)* how much waste is illegally disposed of and what the social costs of illegal disposal are, and *iii)* how important the costs of time spent on recycling are and at what hourly rate the value of time has to be imputed.

The impact of income on waste disposal and recycling is well documented. In general, rich households tend to dispose of more waste but do not necessarily invest more or less time in recycling activities than poor households. Of the twelve studies that allow for income as an explanatory variable, only three conclude that income either has no effect, as in Hong and Adams (1999), or decreases garbage, as in Fullerton and Kinnaman (1996) and Nestor and Podolsky (1998), although only on-site trash is affected in the latter and not curbside or off-site trash. Of the studies that consider the impact of income on recycling, four out of eleven find that rich individuals recycle more. When different materials are examined, two out of the four find that it is only for certain recyclables that rich households have higher recycling rates: glass and plastic in Reschovsky and Stone (1994) and newspaper in Ferrara and Missios (2005). While there seems to be conclusive evidence that the demand for garbage collection services is increasing with income, the income elasticity estimates available to date, coupled with the empirical evidence that poor households do not tend to recycle more, suggests that user charges are likely to be regressive. As pointed out by Reschovsky and Stone, however, waste management involves both monetary costs and time costs. Determining whether the distributional effects of unit pricing are regressive involves incorporating the greater burden in terms of time the system imposes on rich people, who tend to have higher valuations of time than poor people.

Furthermore, low-income people are likely to be renters and live in multi-family dwellings, which are typically excluded from unit pricing as the benefits in terms of scale economies from the use of common waste receptacles outweigh the inefficiencies from flat charges. Given that distributional outcomes can be manipulated through lump-sum cash or in-kind transfers without efficiency being affected, the possibility of user charges being regressive does not constitute a very strong argument against their implementation. Nonetheless, policy makers should be mindful of the problem and consider some sort of administratively feasible and affordable rebate for low-income households.

In addition to user fees, governments often rely on recycling programs as a means of diverting waste from landfills. While recycling is not uncommon among households even in communities with flat fees, voluntary recycling participation, and no extrinsic incentives for recycling (and thus in situations in which waste disposal would be expected to be less costly in terms of time and convenience than recycling, suggesting the presence of some intrinsic or altruistic returns from recycling), recycling programs are supposed to induce households to recycle by reducing the time and inconvenience costs associated with recycling. Because recycling programs represent a quite popular waste diversion policy, very few empirical studies on household waste management practices have data from communities without some sort of recycling program to be able to address the question of whether such a policy is effective at increasing recycling and/or decreasing

waste disposal. A study involving communities from different countries is likely to provide the kind of heterogeneity in waste management policies, including recycling programs, that is necessary to evaluate their absolute and relative effectiveness. Nonetheless, the findings of four different studies suggest that communities with recycling programs tend to have higher recycling rates but not necessarily for every type of recyclables; in Reschovsky and Stone (1994), for example, curbside pick-up only matters for cardboard but not for newspaper, glass, plastic, and metal. On the other hand, the effect of free curbside recycling on waste disposal, which is examined only in Kinnaman and Fullerton (2000), is found to be inconsequential. Other questions about recycling programs considered, although not consistently, include whether the type of program (curbside versus drop-off), sorting requirements, collection frequency, knowledge about and experience with program, the presence of unit pricing, and mandatory recycling make a difference.

The few studies that look at the performance of a curbside program relative to a drop-off program or, more generally, at how accessibility of pick-up location affects waste diversion, those by Jenkins *et al.* (2003), Judge and Becker (1993), and, to some extent, Reschovsky and Stone (1994), find that transportation costs do matter in households' recycling decisions and that recycling efforts tend to increase as collection is made more accessible. In general, households are sensitive to the time intensity of recycling activities and tend to respond favourably to initiatives intended to reduce sorting requirements by allowing households to commingle their recyclables, as found in Judge and Becker. Households are also responsive to changes in collection frequency: as suggested in Ferrara and Missios (2005) and Judge and Becker, the more frequently recyclables are collected, the more households recycle; this may be because households value their space and/or because they derive disutility from having garbage, whether non-recyclable or recyclable, on their premises. Knowledge about recycling programs has a positive effect on whether households recycle, as concluded in Reschovsky and Stone, but experience with recycling programs can only contribute to increasing the probability of recycling newspaper and not of recycling glass and plastic bottles and aluminum, as determined in Jenkins *et al.*

When recycling programs are evaluated in relation to the presence of unit pricing, the available evidence in Reschovsky and Stone (1994) and Callan and Thomas (1997) suggests that curbside recycling is more effective if combined with unit pricing, and vice versa. In general, a recycling program is expected to decrease the time and out-of-pocket costs of recycling by reducing the need of transporting recyclables to collection points or of storing them for long periods of time (this is particularly important for bulky, heavy, and potentially messy materials such as glass and plastic bottles); a unit pricing system increases instead the monetary benefits of recycling (in terms of forgone disposal cost). Both the reduction in time and effort costs and the increase in monetary benefits vary according to waste characteristics such as weight and bulkiness. Hence, a recycling program induces households to recycle items that they would typically not recycle under a unit pricing system because of their low monetary benefits, thus reinforcing the recycling incentives households face under unit pricing. A policy mix consisting of a recycling program and a unit pricing may also be appealing if the user fee cannot be set at the full social marginal cost of waste disposal for political reasons. If curbside recycling is based on mandatory participation, independently of whether unit pricing is in place, it is however not clear whether and how households' decisions over recycling are affected. The empirical findings to date allow for a number of possibilities: *i)* mandatory recycling

has no effect as in Reschovsky and Stone (1994), if no curbside pick-up is available, and Jenkins *et al.* (2003); *ii)* mandatory recycling increases the recycling intensity of many waste materials as in Reschovsky and Stone, if curbside pick-up is available, and Ferrara and Missios (2005); *iii)* mandatory recycling decreases waste disposal, as in Kinnaman and Fullerton (2000).

Another policy instrument that is often implemented to induce households to reduce waste generation is a refundable deposit system. Unfortunately, very little is known about the impact of such a policy on households' waste disposal and recycling activities. In Kinnaman and Fullerton, which is the only study to examine whether the presence of a deposit/refund program leads to any change in how households manage their waste, the policy is found to be ineffective. In the majority of the theoretical studies of household solid waste management, among which those by Dobbs (1991), Dinan (1993), Atri and Schellberg (1995), Fullerton and Kinnaman (1995), Palmer *et al.* (1997), Fullerton and Wu (1998), and Ferrara (2003), the combination of an advance disposal fee (deposit) and a recycling subsidy (refund) is however found to be the best policy approach to induce households to internalize the private and external cost of garbage collection and disposal. As pointed out in Palmer *et al.*, because a deposit/refund system relies on both source reduction and recycling, like a user fee,[19] such a policy is cost-effective as it ensures that resources (efforts) are allocated to where they are most productive. For example, a reduction in the disposal of plastics and aluminum can be more cheaply achieved through reduced consumption than through increased recycling. In Fullerton and Wu (1998), a deposit/refund system is also shown to encourage firms to produce goods with waste contents that are more easily recyclable, and this is something that is administratively difficult to accomplish.

In light of the limited empirical work on deposit/refund systems, in spite of the extensive theoretical work that supports their implementation for socially optimal waste management, more research is needed to determine whether a deposit/refund system that targets specific recyclable materials does indeed make sense in terms of its effects on waste generation and diversion. A very interesting and attractive feature of such a policy, when compared to a unit pricing system, is that it allows policy makers *i)* to tax consumption goods according to their waste contents, thus avoiding the inefficiency associated with a uniform tax on all types of garbage when materials in the waste stream produce different social costs, and *ii)* to ensure that the costs of illegal forms of disposal are internalized when monitoring and enforcement costs are high, which is especially relevant in low-density areas, or, more persuasively, in the absence of a penalty for illegal disposal that is directly correlated to the extent of the illegal activity. Under a refundable deposit system, it is in fact possible to impose a consumption tax (deposit) on households that is reflective of the disposal cost of the consumption residue under the assumption that illegal disposal occurs; the tax is then refunded if proper disposal is opted for, with the refund capturing the incremental social marginal cost of illegal disposal, which is likely to be higher if recycling is chosen over waste disposal. While adding deposits is feasible, ensuring that consumers are refunded according to their choices over disposal is extremely difficult, if at all possible, and expensive to implement and administer. If, or in cases where, legal and illegal disposal costs are comparable at the margin (for materials

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19. But unlike an advance disposal fee which relies solely on source reduction or a recycling subsidy which relies solely on recycling.

with high biodegradation rates), a deposit/refund system that grants a refund only for recycling is still efficient and feasible. The arguments in favour of a deposit/refund system are theoretically valid but must be empirically assessed if such a policy is to be more seriously considered in the design of socially optimal household waste management policies, especially for waste materials that are particularly harmful for the environment and/or in instances where illegal disposal poses a real concern.

Aside from various policy instruments, the empirical literature on waste generation and recycling examines the role of socio-demographic, attitudinal, and contextual characteristics in households' decisions over waste management activities. Among the variables analyzed other than income, which is discussed above, household size and composition, education, age, and home ownership are common to most studies and almost consistently found to be significant, although not necessarily with qualitatively equal effects. Less common are, however, attitudinal elements of influence, with only one study, by Sterner and Bartelings (1999), directly estimating their relevance, and another study by Ando and Gosselin (2005), indirectly assessing their importance through the effect of the indicator for recycling when in public. Other issues still to be explored or expanded upon include whether there are interaction effects between policy variables and socio-demographic and attitudinal attributes; if so, it is important for policy makers to be aware of how and to what extent household and community characteristics can influence the success or failure of different policies to be able to make more informed decisions and set objectives.

When it comes to socio-demographic characteristics, the empirical literature on the household solid waste problem is in fact mainly concerned with how waste disposal and recycling activities differ across different segments of the population identifiable according to some characteristics such as income, education, or age. The results of these analytical exercises are undeniably valuable as they pinpoint areas where policies are more likely to be needed and to succeed. Knowing that richer households tend to have higher recycling rates suggests, for example, that the benefit of introducing a recycling program can be more easily realized if rich communities are targeted. However, a more interesting and relevant line of questioning, as pursued only in Fullerton and Kinnaman (1996), involves determining how the effectiveness of any given policy is linked to the socio-demographics of a community. This can be achieved by estimation of how policy-induced changes in waste disposal and recycling are affected by socio-demographic variables, as in Fullerton and Kinnaman where the effect of unit pricing is smaller in low-income households, in households that subscribe to more daily newspapers, for those with infants, and for married couples. Alternatively, the linkage between policy variables and socio-demographic characteristics can be explored though the inclusion of interaction variables in the waste disposal and recycling equations that capture how the policy effects vary across the population, as in Van Houtven and Morris (1999) where the presence of unit pricing is interacted with the home ownership indicator and the number of residents and found to be more effective in larger households but less effective among home-owners.

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3.   Personal Transport Choice

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1. Introduction

There are basically four means by which to reduce the negative environmental consequences of personal transport: by replacing personal vehicles with more environmentally-friendly ones; by replacing car journeys with public transport, walking or cycling and by car-sharing rather than solo driving; by making fewer journeys (*e.g.* telecommuting, internet shopping); and by travelling shorter distances.

There are also four main types of environmental policies that can be used to achieve these goals: pricing measures, investment in new technologies and alternative modes, information and regulatory measures. Pricing measures make car use less polluting by providing economic incentives for cleaner and more efficient vehicles or more expensive by increasing the variable costs of car use (fuel taxation, kilometre tax, road pricing, congestion charging, parking charges, insurance tax) or the fixed costs of car ownership (car purchase tax, annual road tax, residential parking fees or tax), or by making public transport less expensive (subsidising fares). Investment in new technologies and alternative modes makes car use less polluting by the development of cleaner vehicle technologies, less necessary or less competitive by expanding the public transport system and improving service (frequency, punctuality, comfort, convenience, safety, etc.), improving the infrastructure for cycling and walking or providing park and ride facilities. Informational measures make car use less necessary or less desirable by raising awareness (of the problems caused by car use, of the possibilities of switching to alternative modes, of ways of reducing travel overall) and less polluting by encouraging the purchase of cleaner vehicles, changes in driving behaviour (improved vehicle maintenance, fuel-efficient driving, using telematics to provide information on traffic conditions and parking) and vehicle choice (labelling the fuel economy or emissions of new vehicles). Regulatory measures make car use less convenient (parking restrictions, car-free residential areas, traffic restraint), less necessary (land-use policies such as high-density development, mixed-use zoning, requiring public transport access to new developments, restricting out-of-town shopping centres) or less environmentally harmful (legislation on fuel efficiency and fuel quality).

Policy measures can be compared in terms of their effectiveness in changing travel and in their distributional effects, or their implications for different individuals and groups. The efficacy of policies in changing the individual's travel behaviour will depend on a number of factors: personal circumstances, possibilities of using modes other than

the private car, attitudes and preferences. Thus, the design of a successful policy strategy requires knowledge of the factors determining travel behaviour: how this differs according to income, household type, age, gender, employment status, residential location (rural *vs.* urban areas, large cities *vs.* small towns) and attitudes. The distributional implications – at least in the short run - will also depend on current travel behaviour.

This paper reviews the recent empirical literature on the determinants of personal transport and summarises the major findings of particular relevance to the understanding of environment-related behaviour. Section 2 begins with a general discussion of the determinants of travel behaviour and presents a review of recent empirical studies. The implications for environmental policy follow in Section 3.

2.   Empirical studies of the determinants of personal transport

Personal travel is determined by the characteristics of the individual, the attributes of the transport system and spatial characteristics. Individual characteristics include age, gender, personal and household income, household composition, life-cycle, employment status, preferences and attitudes. The attributes of the transport system relate to the transport infrastructure (access to roads, public transport, cycle paths), the costs of car ownership and use (purchase and running costs) and the cost and quality of public transport. Spatial attributes describe the home location and the accessibility to jobs, education, shopping, services and leisure activities. Most studies are partial in the sense that only a selection of these factors is taken into account. Generally, economists have tended to focus on economic factors (costs of car ownership and use, public transport fares, income), geographers on spatial, land-use aspects (density of residential area, conurbation size, access to facilities and services), and psychologists and sociologists on preferences and motivations (attitudes towards different modes of transportation, emotions evoked by car use, social and personal norms, awareness of problems caused by travel, environmental concern). A comprehensive model of travel behaviour should take into account as many of the different explanatory factors as possible, since omission of important variables can lead to erroneous conclusions concerning the effects of the variables included in the model.

Transport models are generally based on the premise that travel is a derived demand, not desired *per se*, but in order to carry out activities that are spatially separated. Travel is considered a disutility, which has time costs, as well as monetary costs, to be minimised. However, that *all* travel is a derived demand is not uncontested. Mokhtarian and Salomon (2001) argue that "humans possess an intrinsic desire to travel" so that some travel is not a by-product of a given activity, but is the activity itself. They also provide empirical evidence which suggests that well over 50% of individuals in a survey for San Francisco express some positive utility of travel. This is also supported by Ory *et al.* (2004) who find that 50% of commuters in the San Francisco area have no desire to reduce their commuting time. Similar support is found in the Netherlands: people do not only drive their cars because it is necessary to do so, but also because they love driving (Steg, 2005). This positive utility of travel, and particularly car travel, will have implications for the success of environmental policies. As Ory and Mokhtarian (2005) suggest, those who have a positive attitude towards travel may be less inclined to reduce it, for example by telecommuting or living in denser, mixed-use areas. Similarly, those who have a negative attitude towards public transport are not likely to take the bus, even if it provides better service than the car.

In reviewing the empirical literature, it is useful to consider two types of explanatory variables separately: those describing the characteristics of the individuals and their residential location and those relating to the characteristics of the transport system. The reason for this is that the models and data used are generally more similar within these groups, so that the results are more comparable. In addition, most policy measures are directed towards the transport system, by influencing the price, quality or convenience of different modes. There is less scope for influencing the characteristics of individuals; some exceptions are information campaigns aimed at changing attitudes towards travel or vehicle choice and land-use policies concerning locations of housing and shopping facilities. In addition to differences in explanatory variables, the dependent variables also differ among studies. The variables of interest in this review are car ownership, car travel, total travel, vehicle choice and mode choice. Of course, some studies will overlap categories of explanatory variables and/or type of dependent variable.

In the following, we first consider the characteristics of the individuals and/or households and their residential location. These studies are very similar in terms of models and data, as they are all based on disaggregate survey data on individuals or households. Finally, the attributes of the transport system are considered, primarily in terms of costs. In contrast to the studies of individual characteristics, much of the evidence presented relating to costs is based on more aggregate data and dynamic models.

2.1 Characteristics of the individual and residential location

Empirical studies of the socio-demographic determinants of personal transport are of necessity based on survey data of individuals or households. They are generally based on a single cross-sectional survey of individuals at one point in time or on a number of independent cross-sections at different points in time. Far fewer studies are based on panel data. The measures of personal transport analysed vary: car ownership, car travel, mode choice, total travel, and vehicle choice. There is a large body of empirical studies and obviously only a small number of these can be reviewed here. Those chosen are among the most recent, pertain to a range of countries, include a wide selection of explanatory variables, are based on multivariate models that take the interrelationships between explanatory variables into account and apply a sound statistical analysis. An attempt has also been made to include studies which consider the effects of attitudinal variables. Table 1 shows the influence of the most commonly occurring explanatory variables on various travel measures. The studies are described below and some results not included in the table are also noted.

2.1.1 Car ownership

First, we consider studies concerned with the determinants of car ownership. Although there have been a large number of studies of car ownership based on aggregate models, one of the earliest studies which considers a wide range of socio-demographic and economic factors is that by Train (1980). Using a structured logit model for the San Francisco Bay area, the results show that the number of cars owned by the household increases with income and household size and is lower for those living in proximity to the Central Business District (CBD). Not surprisingly, the author also finds that the number of cars owned is strongly related to the number of drivers, while annual car costs (in relation to income) have a substantial negative effect. Slightly different explanatory variables are examined by Bhat and Koppelman (1993), who employ a simultaneous equations approach to model the interdependences between employment, income and car ownership using the Dutch National Mobility Panel. Their results indicate that car

ownership increases with income, decreases with the number of children in the household and is lower for those living in large cities. In addition, households with highly educated husbands tend to have fewer cars, while the educational level of the wife is only relevant if she is employed.

Asensio *et al.* (2002) estimate a car ownership model using data from the Spanish Household Budget Survey. Their results show that car ownership increases with income, the educational level of the head of the household and the number of adults and workers in the household. The age of the head of the household also has a significant effect on car ownership: those younger than 25 or older than 55 have lower car ownership levels than those in the middle age group. This "lifecycle" effect is partially related to the development of income and the number of adults in the household (Dargay and Vythoulkas, 1999), both of which rise as children become adults and then decline as grown children leave the parental home. Regarding residential location, the probability that a household has no car is higher the larger the municipality of residence. This is as would be expected since the largest cities in Spain, Madrid and Barcelona, have the most extensive public transport networks, the worst congestion problems and the highest parking prices.

Table 1 Influence of demographic, socio-economic and land-use factors on various personal transport measures

Independent variable Reference	Income	A	Male	Education	House-hold size	Working (# no.)	Children (# no.)	1 family house	Density	Acces-sibility	City size	Attitude to Environ-ment	Country
Car ownership													
Train (1980)	+												USA
Bhat and Koppelman (1993)	+								–		–		NL
Asensio et al. (2002)	+	+/		–	+	+#					–		Spain
Dargay (2005)	+	–	+	+	+	+	+ 0 –						EU 14
Simma and Axhausen (2004)			+				– #			–			Austria
Abreu e Silva et al. (2006)	+	–	+		+	+ #			–				Portugal
Giuliano and Dargay (2006)	+	–			+		+	+	–	–			USA/GB
Nolan (2002)	+	+	+	+	+	+	+#	+					Ireland
Car use													
de Jong (1996)[1]	+	–	+	+	+	+							NL
Abreu e Silva et al. (2006)[1]	+	–	+		+	+							Portugal
Feng et al. (2005)[1]	+	–	+	+	+	+/#	+#		–		–		USA
Fullerton et al. (2004)[1]	+	–		–	0	+/–	+	+			–		Japan
Steg et al. (2001)[1]	+	+/	+	+	–		–	–				–	NL
Johansson-Stenman (2002)[1]	+	+	+										Sweden
Dargay and Hanly (2004)[1]	+	+/	+		+	+		+	–	–	–		GB
Asensio et al. (2002)[2]	+	+/		+	+	+#		–			–		Spain
Nolan (2002)[2]	+	0	+	0	+	+	+	+		–			Ireland
Simma and Axhausen (2004)[3]			+				– #			–			Austria
Golob and Hensher (1998)[3]	?	+	+/–	–	–	– (F) #	+ (F)				0	–	Australia
Dargay (2005)[3]	+	+	0		+	– (F) #	+ (F)		–		–		GB

Table 1 Influence of demographic, socio-economic and land-use factors on various personal transport measures *(continued)*

Public transport use									
Abreu e Silva et al. (2006)[1]	–	+	–	0	0 #		+		Portugal
Golob and Hensher (1998)[3]	+	–/	–	–/+	+		+	+	Australia
Johansson-Stenman (2002)[1]	–	–/	–	+		–	+	0	Sweden
Dieleman et al. (2002)[3]	–	–	–	0		–	+		NL
Total travel (km)									
Giuliano and Dargay (2006)	+	–	+	+/–	+0	+	+	–	+	USA/GB
Poortinga et al. (2004)	+	–	+	+		0		0	NL

1 km; 2 fuel expenditures; 3 commuting mode.

Car ownership in 14 EU countries[1] is examined in Dargay (2005) on the basis of the European Community Household Panel. As opposed to the other studies presented here, car ownership is defined as "having a car", rather than the number of cars. Income has a significant positive influence on car ownership in all countries. There is a tendency for income to have a greater influence in the lower-income countries, suggesting that the income elasticity declines with increasing income. Households with a woman head are less likely to have a car in all countries but Luxembourg. Those with members over 65 years old are also less likely to have cars than others. The only exception is in Denmark, where being over 65 increases the likelihood of car availability. This may be a result of the high costs of obtaining a car in Denmark, so that pensioners with a high level of savings (not measured in income) can afford a car, as other expenditures (*e.g.* housing) fall. Car ownership increases with the number of adults and the number employed in the household. The effect of children in the household is less clear-cut. In six countries, children increase the probability of car ownership, in three countries they reduce it, and in five, children have no effect. Simma and Axhausen (2004), in a study for the Upper Austria region, find that the number of children in the household reduces the number of cars. This cannot be compared directly with Dargay (2005) since Simma and Axhausen's model refers to the number of cars and the number of children, but it supports the finding of Bhat and Koppelman (1993), also based on the number of cars and children. In agreement with all the studies reviewed, car ownership is greater for households headed by a man than by a woman. Another important conclusion is that the number of facilities (shop, supermarket, bank, post office, kindergarten, school, pharmacy) within a 10-minute walk reduces car ownership. A disadvantage with Simma and Axhausen's study is that income is not included as an explanatory variable, and as is shown by all the studies reviewed (as well as in the literature) income is one of the major determinants of car ownership. This can lead to erroneous estimates for other variables, particularly those correlated with income.

In a study for Portugal, Abreu e Silva *et al,* (2006) use a Structural Equations Model (SEM) to examine the relationships among socio-economic and demographic characteristics, land-use characteristics of the residential and work locations, and a variety of travel indicators. Their results for car ownership are in agreement with the other studies: car ownership increases with income, is greater for men than for women and increases with the number of adults and workers in the household. In addition, they find that car ownership is lower for those living in densely-populated urban centres. This negative relationship between car ownership and density is supported by Giuliano and Dargay (2006) in a study for the United States and Great Britain, who find, in addition, that car ownership decreases with proximity to public transport and is higher for those living in single-family detached houses than for those living in flats or terraced houses. The results for the US and GB are similar with respect to the other determinants of car ownership: it increases with income and household size and is higher for households with children and lower for the over-65s. A major difference between the two countries

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1. Germany, Denmark, the Netherlands, Belgium, Luxembourg, France, the United Kingdom, Ireland, Italy, Greece, Spain, Portugal, Austria and Finland.

concerns the effect of income: it is greater for Great Britain than for the US, supporting the declining income elasticity hypothesis noted in Dargay (2005)[2].

Nolan (2002) presents results for Dublin based on a binary choice model, as in Dargay (2005), which are largely in agreement with the previous studies: households with higher income, headed by a man, with a larger number of adults, at least one person employed and living in a single-family detached house are more likely to own a car than other households. Their finding that car ownership increases with age is in contrast to all other studies, which either indicate a reduction with age, or a lifecycle effect which first increases with age up to the middle-age group and then declines. Regarding education, Nolan finds that those with higher education are more likely to own a car, which agrees with Asensio *et al.* (2002) but not with Bhat and Koppelman (1993). Finally, the number of children is found to increase car ownership, while most other studies find the reverse.

2.1.2 Car use

The next group of studies concern car use. The dependent variable in the studies reviewed is measured as kilometres travelled by car during a given period, petrol expenditures, and trips by car or choice of car for commuting. The earliest study reviewed, de Jong (1996), estimates a duration model for replacement of vehicles in the Netherlands in a system framework which also contains a vehicle type choice model and a model for annual use (kilometres) of the present vehicle. Concerning car use, income has a positive effect, women and the elderly drive less, while the employed and highly educated drive more. The findings of Abreu e Silva *et al.* (2006) for Lisbon are in agreement: car use increases with income and the number employed, and is lower for women and the elderly. In addition they find that car use increases with household size and is lower for those living in compact urban areas, while those in areas well served by major roads tend to make more intense use of their cars.

In another study for the Netherlands, Steg *et al.* (2001) examine the effects of motivational factors on car use in conjunction with a number of socio-economic and demographic variables. They find that car use increases with income, is greater for men, the more educated and those in single-person households and is lower for families with children. Additionally, car use is lowest for the youngest and oldest individuals. The motivational variable is defined as "problem awareness" which was constructed by asking respondents to what extent they thought car use contributes to environmental problems, on a score from 1 (very little) to 7 (very much). Problem awareness is shown to have a significant inverse relationship to car use, indicating that greater conviction concerning the environmental problems attached to car use is associated with less frequent car travel. For Sweden, Johansson-Stenman (2002) finds that car use increases with income and is greater for men than for women and for those with company cars. Again, age shows a lifecycle effect. As opposed to the previous studies, children and educational level were found to have no significant effect on car use. Another interesting result is that people living in big cities are less likely to drive than others, but those who do, drive about as far annually as those in other areas. The author also attempts to estimate the effects of

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2. The income elasticity begins to decline after a certain car ownership or income level, as car ownership approaches saturation.

environmental attitudes by including membership of an environmental organisation, but this has no significant effect on car use.

The final study in this group, by Dargay and Hanly (2004), concentrates primarily on the effects of various land-use measures on car travel. Regarding socio-demographics, the results support those of the studies reviewed above: car use increases with income (both the individual's income and to a lesser degree the income of other household members), is greater for men than for women, for the employed (and greater for full-time than part-time employed) and for those in households with more than one adult, while the lifecycle effect of age is also supported. Concerning land-use variables, local access to amenities and the frequency of the bus service reduce car use, as does the density of the residential location. In addition, car use is lower in the largest metropolitan areas, even after controlling for density.

Studies in the next group are based on *household* rather than on *individual* car use. Feng *et al.* (2005) and Fullerton *et al.* (2004) estimate simultaneous models for vehicle choice and car use in the US and Japan, respectively. Their results are also similar: car travel increases with income, decreases with age, increases with the number of children and is lower for those living in large urban areas. There are some contrasts between the two studies: car use increases with education in the US, but declines with education in Japan. Further, in the US there is a significant positive relationship between car travel and household size and the number of workers, while in Japan household size has no effect on car use and households with two workers tend to drive less than those with one. Feng *et al.* (2005) also find that households headed by men travel more by car, while Fullerton *et al.* find that car travel is greater for home-owners than for renters. The next two studies estimate car use on the basis of petrol expenditures, rather than kilometres. The findings of Asensio *et al.* (2002) for Spain are largely in agreement with the previous studies: car use increases with income, the educational level of the household head, household size and the number employed, and is lower for those living in larger cities, while the age of the head shows a lifecycle effect. Similar results are obtained by Nolan (2002) for Dublin: petrol expenditures increase with income and household size and are higher in households with a male head and where at least one person is employed. The number of children increases car use, as does living in a single-family house. The author finds, however, that the age of the heads of households and their educational level have no significant effect, which is in contradiction to most other studies.

The next three studies look at car use for commuting. Simma and Axhausen (2004) find that commuting by car in the Upper Austria region is greater for men and declines with the number of children. They also find that the number of facilities within a 10-minute walk reduces travelling to work by car, as does accessibility of public transport, supporting the findings of Dargay and Hanly (2004) above.

To explore the extent to which environmental concerns translate into environmentally-friendly behaviour, Golob and Hensher (1998) use a structural equations model[3] to relate latent attitudinal factors, along with a range of socio-economic factors, to a set of behavioural variables representing mode choice for commuters in six capital cities in

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3. Since a structural equations model is used, both the direct and total effects of the exogenous variables are estimated. The total effects, or the reduced form coefficients, are presented here.

Australia in 1994. Regarding socio-demographics, they find that solo-driving increases with age, is more prevalent for women, decreases with the number of household members and is higher in urban areas than elsewhere. There are no clear-cut income effects, but this may be due to the inclusion of car ownership, which is itself determined by income, in the reduced form. The effect of education is non-linear, with those of middle education the most likely to travel by car. The results are not fully comparable with the other studies presented above, since the indirect effects of the exogenous variables acting through the other endogenous variables are also included. However, the direct effects are generally of the same sign, with the exception of the level of education, which has a positive direct effect, and gender which is not significant. Finally, they find a strong causality between environmental attitudes and travel behaviour. Particularly "drive-alone" commuters, whose travel behaviour is less-environmentally friendly than that of other commuters, see global warming and congestion as less of a problem, have a stronger confidence in technological solutions, are less willing to reduce their car use and see the car as a status symbol.

The lower car use for women noted in all but one of the previous studies is examined by Dargay (2005) in a study of commuting mode choice in Great Britain using a dynamic panel data model. There is strong evidence that women and men are *equally* likely to commute by car, once other factors are taken into account. The results indicate that commuting by car increases with the individual's income, is more prevalent for full-time workers and those in households with more than one adult, decreases with population density and is lower for those living in London than elsewhere. There are differences between men and women. For women, car commuting increases with the income of other household members, is greater if they have children and is lower if there are others employed in the household. For men, neither the income of other household members nor the presence of children or other workers in the household has an effect on their choice of commuting mode.

A common finding of all studies is that the income elasticity for both car ownership and car use is positive. There is also evidence that the elasticity declines with income, suggesting saturation. Most studies also conclude that the income elasticity is less than unity in most developed countries (for example, Goodwin *et al.,* 2004; Graham and Glaister, 2004), suggesting that motoring is a necessity rather than a luxury good.

2.1.3 Public transport

Public transport (PT) is considered in the next three studies. For Lisbon, Abreu e Silva *et al.* (2006) find that public transport use (either measured as trips or kilometres) declines with income, increases with age and is lower for men and the employed, but is independent of household size and the number employed. There is also evidence that those living in denser, central, and mixed-use areas make more intense use of public transport. Golob and Hensher (1998), in their study of mode choice for *commuting* in Australia, agree that PT use is lower for men, but find that it increases with income and household size. Regarding age, its effect is the inverse of the lifecycle effect noted for car use: public transport use is greatest for the youngest and the oldest individuals. Education has a similar effect: public transport use is highest for the least educated and the highest educated. There is also evidence that individuals who profess concern for the environment are more likely to choose public transport over car travel. This is not supported by Johansson-Stenman (2002), who finds that membership of an environmental

organisation does not increase the likelihood of using public transport. Regarding socio-demographics, the results for Sweden show that PT use declines with income, increases with education, is lower for men and those with children, and is greater in large cities. For age, the relationship is the same as found in Golob and Hensher: public transport use is greatest for the young and the elderly.

Dieleman *et al.* (2002), using a multinomial mode choice model for the Netherlands, look at trips and distance travelled for different purposes by different modes at the household level. They find that those with lower incomes, lower educational level, living in smaller households without children are most likely to use public transport, while the number employed has no significant effect. The most important factors, however, are residential location and car ownership. Those without a car and particularly those living in large cities are the most prevalent users of public transport. Similar results are found for different trip purposes: commuting, shopping and leisure. However, the *distance* travelled by PT for commuting increases with income and is greater for the highly-educated, suggesting that these persons, probably with more specialised jobs, tend to live further away from their workplaces. The distance travelled by PT is also greater in suburban areas and smaller cities than in large cities, again suggesting longer trips. For shopping trips, on the other hand, distance travelled by PT declines with income, but is still greater in suburbs and smaller cities. That there can be different results concerning trips and distance travelled and different journey purposes is important to keep in mind when comparing different studies. However, it does not resolve the difference found here: Golob and Hensher also refer to commuting trips by PT and find that they increase with income. Both of these studies, however, include car ownership as an exogenous variable, and since car ownership is, itself, determined by income, the estimated income coefficients give only the direct effects of income on public transport use at a given level of car ownership. The total effects of income on PT use will also include the indirect effects of income through its effects on car ownership.

Contrary to the results found for motoring, most evidence suggests that the income elasticity of public transport use is negative, implying that public transport is an inferior good.

Table 2 Influence of demographic, socio-economic and land use-factors on vehicle choice and attitudes

Independent variable Reference	Income	Age	Male	Education	House-hold size	Working (# no.)	Children (# no.)	1 family house	Density	Car owner	City size	Attitude to Environment	Country
Vehicle choice													
Choo and Mokhtarian (2004)	–	–	–	+	–	+	–		+			0	USA
McCarthy and Tey (1998)	–	–	–						+			+	USA
Ewing and Sarigöllü (1998)	0	–	0			0		+				+	Canada
Dagsvik et al. (2002)		+	–										Norway
Attitudes													
Poortinga et al. (2003)													NL
Energy-saving	+	–	0	0	–		–					+	
Technology measures	+	+	0	+	+		+					0	
Behavioural measures	–	–	0	–	–		–					0	
Rienstra et al. (1999)													NL
Transport individual problem	+	–	+	+	+		0			+	+		
Transport social problem	0	–	–	0	0		0			–	0		
Policies are effective	–	+	–	–	0		0			–	+		
Golob and Hensher (1998)													Australia
Greenhouse gas serious	0	0	–	–	0					0			
Congestion not so bad	0	+	–	–	–					+			
Abatement possible	+	–	–	–	+					–			
Car status symbol	+	–	–	–	–					+			
Willing to reduce travel	0	+	–	–	+					–			
Krupnick et al. (2001)													USA
Support for emissions tax	0	–	0	–	0		0			0		+	
Harrington et al. (2001)													USA
Support for congestion charge	–	0	–	+						–		+	USA

2.1.4 Total transport

Giuliano and Dargay (2006), in their study of the United States and Great Britain, find that total travel increases significantly with income, and that the effect is stronger in Great Britain than in the US, suggesting a declining income elasticity for total travel. In both countries, employed individuals, under 34 years of age, living in households with two adults in single-family dwellings travel more than other groups. Individuals in households with children travel more than others in the US, but children have no effect on total travel in Great Britain. Travel *declines* with population density, but *increases* with the size (population) of the metropolitan area, suggesting that the greater choice of destinations leads to more travel. The proximity to public transport reduces travel in both countries, mainly through its influence on car ownership, but more in the US than in Britain.

Energy use for total travel is analysed by Poortinga *et al.* (2004) in a study for the Netherlands. The socio-demographic variables included have similar effects as those for total travel in the previous study: energy use increases with income and household size and declines with age. It also increases with education. They could find no significant relationship between transport energy use and variables expressing environmental concern or attitudes towards global warming. Similar results are reported by Walton *et al.* (2004) for commuters in New Zealand. Environmental concern and knowledge of emissions were found to be independent of behaviour: train commuters showed no greater concern for the environment than car commuters, and "smoky vehicle" drivers did not have less knowledge of emissions or lower levels of environmental concern than those commuting by electric train.

2.1.5 Vehicle choice

Technology, in the form of vehicles with increased fuel efficiency and lower emissions or in the form of alternative fuels (biofuels, natural gas, hydrogen), could play a significant role in reducing the environmental problems associated with personal transport. The impact this has, however, will depend not only on the availability of more environmentally friendly cars, but also on the extent to which individuals and households choose these cars over others. There are a number of studies in the literature on vehicle choice, a few of which are presented in Table 2 and discussed below.

As shown by Choo and Mokhtarian (2004), in a study for the San Francisco Bay area, choice of vehicle (small, compact, mid-sized, large, luxury, sports, minivan/van, pickup, and sport utility vehicle) depends on socio-economic and demographic factors as well as attitudes, personality, lifestyle, and mobility. Regarding socio-demographic characteristics, they find that those most likely to drive smaller, and hence less polluting, cars are more likely to have lower incomes; to be younger, female and better educated; to live in smaller households without children; and live in high-density areas. Regarding more qualitative factors, those who have a stronger dislike for travel are more likely to drive luxury cars, but the variable representing "pro-environmental" attitudes is not found to significantly affect car choice.

Another study, by McCarthy and Tey (1998), looks at the purchase of new vehicles in the US according to their fuel efficiency using a nested logit model. They find that the demand for fuel-efficient vehicles is greater for women, minorities and younger

individuals, even after income differences are controlled for. Income, itself, is inversely related to fuel efficiency: those with higher incomes choose larger and heavier cars. Fuel-efficient vehicles are preferred more by those living in urban areas than by rural inhabitants, presumably since the latter travel longer distances and so choose larger cars and are also less exposed to emissions. As expected, both purchase price and operating costs are inversely related to demand.

The introduction of new technologies, for example electric and low-emission vehicles, cannot be analysed on the basis of observations of actual data since such vehicles are rare or not yet developed. In such cases, stated preference (SP) surveys have been commonly used. An example is provided by Ewing and Sarigöllü (1998). The study uses a SP survey within a random-utility framework to examine the factors likely to influence the choice of innovative vehicle technologies. Three vehicle types are included: a conventional gasoline vehicle, an electric vehicle (EV) and another more fuel-efficient gasoline or alternative-fuel vehicle (natural gas, propane, ethanol or methanol) with fuel efficiency somewhere between the traditional gasoline vehicle and the EV. A number of vehicle attributes were included: purchase price, repair and maintenance costs, range, refuelling time, acceleration, emission levels, commuting time (which could vary by vehicle type if cleaner vehicles were allowed to use express lanes on major roads) and differences in fuel prices and efficiencies. A wide range of socio-economic variables was also considered. The results suggest that older respondents, renters and multi-vehicle households are less likely to choose innovative vehicles, whereas income, gender and the number employed have no effect on vehicle choice. "Concern for the environment" increased the likelihood of choosing an innovative vehicle.

Dagsvik *et al.* (2002) analyse the potential household demand for alternative-fuel vehicles (electric, liquefied petroleum gas, hybrid and petrol) in Norway based on data from a SP survey and several alternative demand models in which the parameters are allowed to differ by gender and age. They conclude that women are more likely to consider alternative-fuel vehicles than men are, and for both genders the likelihood increases with age. Men are particularly negative towards electric vehicles. The authors find that vehicle cost is highly significant, and its importance differs little by gender or age. Driving range is less important for women than for men and its importance appears to decline with age, while fuel costs are more important for men and the importance increases with age.

Although the stated preference approach allows the analysis of new alternatives, because the scenarios are hypothetical, only *intended* behaviour is measured. Models using SP data have often produced implausible results and have been the subject of considerable criticism. It is argued, for example: that there are differences between intended and actual behaviour; that respondents may not understand options not previously existing or unknown; that respondents may respond strategically, rather than honestly, if they think their response may affect policy. Evidence also suggests that preferences derived from SP surveys are contingent on context. Fujii and Garling (2003) present an alternative conceptual framework which draws on attitude theory from social psychology in which stated choices are interpreted as behavioural intentions and explains why these sometimes deviate from actual behaviour. Using panel data obtained from commuters before and after the opening of a new subway line in Kyoto, the authors find intentions differ systematically from actual behaviour: prediction is more accurate if it is based on an intention *not to do* something (roughly 80-90% accuracy) than if based on an

intention *to do* something (roughly 60-70% when the intention is strong, and roughly 30-40% when it is weak). In addition, if the intention involves changing habitual behaviour, the accuracy is reduced even further (roughly 20-30%). However, since there is little alternative to SP data when new technologies are concerned, they have been widely used in transport studies. Some of their shortcomings have been addressed in the development of techniques for combining data on stated preferences and revealed preferences (Ben-Akiva and Morikawa, 1990) and using mixed SP/RP panel surveys (Zhang *et al.,* 2001; Brownstone *et al.*, 2000).

2.1.6 Environmental attitudes

We have seen in the previous sections that there is some evidence that attitudes to the environment are reflected in travel behaviour. However, it is difficult from these studies to establish causality. For example, mode choice itself may affect attitudes (positively or negatively) through the individual's experience of the mode (Golob *et al.*, 1979). In addition, socio-demographics may affect attitudes. For example, people with children may be more concerned about environmental pollution. Understanding the variation in attitudes towards the environment and the acceptance of policy measures among different groups of the population can be useful in the development of transport policies and in changing attitudes towards travel. Some recent studies addressing this issue are shown in Table 2.

The acceptability of different transport measures (cycling, use of public transport, car pooling, and increased fuel efficiency) is considered in Poortinga *et al.* (2003). The study is based on an SP survey for the Netherlands and uses simple analysis of variance models (ANOVA models) to examine the acceptability of home and transport energy-saving measures. Different socio-demographic categories: age, sex, income, level of education, and household type are considered as well as "environmental concern". Transport measures were less acceptable than residential measures for all groups and those with high environmental concern evaluated the energy-saving measures on average as more acceptable than did people with low environmental concern. Older individuals and those with low income found such measures more acceptable than did the young and those with high incomes. Transport measures were relatively more acceptable for single respondents, those aged 65 years and older and for those with low incomes, while couples and families, those aged between 20 and 39 years and those with high incomes found these measures the least acceptable. Couples and families, high-income groups, those aged between 20 and 39 years and the higher-educated found technical improvements more acceptable than others, while behavioural measures were relatively more acceptable for single individuals with a low level of education and low income. In none of the cases were there any differences between men and women.

In another study for the Netherlands, Rienstra *et al.* (1999) examine the perception and acceptance of transport policy measures relating to traffic safety, the environment and congestion. Four issues are examined: perception of problems *for the individual* caused by transport (congestion, parking, pollution, safety, noise, etc.), perception of problems *for society* (congestion, environmental problems, safety), perceived effectiveness of the measures, and support for these measures. Using a logit model to analyse perceptions of problems for the individual and society, the authors find that at the individual level, safety issues are considered to be more important than both congestion and the environment, while at the societal level the opposite holds: environmental problems are most important,

while safety is considered to be least important. Regarding socio-demographics, older respondents consider both problems for the individual and society as less serious than the youngest category, while respondents in the category 30-40 years think the problems are most severe; women also consider both types of problems as more serious than men do. Households with two or more persons, with higher educational level, higher income and living in large cities consider problems for the individual as more severe compared with people living alone, with less education, lower income and living in smaller municipalities, but no difference is found between these groups with respect to problems for society. However, those who travel more -- commuters, car owners and driving licence holders -- perceive transport-related issues as more problematic on the individual level than do other respondents, but their perception of these problems for society as a whole is lower than that of the other respondents.

The perceived effectiveness of policy measures is analysed using an ordered probit model. Congestion and environmental measures are considered to be less effective than safety measures, and price measures and infrastructure/spatial organisation measures to be less effective than technical measures or the support of alternative transport modes (public transport, cycling). The effectiveness of policy measures is considered to be greater by older people than by the young, by women compared to men and by the lower-educated. Commuters, car owners and drivers perceive the effectiveness of measures to be lower than others do, particularly with respect to pricing measures. The middle-income groups consider pricing measures to be least effective, while the lowest-income group perceives price measures as most effective.

The impact of perceptions of social and individual problems, perceptions of effectiveness of measures and personal characteristics on the support for policy measures is also examined. A major conclusion is that safety measures are most strongly supported by the respondents, while environmental measures have more support than congestion measures. Price measures and infrastructure measures have less support than the supply of new modes or technical improvements of current modes. Regarding socio-demographics, there is little difference between groups other than an indication of increasing support with educational level and less support among the under-30s. Car owners and drivers are less likely to support policy measures, and particularly price measures. Perceptions of individual and social problems in transport have a positive impact on the support for measures, with the perception of social problems having greatest impact. Finally, support for policy measures increases with their perceived effectiveness.

Golob and Hensher (1998) also examine the relationship between socio-demographics and a number of attitudinal factors in their study for Australia. They find that women and the less well-educated are more likely to consider greenhouse gas emissions (GGE) a serious threat while men, the more highly-educated and those with fewer cars consider congestion a problem. Women, younger individuals, the less well-educated, those in larger households, with higher incomes and few cars considered abatement of GGE more possible than do men, older individuals, the more highly-educated, those in smaller households, with lower incomes and more cars. Despite the fact that women and the less well-educated are more likely to see the car as a status symbol, they are also more willing to reduce car use. The elderly do not see congestion as a problem but are willing to reduce travel.

Krupnick *et al.* (2001) use a probit model to examine the support for a taxation package based on the miles driven and the pollution per mile in California. The results indicate that younger individuals, those with lower education, Democrats and Independents, Asians and Hispanics are more likely to support the plan, while neither income, gender, household size, number of children, whether the home is owned or not, or the number of vehicles owned or leased by the household were significant in determining support. Attitudinal factors were found to be important: those who were highly bothered by air pollution and those who believed in the efficacy of the policy were more likely to support it. In addition, support declined with the magnitude of the fee. Another study for the US, by Harrington *et al.* (2001), uses a similar model to estimate the support for congestion pricing. The authors find that support declines with income, the number of cars in the household and educational level and increases with household size. There is no significant difference between women and men, *ceteris paribus*, and Asians and Hispanics are more likely to be supportive than other races are. They also find that support for the measure is greater for those who consider congestion more of a problem.

2.1.7 Awareness of environmental impacts of car travel and travel alternatives

Recently, there has been a growing interest in what are generally known as "soft" transport policy measures. These are psychological and behavioural strategies which attempt to influence individual awareness of the problems associated with car use and inform of alternatives, with the aim of encouraging voluntary reductions in car use. Methods include both general advertising campaigns (supporting car sharing, public transport, walking, etc.) and more targeted campaigns aimed at particular groups (school children, commuters, shoppers). Some examples are TravelWise (Hertfordshire County Council, 1993), HeadStart (Hampshire County Council, 1993), Travel Smart (DfT, Western Australia, 2000), Travel Blending (Rose and Ampt, 2001), and the Travel Feedback Program (Taniguchi *et al.*, 2003). It has been suggested that such measures can lead to reductions in car use of over 10% (Cairns *et al.*, 2004; Rose and Ampt, 2001; Fujii and Taniguchi, 2005). However, as pointed out by Seethaler and Rose (2003), research in other areas (public health, energy consumption, etc.) has shown that information-based campaigns alone are generally insufficient for promoting long-term behavioural change. They suggest that the use of persuasion techniques developed within social psychology (Reciprocity, Consistency, Social Proof, Authority, Liking and Scarcity) can do more than raise awareness, by increasing the personal involvement of individuals and thus achieving a lasting change in behavioural patterns. In an experiment to encourage habitual car users in Germany to switch to public transport, Matthies *et al.* (2006) conclude that "soft measures", which target the moral dimension of environmental behaviour, may be helpful if the willingness for commitment is high and if incentives are given (a "habit-defrosting strategy", *e.g.* free public transport tickets for an introductory period). Although the overall effects were found to be small, there was an indication that personal norms have a long-term influence if participants have a strong commitment. In a Swedish study, Nordlund and Garvill (2003) show that personal values and awareness of the environmental consequences of car use and the seriousness of these problems influence personal norms, which in turn influence willingness to reduce personal car use.

Eco-labelling of passenger cars is a part of the European Union's strategy to reduce CO_2 emissions, although the particular scheme is still under investigation. Fickl and Raimund (1999) estimate that such labelling can reduce the EU car fleet's fuel

consumption and CO_2 emissions by 4-5% by 2010. Other studies are less optimistic: DfT (2003a) find that although car drivers generally perceive themselves as caring about the environment, this is not reflected when actually choosing a car.

2.2 Characteristics of the transport system

2.2.1 General pricing measures affecting the cost of motoring

The impact of prices on personal transport has been the subject of numerous empirical studies, particularly since the oil price rises of the mid-seventies. Although the majority of these concern the price elasticity of the demand for motor fuels, a sizeable literature also exists for car ownership, car travel and public transport use. As it is well accepted that there is a difference between short- and long-run price elasticities, we will concentrate on those studies which are based on dynamic models and observations of behaviour over time. The studies are generally based on aggregate time series data for an individual country, or a combination of time series and cross-section data for different countries, areas or routes.

Price elasticities relating to car travel have been reviewed in earlier OECD studies (OECD, 2000 and 2005). The most likely values of these elasticities, based on the review by Goodwin *et al.* (2004), are shown in Table 3.

Table 3. Price elasticities for personal transport.

Elasticity of:	With respect to:	Short run	Long run
Fuel consumption[1]	Fuel price	-0.25	-0.64
Fuel consumption[1]	Car purchase costs	-0.12	-0.51
Vehicle kms[1]	Fuel price	-0.10	-0.29
Vehicle stock[1]	Fuel price	-0.08	-0.25
Vehicle stock[1]	Car purchase costs	-0.24	-0.49
Bus (local)[2]	Bus fares	-0.3 to -0.5	-0.6 to -1.0
Rail (metro)[2]	Fares	-0.3	-0.6
Rail (suburban)[3]	Fares	-0.6	-1.0
Rail (inter-urban)[3]	Fares	-0.7	-1.1

Sources: 1. Goodwin *et al.* (2004); 2. TRL (2004); 3. Oxera (2005).

From these results, fuel taxation is more effective than a car purchase tax for reducing fuel consumption. The effect of fuel prices on car use is about half their effect on fuel consumption, since some of the reduction in fuel use will be achieved by increased fuel efficiency (the rebound effect). It is likely that other variable costs of car use will have similar effects to fuel costs. Assuming this is the case, and if fuel costs make up half of total running costs, the elasticity of car travel with respect to total running costs will be on the order of -0.2 in the short run and -0.6 in the long run.

There is other evidence based on household data. De Jong (1996), using a simultaneous model for vehicle choice, car use and fuel efficiency, finds that the rate of vehicle replacement increases when fuel costs rise and declines when fixed costs (*e.g.* road taxes) rise. Both variable and fixed car costs have a negative impact on vehicle choice. Increasing fuel costs reduces car use, while increasing fixed costs has a much smaller impact, which is in agreement with Table 3. Overall fuel consumption is predominantly affected through car use, while fuel efficiency per car is little affected by

replacement of vehicles with more fuel-efficient models. This conclusion, however, is based on a two-year period and one would expect fuel efficiency to improve over the longer term. Feng *et al.* (2005) estimate a simultaneous discrete and continuous model for car ownership and use for Japan, which includes a nested logit structure to model discrete choices among different vehicle types. Their results indicate that a higher fuel price would shift households away from sport utility vehicles (SUVs) and also reduce miles driven. A tax on vehicle age would induce shifts to newer vehicles with less "wear" and also away from SUVs, as would a tax on SUVs. Fullerton *et al.* (2004), using a similar model for Japan, find that choice of car is relatively inelastic to taxes on cars, so that emissions are more affected by taxes on gasoline or on distance than by taxes on particular vehicles. Comparing different taxes which are equivalent on a per-kilometre basis, a tax on local emissions (in yens/gram) reduces vehicle distances the most, followed by the distance tax (per km), the gasoline tax (per litre), and the CO_2 tax (per gram).

Ubbels *et al.* (2002) consider the potential environmental effects of a kilometre charge for car traffic in the Netherlands, which would replace the existing taxes on new cars and on car ownership and lead to a substantial increase in the variable costs of car use. In agreement with the previous study, they show that the introduction of a differentiated kilometre charge can lead to a substantial reduction of environmental pollution caused by car traffic, a significant decrease in congestion and an increase in the use of public transport and non-motorised modes. On the other hand, such a tax would give no economic incentive for using more fuel-efficient or less polluting vehicles.

The conclusion of Fullerton *et al.* (2005) that car choice is relatively inelastic to differential taxation is contrary to most other studies. McCarthy and Tey (1998), Dagsvick *et al.* (2002), Feng *et al.* (2005) and Ewing and Sarigölü (1998) all find that vehicle cost is highly significant in determining the choice of fuel-efficient or alternative-fuel vehicles. In fact, according to Ewing and Sarigölü, the only economic instrument that is likely to encourage cleaner vehicles is price subsidies, while the use of instruments affecting travel cost and time, designed to favour cleaner vehicles, will divert little extra demand towards them.

Another measure to reduce the levels of CO_2 emissions is the graduated Vehicle Excise Duty, which favours new cars with low CO_2 emissions. Such a scheme was introduced in the UK in 2001. In an attempt to asses this, DfT (2003b) finds that car buyers do express concern about the environment and the impact that the car can have; however, this concern does not necessarily translate into environmentally-friendly behaviour at an individual level. New car purchasing decisions are dependent on a number of factors but environmental considerations and road tax are not among the most significant. Overall price, fuel consumption, size, reliability, and comfort are the most important factors in the decision-making process. They conclude that the current graduated scheme does not offer a large enough incentive to encourage behavioural change.

2.2.2 Location-specific pricing measures

Elasticities relating to area-specific pricing measures, such as parking charges, road tolls and urban congestion charges, will inevitably vary from place to place, since they

will depend on the particular circumstances: the existence of alternative parking possibilities, destinations and routes, public transport options and the extent of the tolled area. Because of this, it is less meaningful to report "average values". In addition, far fewer empirical studies are available.

2.2.2.1 Parking charges

Recent reviews of parking price elasticities (TRACE, 1999; Vaca and Kuzmyak, 2005) suggest that the elasticity of vehicle trips or kilometres is generally quite low, from 0 to -0.3, depending on type of trip, location, etc. A small positive cross-effect is noted for public transport, car-sharing and slow modes (walking and cycling). The magnitude of the elasticity is very location-specific as it depends on the existence, convenience and cost of alternatives to car use.

2.2.2.2. Road pricing

Road pricing can take a number of forms: cordon tolls in urban areas, tolled motorways, bridges or tunnels; and can be based on a flat fee or a variable charge by time of day or congestion conditions. Olszewski and Xie (2005) examine the effects of the road-pricing scheme in Singapore, in which the charges vary by time of day to keep the traffic at an acceptable level. They find that the elasticity is greater on expressways and arterial roads, where there are alternative routes, than the city-centre cordon. The elasticities are quite small: for example, during the morning peak the elasticities are -0.2 and -0.1, respectively. The elasticity increases over the day and reaches a maximum value of -0.3 during the evening peak. This is explained by the greater flexibility in retiming the homeward journey than the journey to work. These results are not very different from those reported by Polak and Meland (1994) for Trondheim, who find, however, that the elasticity is greatest during the morning peak (-0.3).

The congestion charging schemes in London and Singapore are assessed in terms of their performance in reducing congestion and raising net revenue by Santos (2005). She concludes that the system in Singapore, which charges per entry is more effective at reducing congestion than a per-day charge. She also stresses that the success of congestion charging depends on the extent to which it is accompanied by complementary measures that provide motorists with an acceptable alternative to the car.

Brownstone *et al.* (2003) estimate a choice model to analyse a congestion charging scheme in San Diego which allows solo-drivers to use express lanes, which are free for high-occupancy vehicles. They show that those most likely to use the scheme are commuters, women, persons aged between 35 and 45, home owners and those with higher income and education. They conclude that motorists are willing to pay on average USD 30 to reduce travel time by one hour.

Empirical studies of toll or congestion charge elasticities reviewed in Matas and Raymond (2003) range from -0.03 to -0.50. Preliminary results for the London Congestion Charging Scheme (Santos and Shaffer, 2004) suggest that the demand for car trips is far more elastic: -1.3 and -2.0. None of these studies, however, distinguishes between short and long run. Dynamic estimates for toll roads in Spain (Matas and Raymond, 2003) show a considerable variation: between -0.2 and -0.8 in the short run and -0.8 and -1.3 in the long run, for different stretches of motorway.

Despite the success of road pricing in reducing congestion, it remains one of the least popular transport measures. However, as found by Jones (1991) and others, support depends on the use of the revenues. In the UK, support for road pricing increased from 30% to 57% when respondents were told that revenues would be spent on a mix of improved transit, local traffic management and better pedestrian facilities. A smaller effect is found by Harrington *et al.* (2001) for California: the promise to refund a large part of the revenues to the public in the form of reductions in other local taxes increased the support for congestion fees by about 10 percentage points.

2.2.2 Scrappage bounties

Scrappage bounties or voluntary accelerated vehicle retirement programmes have been adopted in about a dozen countries (European Conference of Ministers of Transport, 1999) as a means of reducing emissions caused by older vehicles. Most programmes offer a specified amount for each vehicle over a certain age. The programmes in Europe accept vehicles 10 years or older and some of these programmes require the purchase of a new vehicle. This is not the case for the US programmes. The effects have been estimated in a number of studies, a few of the most recent ones are discussed below.

Yamamoto *et al.* (2004) use a competing risks duration model to investigate the effects of the French periodical vehicle inspection programme and the grant for scrappage of old vehicles, using panel data. Their results suggest that the inspection programme has encouraged households to keep their vehicles 1.3 years longer than without the programme; however, these older vehicles are better maintained than previously and likely to be less polluting. The grant for the scrappage of vehicles over 10 years decreases the average holding duration by 3.3 years. The net effects on emissions are not analysed in the study, but it is likely that the combination of the two measures will reduce overall emissions.

Kavalec and Setiawan (1997) analyse the costs and effects of a large-scale vehicle retirement programme in California. For various numbers of retirement vehicles, they estimate the bounty required, the number of retired vehicles that would be replaced and produce simulations to 2020 of the net effect on vehicle miles travelled, fuel use and emissions, and the welfare effects by income level. Their main conclusion is that a programme targeting vehicles 20 years and older is likely to be more cost-effective and have less of an impact on used car prices than a programme targeting those l0 years and older. The loss in welfare is also less because the bounty required would be lower. In another study for California, Dill (2004) argues that commonly used methods of estimating the reduction in emissions are based on several assumptions and demonstrates that changing these assumptions can significantly alter the estimated benefits. The results show that vehicle retirement programmes are likely to reduce emissions, but probably not as much as expected for a number of reasons: scrapped vehicles are generally driven fewer miles than other vehicles of the same model year, some of the vehicles would have been scrapped anyway, emissions may not be as high as predicted and replacement vehicles are generally older than the fleet average.

2.2.3 Regulation

There are few examples of regulation, and little empirical evidence. The Corporate Average Fuel Efficiency (CAFE) standards in the US serve as our only example. The

effects are examined by Goldberg (1998), using a discrete-continuous model for car choice and car use. Simulation results show that federal fuel taxes would need to increase from USD 0.10 to USD 0.80 per gallon to achieve a similar reduction in fuel use. There are problems with these results, however: they are based on negligible elasticity values and a static modelling framework which fails to take into account the adjustment that occurs over time. Other authors find contradictory results. For example, Kleit (2004), modelling the impact of higher CAFE standards on producer and consumer welfare, fuel consumption, externalities from increased driving and emissions, estimates that a long-run 3.0 miles per gallon increase in the CAFE standard will impose welfare losses of about USD 4 billion per year and save about 5.2 billion gallons of fuel per year, thus costing USD 0.78 per gallon saved. In comparison, an 11-cent-per-gallon increase in the gasoline tax would save the same amount of fuel at a welfare cost of about USD 290 million per year, or about one-fourteenth the cost.

2.2.4 *Public transport fares and quality*

An extensive review of public transport fare elasticities (TRL, 2004) indicates that the demand for bus travel is relatively price-sensitive and for urban rail, slightly less so (Table 3) and in both cases, less elastic during peak times than off-peak There is a wide variation in elasticities: the elasticity increases with the fare level and is greater in less urban areas (Dargay and Hanly, 1999; Bresson *et al.*, 2003). In a recent review of rail fare elasticities for the UK and internationally, Oxera (2005) finds that demand is relatively elastic, and more so for inter-urban than for suburban services (Table 3). Many studies indicate that petrol prices have a positive effect on public transport use (Dargay and Hanly, 2002; Bresson *et al,* 2004; Matas, 2004), but there is less empirical evidence that public transport fares affect car use.

The quality of public transport is also an important determinant of its use. Some studies (*e.g.* Dargay and Hanly, 1999; Bresson *et al.,* 2002; Pratt, 2004) find that service quality is at least as important as fare, if not more so, suggesting that fare increases can be compensated for by equivalent service improvements without affecting patronage. In a review of the literature, Litman (2005) reports that the elasticity of public transport use with respect to service level (generally measured as vehicle kilometres) is found to be on the order of 0.3 to 0.6 in the short run and between 0.6 and 0.8 in the long run. Evans (2004) provides information on the effects of various types of service improvements on patronage: the elasticity of transit use to service level (measured in vehicle-kilometres) is in the range of 0.6 to 1.0; the elasticity with respect to service frequency (called a *headway elasticity*) averages 0.5. Bresson *et al.* (2003) report similar values and also find that service level is more important than service frequency or density.

3. Policy implications

In this section, we consider the implications of the empirical evidence reviewed in the previous section for the formation of environmental policy relating to personal travel. We begin with a summary of the effectiveness of various measures. In the following subsection, the findings concerning differences between individuals in travel behaviour, attitudes and support for policy measures and the implications this has for targeting policy measures are examined. Thereafter, the distributional implications of various transport policies are discussed, supported by empirical evidence. The paper ends by highlighting

the existing gaps in our knowledge and suggests areas where additional insights would be valuable for the formulation of policy recommendations.

3.1 Effectiveness of policy measures

Economic incentives in the form of taxes and subsidies are the most common form of policy measures. As shown in the previous section, such measures do have effects on fuel consumption and mode choice, but they do not appear to be very large, so that substantial increases in the cost of motoring will be required to cause a significant reduction in emissions and particularly in car traffic. For example, the vast difference in taxes on motor fuels between the US and Europe surely explains some of the differences in car use and fuel efficiency, but the smaller differences among European countries seem to have little effect. The empirical evidence suggests that taxes on the variable costs of motoring (*e.g.* fuel taxes) reduce fuel consumption, but that the effects on car use are considerably smaller as households adjust to the increased taxation by buying more fuel-efficient cars, which reduces variable costs and in turn encourages greater car use (the rebound effect), thus eroding part of the effects of the initial cost increase. If reduction in emissions is the sole objective of the policy, this will not matter very much. But if wider environmental goals are at issue, particularly those relating to congestion, other policies will be required. An example is a tax on distance travelled by car. However, unless the tax also takes into account emissions, although car travel may be reduced, there will be no incentive to choose more efficient vehicles.

The fixed costs of motoring (car purchase costs) also affect fuel consumption and total car use, but the effects are relatively smaller than for variable costs. High taxes on car purchase will reduce car ownership, but it will also affect the retirement rate, so that the stock of vehicles will be older, less efficient and more polluting. In addition, use per vehicle will rise. Regarding the effect of car taxes on vehicle choice, the evidence is not clear-cut. Although some authors find that car choice is relatively inelastic to differential pricing or taxation, most agree that such measures can have substantial effects on encouraging the purchase of cleaner vehicles if the taxes are sufficiently large. Unless new technologies are economically competitive, subsidies or a differentiated tax favouring them in relation to traditional vehicles will be necessary.

Road pricing or congestion charging has a potential to reduce congestion and improve travel times, at least in those areas subject to the charge, but can lead to increased traffic in other areas. Also, it gives no incentive for the use of more environmentally-friendly vehicles, unless it provides a reduced charge for such vehicles.

That car travel is relatively insensitive to changes in costs suggests that individuals consider motoring as necessary and that they have few possibilities of reducing car use by switching to other modes. Although this may not be true in an objective sense, it reflects the individuals' attitudes, beliefs and preferences. These preferences will need to change if a shift away from the private car is to be achieved. Information campaigns which make people aware of alternative travel possibilities and the negative environmental implications of car travel could be effective in changing attitudes and improving awareness of alternative travel options, but whether or not this will be reflected in behavioural change is debatable.

Regarding public transport, the effects of fares on both bus and rail patronage appear to be considerable, at least in the long run, which suggests that subsidising public transport can bring about a substantial increase in patronage. This increase will arise partially by attracting new patrons (both from cars and other modes) and by increasing the travel of current users. The relative proportions of these groups will determine the overall effect on travel. When used as an environmental measure, the effectiveness of public transport subsidies must be judged by their ability to attract car users to public transport, rather than increasing the journeys of current patrons or by dissuading individuals from walking or cycling. The empirical evidence on the potential of attracting motorists to public transport by reducing fares is ambiguous and further research is needed to determine the extent to which fare subsidies will be economically efficient in reducing car use. However, there is strong evidence that the income elasticity for public transport is negative, suggesting that individuals consider it to be an inferior good. It is obvious that the negative perception of public transport will need to change if a significant shift from car to public transport use is to be realised. There is some indication that environmental concern is related to mode choice, although there is some uncertainty about the direction of causality. There is evidence, however, that information-based instruments which appeal to personal values and norms, by increasing awareness of the negative environmental consequences of car use, can play a role in individual decisions regarding personal transport.

Of course, a shift from car to more environmentally-friendly travel modes is contingent on the existence of a transport infrastructure that makes other modes feasible alternatives.   Fuel taxes or road pricing, for example, will only be effective if individuals have other alternatives to using their cars. For this reason, the effects of such policies will be reinforced if they are combined with complementary measures: the provision of reliable and inexpensive public transport, safe cycling infrastructure, etc. In addition, there is clear evidence that service quality is as important as price in determining public transport use, so that improving the frequency, reliability and convenience of public transport is essential.

We have seen in the previous section that the response to price (or taxation) changes does not occur instantaneously, but takes place slowly over time. In the short run, individuals have few options to change their travel behaviour. They may be able to omit unnecessary trips or replace some car trips with public transport, walking or cycling. Given their current vehicle holdings, it may be costly to replace their car with a more energy-efficient one. In addition, it will take time to explore the various options, both with respect to vehicle fuel efficiency and other travel modes. Over time the number of options increases. They may choose not to replace their current car, or to replace it with a more energy-efficient model. They can move closer to their workplaces so they will have shorter commuting distances and more possibility to walk or cycle, or move to a more central area better served by public transport. When they are considering changing jobs, they can look for jobs closer to home or in areas where the public transport links are better. Measures can be devised to speed up this process. For example, schemes to encourage accelerated vehicle scrappage and subsidies on more environmentally-friendly vehicles will make changing cars more economically viable over a shorter time horizon than would otherwise be the case. Informational measures can assist in vehicle choice and a shift to other modes.

There are very few studies of individual behavioural response to regulatory measures, apart from those relating to the CAFE standards in the US. Although it is clear that these standards have reduced the environmental effects of car travel, there is little consensus as to whether equivalent reductions could have been realised in a more economically efficient manner by pricing measures.

Localised measures, for example parking restrictions, car-free residential areas, traffic restraint, etc., will reduce car use (and emissions) in the area concerned, but their effect on total car use and travel appears to be small, and few empirical studies consider these policies in a thorough manner. Land-use measures, however, can have substantial effects on car use and total travel. As shown in the previous section, density of population, proximity to town centres and metropolitan size all reduce car ownership, car use and total travel. Larger centres tend to have lower rates of car use because they make public transport options more practicable and have a greater concentration of amenities such as shops, services, leisure facilities and workplaces. The proximity of various amenities to residences reduces total travel and car ownership and use, and encourages walking, which also has wider benefits on health and the social cohesion of neighbourhoods. Another planning issue not addressed by the studies reviewed here is the question of out-of-town retail centres. There is little consensus on their effects on travel: they may result in longer trips, but also in fewer trips, so the net effect is unclear. However, it is argued that they create problems for the viability of city centres and have equity implications, unless they are adequately served by public transport. Unfortunately, there is little reliable empirical evidence on individual preferences relating to land-use options. More research in this area is needed.

In general, there is little consensus as to the relative environmental effectiveness and economic efficiency of alternative policy instruments. It is more certain, however, that individual policies targeted on a single aspect of travel behaviour will not be as effective as a package of complementary policies. Measures directed towards increasing the costs of motoring will need to be combined with measures to make public transport more competitive (either by reducing fares or improving service), and with improved infrastructure for cycling and walking.

3.2 Differences between individuals

From the empirical studies presented in the previous section, some conclusions can be drawn about the characteristics of individuals who are more likely to have travel behaviour patterns which can be considered more environmentally-friendly, in the sense that they travel less and particularly less by car. On the basis of this definition, the travel behaviour of women, the young, the elderly, the less-educated, those living in urban areas and those with lower incomes is more environmentally-friendly than the travel behaviour of men, those in middle age, the more-educated, those living in rural or suburban areas and those with high incomes. However, this difference is not necessarily a result of conscious environmental choices, but primarily reflects differences in transport needs and the options available to different individuals. Those with low incomes, for example, travel less by car not because they are more concerned for the environment, but because they cannot afford cars.

Similar patterns are noted for car choice: women, the young, those with lower incomes and those living in urban areas are more likely to drive smaller and more fuel-efficient

cars (probably because they are less expensive to purchase and run) and are more likely to be favourable to the choice of environmentally-friendly vehicles. However, for all individuals cost is among the most important determinants, and unless this is competitive with traditional vehicles, economic instruments such as price subsidies (or differential taxation) will be required to encourage the widespread purchase of such vehicles. The relationship between environmental concern and vehicle choice is not unambiguous: many studies find that those who profess concern for the environment often indicate intentions to choose more environmentally-friendly options, but there is little evidence that they actually do so. The difference between intended and actual behaviour can be substantial, particularly when it concerns changing a well-established behaviour.

There is some empirical evidence that environmental concern is greater for women, the young and those with higher incomes and educational levels. However, care must be taken in how environmental concern is measured. The evidence as to whether environmental concern actually leads to pro-environmental behaviour is mixed, and needs further investigation.

It is not surprising that those who would be less affected by environmental measures (those who travel less by car) tend to find them more acceptable and believe them to be more effective. In general, it seems that technical solutions and investment in public transport are preferred to price measures. This is particularly true for car owners. Regarding socio-demographics, the evidence is mixed. However, it is clear that men are less likely than women to accept the seriousness of environmental problems, to believe in the efficacy of policy measures and to support them. They are also less willing to reduce travel. In general there is more support for policies which increase travel costs if the revenue obtained is recycled back to the individuals.

Informational strategies will be most effective if they target those groups which have higher car use and are less supportive of environmental policies: men, the middle-age groups and those with higher incomes and education.

3.3 Distributional implications

The effects of taxation of a particular good or service on income distribution depend on the relative share of the good in total consumption expenditures and the ability of the individual to adjust to the tax increase by reducing the demand for the good and replacing it with other types of consumption. The redistributive effects of motor fuel taxation, for example, will depend on the budget share for motor fuel expenditure. If this share increases with income, the tax will represent a greater share of expenditures for high-income households than it will for those with lower incomes, so the tax will be progressive. In the opposite situation, when the expenditure share declines with income, those with lower incomes will need to devote a larger share of their expenditures to the tax (by reducing the consumption of other goods) than those with high incomes, so the tax will have regressive effects. As shown in Berri (2005) and Dargay (2005) for France and the UK respectively, the relative budget shares for transport expenditures for different income groups have changed over time and thus have implications for income distribution. This is particularly the case for fuel expenditures. For France, fuel taxation has switched from being a progressive to a regressive measure. For the UK, the progressive distributional effects are no longer unambiguous: the budget share for motor fuels increases with income up to the middle-income group and then declines, so the

nature of a fuel tax changes from progressive to regressive at this income level. This is also noted by West (2004) for the US and by Asensio *et al.* (2002) for Spain. The latter study also shows that the switch from progressivity to regressivity occurs at lower income levels the smaller the municipality, reflecting a greater reliance on car travel in these areas. Of course, if we only consider households with cars, fuel taxation will be far more serious for low-income households than for those with higher incomes. This is illustrated in West who shows that for households with cars, taxes relating to car use would be regressive over all income groups. As was clear from the literature review, those living in rural areas have more cars and travel more by car than those in urban areas. Because there is little alternative to using the car, rural inhabitants will be particularly disadvantaged by taxation on motoring, and particularly those in the lowest income groups.

Taxation based on the price of the car will have positive distributional effects (Berri, 2005; Dargay, 2005; West, 2004). Also, as shown by West, since wealthy households are more likely to own newer vehicles, a subsidy on new fuel-efficient cars would be regressive, while an accelerated vehicle retirement programme would be progressive. Higher vehicle registration fees for more polluting cars would be the greatest burden for middle-income households and be regressive across the upper half of the income distribution. A uniform tax on miles that does not distinguish between dirty and clean vehicles is less regressive than an emissions tax (West, 2005).

In contrast, Asensio *et al.* (2003) for Spain and the above authors for France and the UK agree that public transport subsidies are generally progressive (and taxation regressive), especially in urban areas. For the UK, there is a difference between modes: bus subsidies are progressive, while rail subsidies have regressive distributional effects.

The distributional implications of transport taxes discussed here describe the immediate effect of these measures on consumption standards. Over time, individuals can adjust to the new price relationships by reducing their use of the taxed transport goods or services in favour of other modes of transport or other consumption goods. The price elasticity of demand is considered a measure of adjustment possibilities and since demand is more elastic in the long run than in the short run, the effects of taxes on individual welfare will decline over time. The implication of adjustment possibilities for long-run distributional effects depends on whether the elasticities differ among groups. Unfortunately, there is little empirical evidence one way or the other. For the UK, Dargay (2002) finds that the elasticities of car ownership with respect to car purchase prices and fuel prices for households in urban areas are twice those for households in rural areas. We would expect the difference to be even greater for car use. If this is also true for car use, the difference in effects between rural and urban dwellers will increase over time. Similarly, if, as found by West (2004), price-responsiveness declines with income, the degree of progressivity in the poorest deciles will be increased and the regressivity in the upper deciles will be reduced.

Over time, a fuel tax can be expected to influence the fuel efficiency as well as the amount of driving. As argued by Bento *et al.* (2005), since higher gasoline taxes could stimulate higher rates of scrappage of older, fuel-inefficient cars and promote shifts in demand from used cars to more fuel-efficient ones, studies that ignore these adjustments could understate the tax's impacts on fuel consumption and give erroneous conclusions concerning distributional effects. Their simulation results show that whether a fuel tax

increase is regressive depends on the manner in which the tax revenues are recycled to the economy. Under tax-based recycling, the fuel tax increase is nearly proportional in its impact with respect to income. However, younger households and those with children would be harder hit, since they tend to drive relatively more than others. The effects of income-based recycling are quite the opposite: the impacts are highly regressive, with the highest income households experiencing a welfare gain. In general, income-based recycling is relatively beneficial for those who do little driving: the retired and those without cars.

A large body of research into the political and social feasibility of transport policies has concerned the case of road pricing for congestion regulation. According to economic theory, the marginal utility of money decreases with income so the value of time increases. This implies that price measures are less acceptable for those with lower incomes because of their lower willingness to pay to reduce congestion, so that low-income groups will most often oppose road pricing or other pricing measures. There is some literature on the distributional effects of congestion pricing. A common conclusion is that low-income and part-time workers who access the tolled area may be particularly affected by tolls as their tolls would be higher relative to their incomes (McQuaid and Grieco, 2005). Examining a hypothetical congestion-charging scheme in Leeds, Bonsall and Kelly (2005) conclude that some drivers will reduce their car use because of the charge and others will have to make economies elsewhere. This could have serious economic consequences for some people, leading to social exclusion. The groups most at risk are those on low incomes who have no realistic alternative to the car for particular journeys, which may be too far for walking or cycling (or they are unable to do so for health reasons) or because lack of public transport. In addition to those with low income, the indicators for being at risk include disability, age, gender, membership of a social minority, and responsibilities for the transportation of others.

Santos and Rojay (2004), however, refute the notion that road pricing is always regressive. Comparing three English towns, they find that impacts are town-specific, depending on where people live, where they work and what mode of transport they use. They argue that when the majority of drivers entering the area prior to the toll have higher-than-average incomes, they will be prepared to pay the charge and enter the tolled area. In such a case the overall effect will be that, on average, rich people will pay the toll and poor people will not. A different view is taken by Mokhtarian and Salomon (1997). They contend that since behavioural adjustments vary in cost and availability, there will always be a potential distributional effect in the sense that different individuals or households can only respond by adopting certain measures which they can afford, and by not adopting others. Low-income people are barred from some alternative responses if their available resources are insufficient. There can be distributional effects on the basis of occupational group: some occupations do not facilitate some responses, *e.g.* telecommuting. Other effects may relate to gender: because of inequality in the distribution of household tasks and childcare, women may have greater constraints than men and can less-easily change their travel patterns. Although there is disagreement concerning the distributional implications of road pricing, most authors agree that the use of revenues is crucial in determining the overall effect on equity.

3.4 Research needs

Although there is substantial body of empirical evidence on travel patterns for different individuals, the response to policy measures (particularly those related to price) and the distributional implications of various policies, there are still a number of questions which remain unanswered. One of these is the economic efficiency of different policy measures. It may be possible to attain the same improvement in the environment by different measures having different welfare implications. The "best" policy will have the greatest effects at the lowest cost, so a better knowledge of the comparative effects and costs of different policies will contribute to a more informed policy formulation.

Another shortcoming concerns our knowledge of the effects of attitudes and information on the acceptance of environmental policy and how this translates into more environmentally-friendly travel behaviour. Although a number of studies have been carried out, the results are often contradictory and it is difficult to judge to what extent this is a result of different definitions and constructions of the attitudinal variables. It would be an advantage to use the same definitions and models for different countries to see if some of the inconsistencies could be reduced. In general, there are far too few comparative studies. Much of relevance to policy formulation can be learned from such studies since the difference in policies between countries is substantial.

Little is known about the options different individuals have for changing their travel behaviour and the implications such changes would have on their quality of life. The role that telecommuting, internet shopping, banking, etc. can play in reducing travel also requires further study.

In addition, preferences regarding the use of revenues obtained by road pricing or other price-related policy measures require further study. The use of these revenues can be important in creating support for such policies. Finally, more information is needed concerning individual preferences relating to travel, lifestyle and support for different policies.

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4. Residential Energy Demand

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1. Introduction

This paper provides a concise review of the empirical literature on residential energy demand. It also discusses the findings in the reviewed literature and their implications for the choice of policy instruments. While there is a plethora of studies on the technical possibilities, *i.e.* the potential energy savings that new technologies allow, it is plain that energy consumption also depends on our attitudes, preferences and income as well as relative prices[1]. Therefore, this review is based on the idea that energy demand is essentially driven by human behaviour and our main task is then to explore a range of empirical evidence that sheds useful light on our limited objective. Indeed, the literature on energy demand is impressively rich; already in the early years of the 1980s there were more than 2 500 papers available on this topic (Joerges, 1988 cited in Weber, undated). This brief review will focus mainly on the economics domain, a limitation to be true, although pointers will be given to findings in related fields.

While our review targets insights from empirical studies within the economics domain, we must at the outset warn that the studies display substantial variations, so large that any firm conclusions about household behaviour must be cautioned beyond the usual caveats. For example, the estimated price and income elasticities show such large variance that it is hard to distil a pattern. Dahl (1993), in *a* comprehensive survey, compares these elasticities with snowflakes – no two are alike. Fortunately, there are a number of cogent explanations as to why there is such heterogeneity of results and we shall return to these in due course.

There are a number of idiosyncrasies that challenge the economic analysis of energy demand; empirics suggest informational failures, imperfect capital markets and certain other deviations between a perfectly functioning market and what we do observe in the real world. In addition, there are peculiarities that are difficult to grasp entirely; for example, not all new and improved technologies are adopted, even if adoption can save a

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1. Energy per se is a good. Energy consumption does, however, lead to a number of negative side-effects. At any rate, whether or not saving energy is a sensible objective as such (rather than focusing upon the negative externalities) need not concern us here.

significant amount of money[2]. According to some observers, this is a good example of how limited standard economic theories are; others are quick to dismiss the apparent "paradox" on the grounds that the data do not stand up to close scrutiny. The literature on this "paradox" is substantial, and we can do no better here than to refer to the compact survey by Nyboer and Bataille (2000) for a review of the differing views.

The rest of the paper is structured as follows. Section 2 provides some background information on residential energy. Section 3 presents the framework that we will use to structure the empirical review. Section 4 is a review of selected studies. Finally, Section 5 discusses general policy implications as well as the choice of policy instruments, in light of the insights gained.

2. Residential energy use: a derived demand

Let us begin by defining terms: "Residential energy use" typically includes space heating, water heating and household electricity consumption. Heating/cooling is a major part of demand.

Space precludes discussion of how residential energy use in OECD countries has developed over time, but it will be useful to recall some salient trends. First, income has grown by more than 2% per year in the OECD area since 1970. Simultaneously, efficiency improvements have been secured throughout the period. Income has a positive effect on demand, while price increases tend to slow it down. The net impact of these factors is uncertain, because efficiency improvements might well be dwarfed by an increasing demand. To give a homely example; while we may have scrapped our old and inefficient refrigerator, we now have two efficient refrigerators and the floor is heated in the bathroom. Haas (2004) gives a useful summary of facts about residential energy demand.

Energy demand by the household is a derived demand – we do not demand energy *per se*; energy is combined with other goods, typically a capital good, in order to produce (or derive) the services we ultimately wish for. For example, we combine electricity and a TV set, oil and a heating system, gas and a stove and so on and so forth.

The close connection between energy demand and capital goods has a number of implications and we highlight three of these here. First, there is the technological component. As technology improves, we can enjoy the same stream of services but with a lower energy input. The literature on the so-called "rebound effect" holds that efficiency improvements can paradoxically lead to higher energy use. According to an often used example, if someone invests in more efficient air-conditioning, he keeps his energy bill constant by adjusting the thermostat on the new device.

Secondly, there is a distinctly dynamic component of energy demand that clearly separates the short run from the long run. Thus, in the short run, the capital stock is fixed; we may be locked in to our heating system with limited possibilities to escape from, say, price increases. The short-run response is therefore likely to be, sometimes significantly,

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2. The literature on technology adoption in agriculture the last 50 years suggests a similar pattern; not all efficient technologies are employed.

smaller than the long-run response to price changes, an insight with substantial empirical support as we shall see. The important lesson is that it takes time before a policy has effect simply because it takes time for households to adjust their real capital stock.

Thirdly, because decisions to buy a capital good are affected by income, the ultimate reason why energy use changes may well be changes in prosperity. Thus, at one level, we can explain why energy demand is affected by the number of appliances in homes. A more satisfactory explanation starts by considering the decision to buy a capital good as endogenous. Dubin and McFadden (1984) are the authors of a classic study that rigorously handled this issue.

3. Framework

There are many different frameworks that can be used to organise a review, including, for example, the so-called A-J model[3] of psychology. The comprehensive review by Lutzenheiser (1993) on social and behavioural aspects of energy use provides yet another way of delineating the empirical insights. Our framework is based on an augmented version of the simplest energy demand model for the household. Our approach separates the variables of interest into two subsets: "economic variables" and "other variables". Unfortunately, this is not a clear-cut separation, for the simple reason that "preferences" and "attitudes" can be put in both categories. We will nevertheless stick to this separation here.

Let us begin by discussing preferences and then turn to the various constraints that the household faces. Combining preferences and constraints with the assumption of utility maximisation will then lead to a demand function conveniently summarising a number of factors that ultimately affect demand. We proceed with comments of a more conceptual nature and try to pin down what various theories of choice and behaviour tell about what impact on energy use can be expected from different variables.

3.1 Preferences

Demand for energy depends on the household's preferences for goods and services. Preferences vary across populations; the elderly may well prefer an in-door temperature that does not suit the young and, as many parents of teenagers will testify, the number of showers varies with a household's demographic composition. Empirical research on residential energy demand shows how demand fluctuates between households of different sizes, composition and so on. What is more, demand differs between households of a given social class living in the same category of buildings. Importantly, even households with the same kind of equipment consume energy at different levels. Different preferences regarding, for example, the opportunity cost of time is one possible explanation of this fact.

Because preferences differ, it is obvious that two households with identical observable characteristics (income, education, sex and so on) may demand different baskets of goods, including energy goods. Detailed research by Lutzenheiser *(*1993, p. 249*)* shows

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3. The A-J model of psychology examines the links between attitudes and behaviour (see Ajzen, 1991).

that similar households living in similar housing display widely varying energy consumption patterns. The conclusion is that if preferences are heterogeneous across the population, the response to price changes may well differ between otherwise identical households. We will come back to this point repeatedly.

While preferences are usually defined over goods that are sold in markets, it is reasonable to include non-market goods as well, when discussing demand for energy. Thus, energy demand will also depend on air quality or other non-market goods that relate to environmental quality. We know from the European Union's barometers that preferences over environmental issues vary substantially across the EU-25. This barometer provides some information about attitudinal variables, such as the households' view towards "green" consumption across the EU. There is abundant academic literature on the green consumer and the green firm. Whether or not consumers are willing to pay a premium for green goods remains unclear. Empirical results cut both ways and we cannot do justice to this large literature here, suffice it to say that the importance of the "green consumer" for energy consumption can hardly be neglected.

3.2 Income

Income is a key driver of residential energy demand and perhaps more important as such than what it would seem at first glance. Superficially, the link is straightforward. As we become richer, we can afford to use combinations of energy and capital goods as substitutes for, say, our input of time. For example, when buying a dish-washer, a washer or similar appliances, we can trade off some other private consumption goods to gain leisure time. Furthermore, as income increases, we might make intra-fuel substitutions and switch from one heating system to another that is likely to be more efficient. But perhaps the most useful insight we obtain from economic theory is that income encompasses many of the attitudinal variables that superficially appear to affect demand.

The concept of income seems to be rather important in this context. Indeed, it is reasonable to expect that energy demand is closely connected to future income, and perhaps more so than current income. Future income is uncertain and expectations about future income are notoriously difficult to model. In the review of empirical studies below, we give examples of how this problem has been handled.

3.3 Price

If the relative price of energy increases, we expect reductions of demand *ceteris paribus*. How strong the response to price is remains a subject of debate; economists are, perhaps, more optimistic than other researchers (Huntington, 1987*)*. We will review insights from the literature on price elasticities below, but we will make some general comments before turning to the results.

The first point to make from a conceptual point of view is that we must consider two kinds of price elasticities, short run and long run. In a policy perspective, long-run elasticities might be considered more important, yet short-run elasticities will speak clearly about distributional consequences during a period of time when households have not fully adjusted their capital stock. Because time provides additional possibilities for adjustment, we expect long-term price elasticities to be larger, in absolute value. The

empirical literature shows this pattern very clearly, notwithstanding significant variations from one study to another.

Secondly, it is known from basic economic theory that there is a close link between price elasticity and substitution possibilities. Hence, when substitution possibilities are limited, price elasticities will also be small. A household facing higher energy prices can typically use a whole array of different ways to lessen the impact of the price increase on their budget. For example, indoor temperature can be adjusted; washing schedules can be tweaked to reduce energy consumption and so forth. Ultimately, the household can move to a different house that uses another, less expensive, heating and cooling technology (in a general equilibrium setting, the relative price of such a house will have increased, however). Because these substitution possibilities vary across households (compare those living in apartments with metered consumption with those living in single-family homes), we expect price elasticities to vary across the population, a hypothesis that is given ample empirical support in the literature. It is also consistent with the general message here: households are heterogeneous as regards their consumption of energy and response to changing policies.

Thirdly, the bulk of the empirical literature on residential energy demand is based on a partial equilibrium view. In a general equilibrium analysis, one takes into account the fact that income depends on prices and that all markets interact, more or less directly. In such a setting, price responses are not as clear as in the partial equilibrium world, yet we still expect that higher prices will reduce demand.

Fourthly, expectations about the future must be considered when examining responses to current price changes, not the least when policy packages of various kinds have a direct impact on relative prices. Thus, policies such as some subsidy packages certainly affect the time profile of energy investments within the household, as, for example, when the government is expected to subsidise conversion from electrical heating the following year. The response to a price increase of electricity today is not necessarily the same then as when the household expects no subsidy for conversion: without the subsidy, it might be worthwhile to make the adjustment much sooner.

3.4 Attitudinal and other "non-economic" variables

Attitudinal variables portray an individual's state of mind or feeling. A definition of "attitude" in social psychology is the valuation of a concept or an object (Sjöberg and Engelberg, 2005, p.3). Useful reviews of the literature linking attitudes to residential energy demand include those by Lutzenheiser (1993) and Sjöberg and Engelberg (2005) ; Fransson and Gärling (1999) summarise the literature related to environmental concerns, arguing that these concerns are only weakly correlated with socio-demographic and psychological factors.

Overall, the links between attitudes and energy demand are often found not to be strong. Yet, recent studies of the California energy crisis are shedding new light on the role of attitudes as we shall see below. Insofar as the impact of demographic variables on energy consumption can be detached from income influence, empirics suggest that energy consumption varies over the life cycle, between ethnic *groups* (Poyer *et al.*, 1997) and cultural practices.

4. Empirics of residential energy demand

Empirical studies of energy demand have cascaded in waves, being propelled by the oil crises of 1973 and 1979 and later by the climate change issue. Earlier surveys include those by Taylor (1975), Bohi (1981), Dahl (1973), Madlener (1996) and Ferrer-i-Carbonell *et al.* (2000). A recent meta-analysis (Espey and Espey, 2004) summarises 36 studies on residential electricity demand published between 1971 and 2000 and covering the years from 1947 to 1997.

A significant number of papers use microdata focusing on electricity. Demand functions are estimated through variables such as prices, heating technologies, house type and socio-economic characteristics. A substantial number of studies often appeared first in the grey literature (*e.g.* consulting reports that look at the California energy crisis) or as part of research report series (*e.g.* those from national statistical offices).

An important change in the empirical literature on residential energy demand has been the more frequent use of detailed microdata on households. The shift towards microdata has opened the scope for detailed assessments of household behaviour by tapping recent developments in economic and econometric theory. It has enriched our understanding by unraveling the significant heterogeneities that exist.

We will now consider the different factors in turn, beginning with income. In each of these sub-sections, the different explanatory variables examined in the studies are reviewed and their significance compared and discussed.

4.1 Income elasticity

A basic lesson from the empirical literature on residential energy demand is that the link between income and demand is difficult to pin down precisely; the estimates vary considerably across studies. There are a number of potential reasons for this and we shall consider them briefly, but first let us discuss some of the empirical results.

Dahl's (1993) extensive survey concluded that our understanding of the links between energy demand and income was quite limited, despite the impressive number of studies. In an earlier survey by Taylor *(1975),* the author suggested that the results were too tenuous to merit a summary.

Dahl found a significant difference between studies based on aggregate data and those based on disaggregate data, and that elasticities lowered over time. She argued that the larger elasticities found in studies using aggregate data are due to the fact that they capture demographic change better. Overall, the income elasticity might be less than 0.4 in the short run and higher, but less than one, in the long run (p.182).

Similar conclusions were obtained in later surveys, *e.g.* the meta-survey of household electricity use in Espey and Espey (2004)*.* In that analysis of 36 studies, the short-run income elasticity is in the range 0.04 to 3.48 with a mean of 0.28, and the long-run income elasticity ranges between 0.02 to 5.74, with a mean of 0.97 (p. 66). The short-run estimates were on the average higher in studies using time-series data and covering countries other than the United States.

The classic study (earning its authors a prestigious academic prize) on residential energy demand is the one by Dubin and McFadden *(1984)*. It was the first study to rigorously take into account the fact that there is both a discrete choice (buying certain equipment) and a continuous choice (consuming electricity, say) prevalent in energy demand. We choose which durable good to buy and how much of its services to consume simultaneously, so that the characteristics of the durable goods are endogenous in the demand equation.

Dubin and McFadden allowed choice for space and water heating to be natural gas or electricity and found an income elasticity barely greater than zero. Their approach inspired a large literature and is standard in engineering models (for instance, the Residential End Use Energy Planning System). The low income elasticity they found could be due to a number of factors, including the restricted choice set, only two fuels (see McClung, 1993).

Recent studies also using microdata generally find small income elasticities. Baker and Blundell (1991, UK data), Poyer and Williams (1993, US data), Nesbakken (1999, Norwegian data) and Rehdanz (2005, German data) all report energy expenditure elasticities of about 0.1 to 0.2. Recent micro-studies on electricity demand, those by Damsgaard (2003, Swedish data), Leth-Petersen (2002, Danish data) and Berkhout *et al.* (2004, Netherlands data) display congruent results: income elasticities are found to be in about the same range as those covering household energy consumption in total. When energy demand is dominated by heating expenditures, this is not a surprising result. However, as Vaage (2000, p.663) notes, time-series analysis often gives much higher values on the income elasticity (around unity or more), because households increase their stock of energy-using appliances when they become richer (and thereby their energy consumption).

Finally, it must be stressed that income elasticities are not necessarily constant. For example, they might be lower in the top deciles of the income distribution (Baker *et al.*, 1989*)*, they can be lower for newly established households (Halvorsen and Larsen, 2001); in general, they vary with socio-economic variables.

4.1.1 Measurement difficulties

Why is it so difficult to pin down the income elasticity, as Dahl's and Espey and Espey's surveys imply? First of all, income elasticities typically vary with type of data; as noted, time series often give higher elasticity estimates compared to cross-section data. Secondly, results might vary according to estimation technique, because each different technique typically entails different assumptions. Thirdly, in micro-econometric studies, it may be difficult to measure income precisely, if only because households can be reluctant to report their true income. Fourthly, the concept of income to be used could be of importance. Possible concepts include current income, expected future income and wealth.

4.2 Price elasticity

Economists have been quite optimistic regarding the price sensitivity of energy. As noted by Huntington (1987), by and large economists have been rightly optimistic. If nothing else, the oil crises OPEC I and II provided large natural experiments to verify the

hypothesis; yes, over the longer term, households respond to price incentives. Even so, it might seem bold to suggest anything like a consensus estimate of price responsiveness. Yet, it seems as though a consensus estimate is 0.3 for the short run and 0.7 for the long run. But the variability is still substantial. Estimated elasticities vary across energy types, study types and regions. What is more, price elasticities vary according to household type, demographics and so on. We will come back to these points when discussing the non-economic variables in Section 4.3, but let us first return briefly to the results reported in previous surveys.

The extensive survey by Dahl (1993) provides a range of elasticities. For energy, the short-run price elasticity is often lower than 0.3. The NEMS (National Energy Modeling System, USA), uses Dahl's survey in its residential demand module and puts the short-run elasticity at 0.25 (EIA, 2005, p.24).

A selected sample of studies not focusing on electricity includes those by Baker *et al.* (1989) and Berkhout *et al.* (2004). They find price elasticities for gas ranging from 0.44 to 0.19. Turning to electricity, the survey by Taylor (1975) reports short-run and long-run price elasticities at 0.2 to 0.9 respectively. Bohi and Zimmerman's (1984) update of this survey presents rather similar results. In their meta-analysis, Espey and Espey (2004) suggest an average short-run (long-run) price elasticity for electricity of 0.35 (0.85). They find that short-run elasticities are generally higher in studies that include stocks, are based on time series and use average (rather than marginal) price, and lower in non-US studies. Long-run price elasticities are generally higher in studies that include stocks, substitutes, are based on time series and are undertaken outside the United States.

Reiss and White (2005) use detailed data on 1 300 Californian households to estimate price elasticities. They find that the response has a spike at zero; about 44 % of the households in the sample would not react to price changes in the short run. The distribution of elasticities is markedly skewed and about 13% of the households sample is estimated to have a price elasticity exceeding one. These results bring new light to the question of how households respond to energy price changes.

Price elasticities are not necessarily constant. For example, they might vary over time (Halvorsen and Larsen, 2001); over income groups (Rehdanz, 2005; Reiss and White, 2005a); across household sizes (Damsgaard, 2003); and also be different for price increases and decreases (Haas and Schipper, 1998). In general, they can vary across all variables that affect demand.

To summarise: empirical studies show that: *i)* households respond to price signals, and *ii)* residential energy consumption in the short term is one of the most inelastic goods in the economy.

Policies that affect the price of energy have impacts, but it will take some time before households adjust their capital stocks. Furthermore, the price responsiveness varies across households in a number of dimensions.

4.2.1 Measurement difficulties

After having established a significant variation of estimates, possible explanations of the variance remain to be explored. Beyond the methodological differences that are basically the same as already discussed for income, the key issue concerns variability of

price within a given country. Before the deregulation of energy markets, there was little variation in *e.g.* the electricity price. If price does not vary, it is difficult to estimate the price elasticity precisely.

Furthermore, there may be limitations in the data; for example, electricity expenditures are not separated into fixed and variable costs. There is a literature on the difference between estimates based on average cost and those based on marginal cost (see Dahl, 1993 for a summary), and on the extent to which households understand the difference between these two concepts (see Lutzenheiser, 1993). It should be noted that price could vary in other ways. Reiss and White (2005, p.21, footnote 24) state that "An additional concern that has dogged this literature is that randomized pricing experiments are rare in energy demand research. Most rely upon voluntary participation and small samples, raising familiar attrition- and selection-bias concerns that impair generalization..."

We now turn to variables other than income and price that may affect energy demand. We will omit tenant/owner issues that have been dealt with by Levinson and Niemann (2004) and focus on a number of characteristics of individuals, households and more abstract items like information.

4.3 "Non-economic" variables

The extensive literature on energy demand includes, as noted, contributions from many fields. In what follows, we provide a glimpse of sociological, psychological and similar research. As stated in the introduction, this paper is essentially examining residential energy demand from an economic point of view; the summaries below are, indeed, incomplete. Our objective here, at any rate, is to distil some insights into the importance of the "non-economic variables".[4] We begin with some brief remarks on key conclusions from sociological and psychological research and then go on to look more closely at specific "non-economic" variables that may affect energy demand.

4.3.1 General findings

Lutzenheiser (1993), in perhaps the most comprehensive review available of social and behavioural aspects of energy use, details more than 200 studies that have observed household energy behaviour by means of a wide range of methods. The analysis supports the general argument presented here, namely that households are heterogeneous in many dimensions. Lutzenheiser also argues that a limit of economic studies is that they are based on tenuous assumptions, such as the assumption that fully-informed and rational consumers take decisions without regard to social contexts: "There seems to be a consensus in the literature, however, that adequate models of energy and behavior must be more directly concerned with the social contexts of individual action." (p. 262).

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4. Some studies suggest that attitudinal variables are important for deliberate behaviour (intent-oriented), while socio-economic variables are more important for understanding impact-oriented use of, say, energy. For example, there are studies showing that household energy use is mostly explained by socio-economic, rather than attitudinal, variables. But it is not difficult at all to find exceptions. For example, Carlsson-Kanyama *et al.* (2003) found, in their analysis of 600 Swedish households, that environmental attitudes and attitudes to energy are important for the use of appliances in households.

Shove (2003) has developed sociological models that look at evolutionary aspects; how do social norms regarding comfort and cleanliness develop over time? The importance of such variables for residential energy demand is commented upon below.

Sjöberg and Engelberg (2005, p.8) argue, from a psychological research angle, that "Research on energy consumption and conservation shows that attitudes are rarely much affected by campaigns, that attitudes have moderate predictive value, and that behavior is frequently not in line with expressed attitudes." Furthermore, they also claim that the largest share of the variance of energy consumption can be explained by differences in social habits. In a similar vein, Viklund (2002) concludes his review of the literature with "[there is] no room for psychological factors to explain energy savings behavior".

Finally, Aune *et al.* (2002, p. 10) summarise earlier research (from a socio-technic point of view) on household energy demand by claiming that "Among the results that still hold interest from this period [1973 to 1990], is that information campaigns are less effective than expected, that the link between attitudes and behavior concerning energy is weak..."

4.3.2 Specific findings I: Individual characteristics

Energy demand varies with the age of the individual, but the direction is not clear according to empirical evidence. For example, some studies suggest that older households are less likely to invest in conservation measures, for various reasons (lack of know-how, lower expected rate of return and so on). It has also been argued that elderly people live in sub-standard houses, raising the value of conservation measures. Liao and Chang (2002) report that an ageing population in the United States increases space-heating demand. Yamasaki and Tominaga (1997) present a detailed macro-analysis arguing that an ageing population pushes demand upwards in the Western world in general, and in Japan in particular. All the same, *a priori* there seems to be no particular reason to expect that age is positively or negatively correlated with demand, not the least because of the delicate issues of separating age from income. Some studies report that energy demand also varies across ethnic groups, a point we will return to below.

In a more comprehensive survey than this, *i.e.* one that included "non-stationary" energy demand (such as travelling), it would have been of interest to discuss "life style" variables. But we move on to household characteristics.

4.3.3 Specific findings II: Household characteristics

A number of studies point to household characteristics as key determinants But here again, results vary. The number of children has been found to affect demand: *i)* positively (*e.g.* Baker *et al.,* 1989); *ii)* insignificantly (Nesbakken, 1999; Vaage, 2000; Leth-Petersen, 2002); and *iii)* negatively (Rehdanz, 2005).

4.3.4 Specific findings III: Information

Whether or not information is an important driver of energy demand is a subject of seemingly never-ending debate between different researchers. Why, an economist might argue, is consumption of energy special? Why are the informational failures more attenuated in this area? At any rate, policies are often based on providing consumers with

information and the question is whether targeted information affects residential energy demand.

Perhaps the most constructive piece of evidence is the recommendations that come out in Lutzenheiser's (1993) survey. Research has shown that mass information (via, say, labels) is "easily ignored", while more directed information seems more effective. Thus, a potentially useful line of attack is to use structured information through, say, "role models".[5] There seems much to be gained by tapping the experience and insights gleaned from the many experiments conducted in psychology on the role of information. What is more, fresh insights obtained via recent scrutiny of the California energy crisis provide food for thought. There, the message is rather more optimistic regarding the role of information campaigns (see Section 4.4.4 for additional details).

4.3.5 Miscellaneous findings: Weather

Demand is strongly correlated with the deviation from comfortable indoor temperatures. The recent years of unusually hot (and cold) weather in Europe have mapped into price increases on the market for carbon dioxide emission permits. These price changes are partly a reflection of residential energy demand. Almost all studies on the matter display a correlation between deviations from comfortable temperatures and energy demand. Indeed, rather than lowering indoor temperature to something like 16°C, indoor temperature is more in the neighbourhood of 20°C or more in Western Europe during the cold season. There is some evidence that cold weather affects demand more than hot weather (Henley and Peirson, 1998).

4.4 A sample of studies

This section summarises a few studies, selected essentially because they illustrate the new wave of micro-econometric demand analysis and because they include unique information about energy price fluctuations (the California energy crisis). There exist many other interesting studies, not reviewed here, such as those by Akmal and Stern (2001a and 2001b), Lins *et al.* (2002), Ryan *et al.* (1996). We also add a summary of a recent paper on the energy efficiency literature, because it has, *inter alia,* bearing on policy implications Rosenfeld *et al.* (2004).

4.4.1 Study of energy consumption in Germany by Rehdanz

Rehdanz (2005) studies residential energy demand in Germany, using extensive data on energy use by a large sample of German households (more than 12 000) in 1998 and 2003. The analysis focuses on conditional demand (the capital stock is given). She includes a substantial number of socio-economic background variables in her regressions and provides some interesting insights into factors such as age and the number of children in the household. The economic key variables, income and price, significantly affect energy expenditures; the expenditure elasticity is about 0.1. She reports a gas-price elasticity at 0.43 (p. 16), where expenditures are limited to those for space heating and water heating. Thus, the price elasticity is equal to -0.57, which is in line with other studies on gas demand by households. As noted, she finds that the number of children is

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5. For instance via commercials that feature well-known individuals.

negatively correlated with energy expenditure. Overall, she finds that a set of socio-economic variables and descriptors of the building is correlated with household energy demand.

4.4.2   Study of energy consumption in Sweden by Damsgaard

Damsgaard (2003) collected a microdata set for Sweden with the explicit purpose of examining the relative importance of different explanatory variables driving electricity demand. He collected household survey data (household characteristics, size of dwelling, heating system, insulation and other energy conservation measures, the stock and use of appliances, and awareness about and interest in energy conservation issues) and he combined them with public and company register data on income, prices, consumption and local weather conditions. In all, the data set comprises 1 225 observations. He finds that the price elasticity is highest in households without direct electrical heating, a result which is not congenial to intuition. One would expect that, if the budget share for electricity is low (which it would tend to be in households that do not use electrical heating), the price elasticity would also be small (in absolute value). The income elasticity is generally found to be low, even zero, for households having electrical heating. This result is, on the other hand, intuitively plausible. When we become richer, we do not spend the extra money on heating the house even further (but over the long run, more appliances will be bought and will be driving consumption). Damsgaard further finds that advice on energy conservation has little or no effect on consumption. He concludes (p. 23) that "Overall the introduction of the attitude and interest variables has a small, if any, effect on the explanatory power of the regressions."

4.4.3 Study of household electricity demand in Norway by Halvorsen and Larsen

Halvorsen and Larsen (2001) use panel data to shed some useful light on price elasticity changes over time. They use the Norwegian Consumer Expenditure Survey from 1975 to 1994 within a discrete-continuous framework (see McFadden *et al.*, 1977). The pooled data provide information about 23 284 households, including detailed data on household characteristics, price and temperature. Their model relates electricity consumption to appliances (freezers, refrigerators, washing-machines, dishwashers and kitchen stoves), prices of electricity, alternative heating fuels (kerosene and heating oil), socio-economic household characteristics and heating days. The key contribution is the study of the price elasticity for electricity over time; it turns out to be roughly -0.8 at the beginning of the study period (1976) and at the end (1993). Demand became price-elastic over a short spell (1981/82). The most curious finding is that the long- and short-run elasticities are virtually the same. The explanation is, according to the authors, that there are no substitutes, even in the long run. As the authors explain, they only had information about household appliances. With more information about heating alternatives, it is likely that the results would have been different. The income elasticity is found to be rather low, around 0.1, but with a slight upward trend (the maximum is around 0.2). Interestingly, the income elasticity is lowest for newly established households.

4.4.4 Studies on the energy crisis in California

Studies of the California energy crisis in 2000 are now becoming increasingly available. Many of them shed new light on how consumers react to dramatic price fluctuations and information campaigns. Consumers experienced a significant electricity

price increase in 2000, which was followed by price caps on residential electricity prices and public energy saving campaigns. Data therefore allow an assessment of how households respond to price incentives and public appeals. Reiss and White (2005b) find that consumers are surprisingly price-responsive; households are found to have cut consumption by about 12 % in roughly two months. However, when prices were capped, consumption rebounded. What seems more surprising is that public appeal to conserve energy "worked"; the average household reduced consumption even though it faced no pecuniary incentive to do so. In short, this study suggests that consumers may be reacting much quicker to pecuniary and non-pecuniary incentives than previously believed.

Bushnell and Mansur (2005) analyse the price variations faced by San Diego households during 2000. A key result is that consumers seem to be lagging behind in their response to price changes; their responses are primarily based on previous rather than current information.

Lutzenheiser (2002) presents a detailed exploratory analysis of the same crisis, combining in-depth telephone interviews with billing data. Given income and a number of other variables, conservation behaviour differs according to: ethnicity (African Americans are more likely to report turning off their lights and television set); age (the older the respondents, the smaller the probability that they shift use to off-peak hours); household composition (single parents are more likely to turn off equipments than couples with children for a given income); dwelling type (mobile home-owners are more frugal regarding energy) and square footage (the larger the house, the more likely appliances are turned off).

4.4.5 Rosenfeld et al. on energy efficiency

A useful summary of the developments and importance of energy efficiency appears in Rosenfeld *et al.* (2004). The authors argue that "The most effective path toward energy efficiency has been standards for autos, buildings, appliances, and equipment." (p.374)

They provide a striking illustration of how refrigerators have improved energy efficiency by about 5% per year since the late 1970s. The difference between 1974 and 2001 energy efficiency levels (assuming 150 million refrigerators) is the equivalent "of avoiding 40 GW of power plant". They go on to cite similar impressive energy efficiency improvements for other appliances, also pointing the lacklustre performance for cars. The main argument is that building and appliance standards, not the least when combined, can contribute to significant energy savings.

Of course, we do not know what the level of residential energy consumption would have been in the United States without the standards. Furthermore, imposing standards is not necessarily the most cost-effective way of reaching an energy saving goal, even though the authors promote energy standards as a key ingredient of energy policy.

5. Conclusion and policy implications

Empirical analysis of residential energy demand teaches two general lessons of significant policy importance. First, that human behaviour matters decisively for energy consumption; when shaping a more efficient energy policy, it is not enough to consider the various energy-saving technologies that exist. Secondly, that human behaviour varies

considerably with regard to energy demand; thus, looking only at the averages can be misleading.

The rich literature on residential energy demand includes contributions by, *inter alia*, engineers, economists and researchers from other social sciences. Economists tend to stress the importance of economic variables such as price and income, engineers the existence of technological solutions (and the tardiness of adoption, the so-called energy paradox), while the force of attitudinal factors are focal points in studies by other social scientists. The relative importance of the factors thought to affect residential energy demand remains debated. Even so, empirical evidence strongly suggests that energy prices and income affect demand; the role of attitudinal variables is more uncertain.

Many empirical studies focus on electricity demand and use data from the United States. There are studies on other energy sources, notably petrol and natural gas, but a majority of those that concern us here (residential demand) deals with electricity. Furthermore, the empirical studies have been using a smorgasbord of different estimation methods, data sets and levels of aggregation (macro-economic *vs.* micro-econometric, state *vs.* country, and so on). Thus, it is not so surprising if results vary and are not straightforward to summarise. Let us, nevertheless, present a digest of some empirical insights:

- Demand for energy is generally quite price-inelastic. There is some consensus on the short-run price elasticity being about 0.3. The long-run price elasticity could be 0.7. The important point is that energy demand responds to price in a non-negligible manner over the long run. Economists have been more optimistic than many other researchers about the price response.

- Demand for energy responds to income, but the response varies substantially across studies. The income elasticity is likely to be lower than unity, even in the longer run. It is much lower in the short run. More recent estimates tend to suggest rather low income elasticities.

- According to the mainstream economic view, income encompasses a large number of factors that superficially seem to affect demand. For example, while additional appliances increase energy demand, they were bought because of income increases.

- Empirical studies are yet to converge on the relationship between socio-economic variables like age and number of children. In some studies the relationship is negative, in others non-significant; yet there are studies that find positive relationships.

- Attitudes have been found to correlate with energy conservation behaviour. Psychology-based studies show mixed results. Mass information has limited success. Targeted information campaigns can be more effective.

- Demand for energy depends on a host of exogenous factors, most importantly temperature. Insofar as the impact of demographic variables on energy consumption can be detached from the impact of income, empirics suggest that energy consumption varies over the life cycle, between ethnic groups and cultural practices.

General policy conclusions include the following:

1. Households respond to economic incentives and economists have basically been correct in their optimistic view on households' response to higher energy prices over the longer term. When structuring policy packages, it is important to keep in mind that the short-run response is much smaller; during the period when households are adjusting their capital stocks, consumption does not change much.

2. Because price and income elasticities vary across data types (times series, cross-section, panel), methodology, time period and short-run *vs.* long-run, it might be dangerous to use average elasticities when trying to judge a demand elasticity in a particular case.

3. Policies based on non-pecuniary incentives are widely used and widely debated. Recent analysis of the California energy crisis brings fresh and somewhat more positive results on the value of information programmes to curb energy consumption. Information campaigns can make a difference, at least in the short run, and all the more so if they are structured effectively.

4. Energy policy must be analysed broadly and holistically, given that many different factors influenced by other policies affect residential energy demand.

A comparative analysis of policy instruments cannot be undertaken without specifying the underlying policy objectives. In energy policy, objectives traditionally include safety, security, affordability and environment-friendliness. There may also be quite specific objectives such as reducing the use of electricity for heating (Sweden), improving energy efficiency in the residential sector (the Netherlands), promoting district heating (Denmark) and fighting fuel poverty (United Kingdom).[6] At any rate, we cannot go much further than the standard efficiency criteria in this paper.[7]

A wide range of policy instruments is currently being used in the OECD countries to address energy policy objectives.[8] These instruments include, among others:

1. Energy taxes
2. Energy efficiency standards for appliances
3. Energy labels
4. Energy conservation grants
5. Thermal efficiency standards

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6. See *e.g.* the UK Government White Paper on Energy (DTI, 2003).

7. In the environmental economics literature, policy instruments are compared on issues such as *i)* precision (regarding reaching the policy target), *ii)* cost-efficiency, *iii)* incentives to develop new technologies, *iv)* revenue generation and *v)* equity properties. Usually no instrument dominates in all these dimensions.

8. A recent review of energy policy instruments covering more than 50 countries has been undertaken by the World Energy Council. Beyond the instruments considered here, it also includes energy audits; see www.worldenergy.org.

Comparative analysis of such instruments for *e.g.* residential space heating in certain countries is available in projects such as EPISODE[9]. We consider each instrument in turn:

Energy taxes. An overwhelming amount of empirical evidence, some of it included in this paper, shows that higher energy taxes reduce energy consumption. An impressive body of evidence also shows that energy taxes are regressive. From an efficiency point of view, they stand out as the most useful instruments.

*Energy efficiency standards for appliance*s. These are regulations that specify energy efficiency requirements that products must meet. They have been adopted in several countries for several products (*e.g.* refrigerators, air-conditioners and freezers). According to recent reviews, they have reduced energy use cost-efficiently (Nadel, 2002) and significantly (Rosenfeld *et al.*, 2004), creating only "minimal adverse impacts" on producers (Nadel). On the negative side, such standards could be considered (and used as) non-tariff barriers to trade, as several international disputes suggest (fuel efficiency standards have generated several international disputes reviewed in Zhang and Assuncao (2001). At least at a conceptual level, cost efficiency is in doubt.

Energy labels. Most, if not all, industrialised countries use energy efficiency labels for home appliances (Newman, 2000). As we have seen, their effect on behaviour is unclear. Priddle (in the Foreword to Newman, p.3) enthusiastically kicks off a recent IEA review of energy labels with the statement "Policy makers cannot afford to neglect them". True, labels could be inexpensive instruments and, if they deliver, remain a very attractive policy instrument. Yet, the links to non-tariff trade barriers are important from an efficiency point of view and the impact of labels on choice remains unclear.

Energy conservation grants. These grants come in various forms and are sometimes motivated by the well-established fact, as we have seen, that consumers (and firms) often use a high implicit discount rate for energy conservation investments. Despite substantial empirical evidence, debate still continues on whether or not there exists a market failure of import in this case. Subsidies that are not connected to an underlying market failure are socially costly and should be avoided from an efficiency perspective.

Thermal efficiency standards. Empirical evidence suggests that they have been important as building standards seem to have reduced the demand for space heating in certain countries, as is asserted in Rosenfeld *et al.* (2004). From an efficiency point of view, the usual argument applies: in a perfect market these standards are hardly needed.

Which policy instrument is the most suitable? Again, the answer to this question depends on the objectives: what is the policy trying to achieve? Furthermore, we need to define exactly the reason why policy A is preferable to policy B. That is not easy to pin down, as centuries of debates in various studies show. For the most part, many economists are satisfied with an efficiency criterion; A is better than B if the goal is reached at least cost. This depends on the possibility of separating efficiency and equity, so that distributional concerns can be mitigated in the usual ways (via parameters in the

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9. EPISODE is a project funded by the EU on "effective policy instruments for energy efficiency in residential space heating-an international empirical analysis".

tax system, for example). Theory and empirics strongly suggest that incentive-based instruments are the most cost-effective in meeting an energy-saving objective. It is equally well-known that taxes on energy, for example, have a regressive impact. Much less is known about the distributional impacts of other instruments, but they can certainly have regressive impacts as well. (see Serret and Johnstone, 2006).

From an efficiency viewpoint, there is little to conclude beyond the fact that incentive-based instruments have an advantage. As noted, the other instruments have affected energy use, save the unclear impact of labels. From an equity point of view, no clear conclusion emerges, because each case will be unique. If an energy tax is increased, for example, equity impacts depend on how revenues are returned. Reducing labour taxes (as per the "double dividend" argument) maps into a different, and typically more regressive, distributional profile compared to a lump-sum return (see Serret and Johnstone, 2006). The next stage of this project will be tailored to provide additional information about the effects of different policy instruments across different populations.

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5. Environmentally Responsible Food Choice

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1. Introduction

The purpose of this paper is to review and assess the role of relevant explanatory variables that influence individual purchase decisions for "environmentally responsible" food consumption. In particular, we provide a detailed review of the key empirical studies in the area of consumer demand for those foods which can be broadly considered as environmentally responsible products (ERPs). We give this definition because the choice of ERPs is a consequence of individual concerns towards environmental and health issues and consumers are directly and indirectly responsible for the environmental and health effects of their food consumption choices. The decision to purchase ERPs should reduce negative environmental effects from intensive agricultural practices, helping to preserve a public good like the environment. Consumption of ERPs should also curb health risks from chemicals for all the household members eating the food purchased in the shops. Therefore, the choice of ERPs reflects both "public" and "private" demands.

Private demand for quality attributes associated with food choices and which are linked to the environment is a tangible signal that people increasingly value production processes that provide environmental services, *i.e.* that contribute to improving the quality of the environment. The income elasticity of demand for environmental quality in OECD countries is thought to be significantly positive, implying that as income grows, demand for environmental quality increases. At the same time, the stock and quality of natural capital in OECD countries may decrease with higher income and aggregate demand. In the presence of uninternalised externalities, this clearly introduces a "public" reason for supporting the demand of ERPs.

One solution to the problem of environmental quality degradation is through direct government intervention with the adoption of regulatory instruments. Some examples are constraints on the use of environmentally damaging agricultural practices. Economic instruments may also be applied, such as taxes on chemical pesticides which are thought to generate significant agricultural run-off and water pollution. In addition, subsidies can be provided for the introduction of less environmentally damaging agricultural practices.

A further possible intervention – which is particularly relevant for household decision-making - stems from the fact that food markets for quality-differentiated products are affected by imperfect information. These markets function efficiently only if a sufficient level of information on quality is conveyed to consumers. Antle (1999) suggests that information is basically a "club good", non-rival in consumption but excludable: as a

public good, information can be consumed by one person without diminishing its value to others, but contrary to a public good, the cost of acquiring and using information limits access to it. If information has these characteristics, then the role of governments would be essentially the creation of rules able to protect the "producers" of information from free-riding and to assure the truthfulness of the information itself. Eventually, the cost of the information system is paid by consumers: they are now allowed to "read" the product's (environmental) quality attributes and therefore they express their willingness to pay for the product according to its quality.

A potential barrier to the effectiveness of such indirect forms of policy intervention is the excessive production costs of the quality-differentiated product: in this case the consumer's willingness to pay may not be sufficient to justify the production of the good. Public programmes aimed at the standardisation of environmental certification and at the development of low-cost certification methods may partially solve the problem, enhancing the effectiveness of policies aimed at improving the quality and quantity of information provided, without fully supporting the cost to the consumer.

In any event, in order to design a correct policy intervention, the understanding of the consumers' behaviour towards the choice of (environmental) quality-differentiated products becomes crucial. Current literature on the demand for ERP consumption, and in particular for organic food, provides useful insights into the major determinants of consumers' behaviour. The willingness to pay for or to actually buy specific environmental quality attributes represents a measure of the individual demand for the consumption of environmentally differentiated products. This demand is affected by several socio-demographic and attitudinal variables, as well as by the degree and reliability of the information on quality attributes. Food (environmental) quality regulations affect attitudes about both private and public goods (attributes): for example, the mandated prohibition of most agricultural synthetic chemicals for certified organic produce may have the following effects on individuals: an increase in the price of organic foods, a reduction of individual health risks, a reduction of option value due to a loss of future consumption choices, an improvement of environmental quality. A full understanding of these factors becomes crucial in planning and choosing the most efficient policy instruments for environmental conservation.

Are preferences for environmental attributes heterogeneous across population segments? Is the assumed high income elasticity confirmed in studies on demand? Is the consumer's choice for ERPs mainly driven by private (food safety, higher sensory quality) or public (environmental and wildlife preservation) attributes? Is food labelling perceived as a reliable quality signal by consumers? These are the main questions that are addressed in the empirical literature and that must be taken into account in order to implement relatively efficient policy mechanisms.

ERPs include a wide range of products, spanning from organic foods, those obtained from the most "environmentally concerned" production methods, to products obtained by using less constrained methods, such as integrated production management (IPM) methods. GM-free food products may also be considered by some to be ERPs, at least until new scientific evidence on the potential environmental risks becomes available. Nevertheless, in our review we focus essentially on organic and IPM products, and on a small number of relevant studies on genetically modified (GM) products.

This review is not intended to be exhaustive. It includes those studies that in the author's opinion are more in line with the general objective of the project. In particular, our aim will be to identify the factors that affect the joint demand for food, environment preservation and food safety. The basic idea behind this analysis is that besides the usual determinants of food consumption, the environmental and food safety concerns raised in reaction to the use of modern production techniques may also affect individual preferences for food consumption.

2. The environmentally responsible food choice: a conceptual framework

Consumers are becoming more and more concerned about food quality attributes related to particular issues such as environment, health and safety. Unfortunately, as these attributes are generally unobservable, a related problem of asymmetric information emerges. The coexistence of these two related problems -- the emergence of new quality attributes and the fact that they are mostly credence attributes -- creates a complex scenario for the analysis of food consumption. On the one hand, it implies that consumption models need to include new variables able to capture the effects of these emerging attributes on consumption, and on the other hand that only those products having a certain degree of reputation may be able to "inform" consumers of these unobservable attributes. Signals such as labels and prices, as well as investments in reputation (for instance certification systems), will affect the demand for ERPs, making the choice of relevant variables quite difficult.

2.1 How to measure the demand for ERPs

Although virtually all the empirical models in the literature begin with a utility maximisation framework, often neoclassical, in which consumers maximise utility subject to a budget constraint, the lack of empirical data on either the quantity of ERPs consumed or expenditure necessitates the modification of both the theoretical and empirical set-ups.

2.1.1 Neoclassical demand models

Whenever data on retail sales are available, the demand for ERPs, such as organic foods, can be modelled and price and income elasticities can be estimated. Moreover, if the objective is to detect the impact of food safety and environmental issues on food demand, the classical demand models can be extended to accommodate an information variable as an indirect means of evaluating the consumer's perceptions of risk (Kalaitzandonakes *et al.*, 2004). Another approach is to incorporate information and risk perception variables in a household production model to examine how changes in consumer risk perceptions affect food demand (Smallwood and Blaylock, 1991).

2.1.2 Choice modelling

The central idea behind choice modelling is that individuals can choose between alternative options that are described by a number of attributes with different levels. Respondents are not asked to report by how much they prefer some alternatives, nor even how much they value changes in an attribute; they are merely asked to identify which of a number of options they prefer. Formally, it is based within the framework of the Random Utility Theory, and there have been extensive applications in marketing and environmental valuation (*e.g.* Bennett, 1999; Morrison *et al.,* 1996; Adamowicz *et al,* 1998; Blamey *et al.*, 1998). Choice modelling represents the choice process as a

comparison between the welfare, or utility, gained from each option. When faced with the task of choosing among alternative products, the respondent expresses his preference for the product profile associated with maximum utility. The assumption is that the consumer prefers the alternative with the most desired set of attributes. For example, if the objective is to analyse the determinants of the preference for organic food items, a binary choice variable between organic and conventional products is modelled against prices and attributes of both products as well as income and socio-demographic characteristics.

Within this general framework, Viscusi (1989) and Eom (1994) propose an expected utility framework, where individuals have separate utility functions expected for each different consumption choice they are presented with, conventional and IPM or organic produce. The different choices are characterised by a set of variables: price, risk perception, socio-demographic variables. The dependent variable consists of a discrete variable that represents the choice made by the consumer.

2.1.3 Contingent valuation (CV) to measure willingness to pay (WTP)

A large body of studies deals with consumer awareness and willingness to pay for ERPs by using contingent valuation methods. CV allows a direct estimation of WTP for specified benefits by means of different (direct) elicitation techniques. Consumers simply indicate their WTP without purchasing the (non-market) hypothetical product. Direct methods like both CV and experimental markets have raised several concerns about their reliability (Lusk and Hudson, 2004). Nevertheless, the selection of appropriate survey and elicitation methods tends to reduce the bias. Through this method, survey respondents may be presented with a risk-reducing option and asked what they would be willing to pay for its implementation. Theoretically, WTP analysis can be interpreted as a consumer choice problem (Cranfield and Magnusson, 2003). Consumers would be willing to pay a positive premium for a product differentiated in terms of one or more quality attributes if the utility gained from its consumption is higher than the utility from the consumption of the corresponding reference product previously purchased. In practice, the utility represents a latent variable, which is unobservable, and only the outcome of the decision process is observed.

2.2 Theoretical background

The neoclassic demand utility maximisation framework leads to demand functions where consumption is simply determined by prices (P) and income (Y) under the hypothesis of constant preferences across consumers.

The theoretical developments proposed by Lancaster (1966) allow for the modelling of (food) consumption in terms of the quality characteristics (attributes) that the products contain: preferences are defined over a set of characteristics rather than a set of products. Some attributes are product-specific (sensory attributes as taste and texture), other are intrinsic attributes (freshness, nutritional benefits, etc.) and can only be enjoyed when eating a specific product. Instead, the presence and intensity of other attributes are common to all the goods in a specific product group. Within the broad category of organic goods, this may hold for attributes such as animal welfare, environmental attributes and to some extent health attributes (Wier *et al.*, 2005).

Several authors (Ladd and Zober, 1982; Baker and Crosbie, 1993) have applied the product characteristics framework in order to obtain demand as function of a vector of relevant product attributes (**a**) as well as traditional demand variables (P, Y). Vector **a** could for example refer to environment-related characteristics (IPM, organic), as well as to other attitudinal variables.

There is a rich body of literature on food demand relying on the self-reporting of purchase behaviour, individual attitudes and personal values, elicited through questionnaires completed by means of direct, mail or telephone interviews. However, it is only in recent years that figures on the effective consumption of ERPs have been clearly differentiated from consumption of conventional products through data generated by retail scanners. These data became available with the relative increase in the market share of organic products.

Besides the traditional explanatory variables for food demand, if we consider the most important attitudinal factors affecting consumers' decision to buy food, quality attributes (taste, freshness) and personal health reasons seem to prevail (Govindasamy *et al.*, 1997), while environmental effects are not ranked as being very important (Byrne *et al.,* 1992; Chang and Zepeda, 2004; Groff *et al.*, 1993). Looking at food components, consumers are very concerned about residues, absence of pesticides (Govindasamy *et al.*, 1997), content of "bad ingredients" (cholesterol, fat), but not about growth regulators. The fact that consumers seem to understand the meaning of ERPs, in particular organic foods, identifying them as "free of chemicals and residues", supports the idea that "environmental concern" is not particularly strong in food consumers, even though more recent studies (McGarry Wolf *et al.,* 2002; McGarry Wolf, 2002; Robles Robles *et al.*, 2005) found quite a high ranking for the same factor.

Clearly the response depends on the characteristics of the sample and of the elicitation method, as well as on external uncontrolled factors, and therefore comparisons among different studies could be misleading. Nevertheless, this finding that personal health concerns dominate public environmental concerns represents an important preliminary conclusion. However, it is essential to bear in mind that concern about the environment, which may be linked with concern for personal health, is difficult to isolate for empirical purposes.

The poor rating of environmental concerns in purchase decisions may reflect the importance of other (negative) factors associated with ERPs such as excessive prices, difficulties in finding the products, but also the uncertainty about the real benefits from consuming the products and a lack of trust in the regulatory system (certification methods).

We classified the variables suggested in the literature we reviewed into four main sections:

- Traditional economic variables from neoclassic demand analysis, including also demographic determinants of preferences.

- Sensory variables, that refer to intrinsic quality attributes.

- Attitudinal and behavioural variables, which characterise an individual's beliefs, concerns, and view of the world.

- Policy and marketing variables, which include policy instruments, essentially labelling and certification, implemented institutionally to solve market failures, and marketing strategies, such as advertising, providing "private" information to consumers.

In what follows we discuss the direction of the relationships between these explanatory variables and consumption-related dependent variables, both discrete and continuous. We include some text references to support the assertions made in our text.[1] The discussion of policy implications and some final remarks conclude the paper.

3. Empirical evidence on the determinants of the ERP food choice

Four main measures of ERP consumption emerge from the previous section: empirical specifications of the binary choice between organic and conventional products; empirical specifications of the multinomial choice among organic, IPM and other definitions of certified/uncertified ERPs; willingness to pay for a particular class of ERPs, for example organic; and consumption measured as the expenditure share on a particular ERP category. While the first three dependent variables are discrete, the last one is continuous and allows for the estimation of classical demand systems (usually within the family of flexible demand systems). Whenever the models rely on discrete dependent variables, the set of explanatory variables may include any of the following categories: traditional variables like income and price level, individual or household socio-demographic variables, sensory variables referred to specific quality attributes, attitudinal variables like food risk and environmental concerns. Instead, whenever a classical demand system is estimated, the set of explanatory variables includes "traditional" variables like income (expenditure) and prices, and rarely some measure of risk concern.

3.1 Traditional economic variables: prices and income

Neoclassical demand theory indicates three basic factors that influence individual consumption choice: prices (own and related products), income, and preferences. The last variable relies upon individual and household socio-demographic characteristics.

3.1.1 Prices

In the demand literature, prices are considered in different ways depending on the methodology adopted in the study:

- Own price is an explanatory variable in discrete choice models where product alternatives are offered at different price levels.

- In demand systems employing real market data, as in the case of AIDS applications, prices enter among the independent variables.

- Consumer's sensitivity to low or high prices can be coded as a discrete explanatory variable even in qualitative models aimed at explaining consumers' purchase attitude towards specific foods.

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1. The results drawn from an extensive sample of relevant studies are presented in the related online report, "Environmentally Responsible Food Choice: Characteristics and Summaries of Studies", at *http://dx.doi.org/10.1787/482421838431*.

The idea that prices represent a monetary measure of consumers' marginal utility justifies the use of WTP as a dependent variable in models that explain consumer preferences for particular food varieties. WTP refers to the maximum price a consumer would be willing to pay for a given product. WTP is generally elicited using contingent valuation (CV) methods or experiments, for example with auction methods. This methodology is quite common whenever real markets for the products which are being evaluated do not exist or when it would be too costly to undertake a study on the basis of a real-life scenario. In the case of ERPs and in particular for organic products, this method is probably the most commonly used in the literature in order to provide a measure of consumers' preferences.

If price is perceived as a quality signal, then a positive sign may result (Cicia *et al.*, 2002; Huang, 1996), although for ERPs, consumers' perception of quality is generally defined in relation to other characteristics, such as intrinsic attributes or certification. Therefore, whenever price levels or price perceptions are included as explanatory variables, expectations are for a negative effect of own price on the demand for ERPs (Batte *et al.,* 2004; Eom, 1994).

Own-price elasticities calculated in demand systems indicate a high sensitivity of demand for organic products to price changes. Prices of related products are included only in complete demand models, estimated by using market data from official statistics or from supermarket scanners. The results indicate that conventional and organic products are usually substitutes (Glaser and Thompson, 2000; Thompson and Glaser, 2001). Results from WTP models generally indicate a positive WTP for ERPs, although its magnitude may vary greatly depending on the consumer's individual characteristics and concerns.

3.1.2 Income

In demand analysis, the income level is particularly important in the definition of the feasible consumption set that a consumer can reach. In the case of ERPs, some other factors may determine a substantial reduction in the importance of income as an explanatory variable for consumption. However, even if income does not seem to be a very important factor in explaining the demand for ERPs (see Harris *et al.*, 2000 for a comprehensive explanation), there is no doubt that it represents a constraint to the consumer's purchasing decision. Most of the empirical studies include (household) income as an explanatory variable, measured either as a continuous variable, a discrete dichotomous (high/low income) variable, or a multinomial variable. As Thompson (1998) suggested, the existing literature indicates that "higher household incomes do not necessarily indicate higher likelihood of organic purchases" (p. 1115), and therefore other factors are probably responsible for this anomalous result.

The higher prices usually charged for ERP foods imply that expectations are for a positive impact of income level on the choice of organic foods, and this is confirmed in most of the studies where income is significant (Byrne *et al.*, 1991). Nevertheless, Buzby *et al.* (1995) found that WTP for a safer grapefruit was inversely related to income, and the (weak) argument to support this result is that respondents with higher income have access to better information about pesticide risks and may be less concerned about food safety. Therefore, the expected sign of the effect is controversial, even though the arguments sustaining a positive effect are more convincing.

Traditional approaches to demand analysis provide some interesting results. Glaser and Thompson (2000) found large negative expenditure elasticities for organic milk. These findings make sense in a context with a decreasing per-capita demand of beverage milk, indicating that organic milk purchases will increase as total milk expenditure declines. For other food categories, results do not support the hypothesis of a positive effect of expenditure on the demand for specific organic foods (Thompson and Glaser, 2001).

3.1.3 Individual socio-demographic characteristics

The relevant demographic factors that determine individual preferences refer to: age, gender, education, race, marital status. These will be discussed in turn.

Age: The majority of the studies tend to show a negative relationship between age and purchases of ERPs: the older the respondent, the lower the probability of buying organic food (Durham and Andrade, 2005; Magnusson and Cranfield, 2005; Underhill and Figueroa, 1996) or of rating organic food "better" than conventional food (Groff *et al.*, 1993). A good explanation stems from the fact that older people seem to be less worried about cancer risks and generally about health risks. Loureiro and Hine (2002) also found that older consumers were more likely to choose regular apples because they were less concerned about the impact of pesticides on the environment or food. In this case, we would expect a negative effect on the demand for ERPs.

The same negative relationship emerges also in terms of WTP, where older people are generally only willing to pay lower prices for ERPs (mainly organic) than younger segments of the population (see for example Buzby *et al.*, 1995; Loureiro and Lotade, 2005) or are less likely to pay a premium (Shuzzler *et al.*, 2003), although the age limit that characterises the different WTP changes substantially. Cranfield and Magnusson (2003) found that respondents 35 years old or younger are more likely to pay a premium of 6% or more. Govindasamy and Italia (1997) suggest that individuals under 65 are most likely to pay a 10% premium for organic produce, while another study (Govindasamy *et al.*, 2001) reports that respondents under 36 years old have the highest likelihood to pay at least a 10% premium for IPM produce.

There is also some evidence for a positive effect: Misra *et al.* (1991) indicate that over-60 respondents are less price-elastic than those aged 36-60. Batte *et al.* (2004) found that increased consumer age was associated with increased WTP for 100% and over 70% organic content; Shuzzler *et al.* (2003) found that consumers older than 50 are more likely to buy organic produce frequently. In Govindasamy and Italia (1998), respondents below the age of 35 were found to be less concerned with pesticide residues than older ones. Unfortunately this result is not supported by a convincing explanation, and in fact none of the studies reporting such a relationship provides a plausible explanation for their findings.

Gender: Generally, female consumers seem to prefer ERPs more than males because apparently they have a higher risk aversion (Jolly, 1991): several studies (Byrne *et al.*, 1991; Groff *et al.*, 1993) report that males are less likely to rate organics higher than conventional produce. Underhill and Figueroa (1996) show that women have a higher probability of purchasing organic food with certified organic labels than certified pesticide residue-free and grown with IPM.

Female respondents also show a higher willingness to pay than male respondents for a reduction in pesticide exposure, such that they purchase organic foods (Batte *et al.*, 2004; Govindasamy and Italia, 1999; Boccaletti and Nardella, 2000). A possible explanation is that female respondents tend to be the primary food shoppers in the household and are probably more family-oriented and sensitive to safety problems, as indicated by their higher aversion to pesticides. Therefore, the indication emerging from the literature is that women are more likely than men to place pesticide residues as a top concern and to pay a premium for certified residue-free produce.

Education: The level of education may affect preferences for ERPs in different ways: the higher level of general knowledge about the positive health and environmental impact of ERPs may determine a positive effect of education on the demand for these products. But it is also true that individuals with higher education may not perceive a current food safety problem, because they may better understand the true risks associated with residue contamination. In fact, more educated people are usually in a better position to understand the uncertainty around scientific information. Therefore, they are more sceptical about the benefits of ERPs if they perceive that the risks avoided are small (Eom, 1994). Another possible explanation for a negative effect is suggested in Govindasamy and Italia (1998), where higher levels of education were found to increase the level of trust in university scientists and federal agencies: this would reinforce the idea that highly educated respondents are less likely to believe that pesticides are risky. This "trust in institutions" effect may be responsible for the positive relationship between education and certification labels promoted by public agencies found in Hearne and Volcan (2002).

Further evidence for a negative educational effect is found for example in Misra *et al.,* (1991), where the results suggest that respondents with a higher education (college) are less likely to be willing to pay more for certified free-of-pesticide residues products, and in Byrne *et al.* (1991), with higher education adversely affecting the purchase likelihood of higher priced organic produce.

Other factors: Expectations indicate that single persons are more willing to buy ERPs, even though there is little evidence in the literature (Galloway and Bailey, 2005; Jolly, 1991). There are no *a priori* expectations about the effect of race. Misra *et al.* (1991) found that respondents of European origin (white) were more likely to pay a higher price for certified pesticide-free produce. Since ERPs usually cost more than conventional produce, this finding implies that whites would be more inclined to purchase ERPs than non-whites. However, Batte *et al.* (2004) found the opposite.

3.1.4 Household socio-demographic characteristics

Most of the empirical studies refer to households as consumption units, and therefore the objective is not to elicit the respondent's preferences, but rather to infer from his answers his family's demand. The most common variables employed in the literature which enable us to capture the household preferences for ERPs are: household size, presence of children, place of residence, main shopper in the family.

Household size: The number of persons in the household is a proxy of the degree of consumption but also of the qualitative characteristics of the demand, such as package size and convenience. Sometimes the number of family members employed is also evaluated, which represents an indirect way to assess the income constraint. In fact,

household size can be correlated with total food expenditures because the larger the household, the more food is required. Because ERPs are relatively expensive, one might expect consumption of ERPs to fall (either absolutely, or as a share of food expenditures) as household size rises.

Expectations are for a negative effect of this variable on the demand for ERPs: this finding is consistent with the marginal effect of income in that larger households generally have less disposable income per person than smaller households do (Govindasamy and Italia, 1999; Eom, 1994). An opposite result is reported in Shuzzler *et al.* (2003), where households with more than four members are more likely to purchase organic produce frequently than smaller households. As reported by the authors, a possible explanation could be a higher household median income level in the area where the survey was conducted, or a more evident preference for fresh produce.

Presence of children: The variable usually includes children 12 years old or less, but the age limit may vary across studies, ranging from 12 to 18 years (sometimes two variables are defined, one for children and the other for teenagers). This variable captures the preferences of a peculiar segment of the population. Empirical results indicate contrasting effects on the choice for organic: positive if the safety concern dominates (Batte *et al.*, 2004; Loureiro *et al.*, 2001), negative if the budget constraint is a priority, even though some of this latter effect should be captured by other variables like "income" and "household size". Loureiro *et al.* (2001) found that the probability of purchasing organic apples relative to the probability of purchasing conventional produce increases when consumers have children under the age of 18 but tends to decrease with family size, in line with the idea that shoppers with large families have an economising mind-set.

The explanations from the literature why ERP products and organic in particular are more desirable for consumers with children are that they may be perceived as safer for children because of lower pesticide residues and also that they contribute to preserve the environment for future generations. In a different study, Loureiro *et al.* (1999) provide an interesting result that confirms this "child caring" attitude: the presence of children in the household negatively affects the probability to purchase apples from sustainable agriculture, implying that consumers will buy organic if they are offered as a substitute. The decision to switch to organic may be caused by the perception that these products are associated with the idea of "no pesticide use", while products from other environment-friendly methods are seen as obtained from a simple reduction in pesticide use, with personal benefits more difficult to measure in the latter case.

Place of residence: Refers to "rural" or "urban" area, and/or to large or small city. The first variable captures various effects, for example the "green" attitude of consumers living in rural areas (Govindasamy and Italia, 1997). There is also some evidence of a negative effect in rural/suburban areas, and the explanation is that people living in these areas, for example in a farm or with a garden, may use relatively more pesticides (Underhill and Figueroa, 1996). Another explanation could be that people living in rural areas trust conventional produce and current agricultural practices. Therefore, there seems to be no clear expectation about the sign of this effect on the demand for ERPs.

Main shopper in the family: When the respondent is the primary shopper, then he or she could feel the responsibility for buying food for the entire household and his/her concern about environment/health may be higher (Govindasamy and Italia, 1997).

3.2. Intrinsic quality attributes

Consumer appreciation of sensory intrinsic quality attributes usually translates into higher WTP for products with a higher level of these attributes (Hu *et al.*, 2005). This idea can be used to model consumers' preferences for ERPs: in fact, the use of environment-friendly techniques may have an impact on the intrinsic quality level of the product. It is a common belief that the produce obtained from a lower use of chemicals may present a lower visual quality, in terms of appearance and defects, counterbalanced by a series of perceived quality improvements, such as higher nutritional value, sweeter fruit, safer products, etc.

Therefore, there is a strong expectation that consumers will also evaluate intrinsic quality attributes when they consider the purchase of ERPs, and this is confirmed by the inclusion of specific quality variables in ERP demand models. Boland and Schroeder (2002) suggest that, in the case of meat, consumers valuing particular intrinsic quality attributes may under-rate organic certification, but this may vary across consumer groups and across cuts.

The variables used in the literature refer to specific attributes, such as appearance and defects, or to an overall quality assessment, usually in comparative terms with respect to conventional products (Byrne *et al.,* 1991). Consumers may use the organic characterisation of food as an indicator of higher nutritional quality, and this can contribute to explain a higher WTP (Loureiro and Hine, 2002) or simply the preference for organic (Huang, 1996). Rimal and Moon (2005) and Soregaroli *et al.* (2003) consider nutritional value in the calculation of a perceived benefits index for genetically modified foods.

There is also some limited evidence of a better intrinsic quality of organic products (Ara, 2003; Shuzzler *et al.,* 2003). This would help to differentiate ERPs from conventional products with a further positive effect on the consumer's expected utility from consumption and a reduction of uncertainty. In the same vein, freshness seems to affect preferences for organic fresh produce in a positive way (Loureiro and Hine, 2002).

Appearance is a recurrent variable in studies that consider preferences for organic food because the reduction in the use of chemicals generally has a trade-off in terms of "visual quality", especially for fresh produce, where appearance may represent the first "search" attribute considered by consumers in their purchase decision. Sometimes this attribute is sided with "size" to capture another relevant search choice variable. Thompson (1998) measures product defects directly in store by noting differences with common quality standards. Huang (1996) models directly the acceptance of sensory (external) defects as a function of demographics and appearance. Other authors (Baker, 1999; Cicia *et al.*, 2002; Hearne and Volcan, 2002; Durham and Andrade, 2005; Scarpa *et al.*, 2002) include appearance as a (negative) determinant of preferences for ERPs. The effect, when significant, seems to support the hypothesis that consumers prefer absence of external defects.

3.3. Attitudinal and behavioural variables

In this category we consider all those variables that would presumably concur to affect the consumer's beliefs and attitudes. Consequently, the assumption is that consumers'

purchase behaviour results also from all those variables that have an influence on individual attitudes and behaviour. In particular, two seem to be the most relevant factors that are changing our lifestyle: the environmental impact of all our consumption actions and the progressive environmental degradation resulting from high consumption rates in developed countries on the one hand, and the health risks from these high consumption rates, resulting from the increasing complexity of the goods and services consumed, on the other hand. With particular emphasis on food consumption, the intensive use of chemicals and genetics in agricultural practices poses some serious environmental problems, while the food scares experienced in the last 15 years are responsible for a higher perception of food risks. We discuss extensively environmental and health concerns and the degree of understanding of these issues, and we also mention several less important variables employed in the literature, such as ethical factors.

3.3.1 Environmental concern

Concern for the environment should represent a strong motivating factor for consumers exhibiting a preference for ERPs. In this category we consider only the effect of a direct concern about the environment and not an indirect concern associated with perceived reduced health risks. According to Dunlap and Van Liere (1978, cited in Verhoef, 2005) environmental concern is defined as the belief about humanity's ability to upset the balance of nature, the existence of limits to growth for human societies, and humanity's right to rule over the rest of nature. Clearly, if the aim of environment-conscious consumers is to avoid this degradation of nature, food consumers will try to minimise the impact of their consumption choices on the environment, therefore demanding some sort of ERP foods. The expected direction of this effect is positive, *i.e.* individuals with a higher degree of environmental concern should show a stronger preference for ERPs, which translates into both higher demand and larger WTP.

There is no theoretically justified or standardised way to define which variables should be included in a food consumption model aimed at formalising the impact of environmental concern on food preferences. Recently, Verhoef used a 7-point scale to rate some statements regarding environmental consciousness (should nature dominate human behaviour or the opposite?) and green behaviour (use of "green" energy, sorting of waste, green investments). He validated the hypotheses that environmental concern, green behaviour and perceived consumer effectiveness (intended as the consumer's capacity to improve the well-being of animals) positively affect the choice and consumption frequency of organic meat. The results indicated a positive and significant effect for green behaviour and consumer effectiveness, although this last effect was rather weak. Instead, contrary to the environmental literature, environmental concern was not significant, and the reasons adduced by the author are that purchasing organic meat is a rather specific behaviour and also that the environmental concern effect may enter indirectly the model influencing other perceptional and emotional variables included in the model.

Magnusson and Cranfield (2005) include the perception of the negative effect of pesticides and of the positive effect of sustainable agriculture on the environment using a 5-point Likert scale. Unfortunately, the parameters estimated for variables obtained from multiple statements are difficult to interpret: they represent an aggregation of different effects and it is not clear which effect dominates. For example, in the Magnusson and Cranfield's work, one factor includes three questions regarding the concern over pesticides in the environment, pesticide residues on food and importance of labels on

food products, while another factor sums the perceptions of the importance of family farm income and of the use of sustainable agricultural practices. Their results indicate that only the first factor is significant: the stronger the respondent's level of concern over pesticides and chemicals in the environment and food, the higher the probability of choosing a pesticide-free certified food product.

An alternative approach to the problem is to measure environmental concern as a trade-off between environmental quality and job creation (Loureiro and McCluskey, 1999; Loureiro *et al.*, 2001). This particular way to pose the question informs consumers that the adoption of environment-friendly techniques entails some benefits but also some costs to society. Respondents with a strong environmental attitude present a higher probability of purchasing organic apples with respect to the probability of purchasing the alternatives (eco-labelled and regular produce).

An interesting and quite complete way to assess environmental concern is the one suggested in Durham and Andrade (2005), based on the study by Roberts (1996), where two factors are derived from a list of attitudinal questions about environmental consciousness: Environmentally Conscious Consumer Behavior (ECCB) and Energy Conservation and Recycling Behavior (ECRB). The first factor represents a synthetic measure of environmental concern translated into the purchase decision, while the second factor intends to measure the environmentally driven general behaviour of individuals, with questions regarding for example efficient energy consumption and recycling. In particular, the authors extract several factors: an Environmental Purchasing Behavior factor, that measures the preference towards organics for environmental reasons, a Health Environment Sensitivity factor, which measures the concern about health risk from chemicals, and a Personal Health Responsibility factor, that should capture how much individuals feel responsible for their health. The first variable (factor) proved to be the most relevant determinant of the preference for organic, confirming the positive relationship between environmental concern and ERP consumption.

Johnston *et al.* (2001) apply the same procedure to isolate three factors indicating environmental concern based on abstract reasons, likelihood of purchasing specific types of environment-friendly products, and change in behaviour in response to environmental reasons. They found that anti-ecological purchasing behaviours as measured by high scores on the three factors (in the study high scores meant anti-environmentalist behaviour) were associated with a significant decrease in the probability of buying eco-labelled seafood products.

Dunlap and Beus (1992) determine the principal components of the overall attitude towards pesticides and find three factors: necessity of pesticide use (the "positive" attitude), safety of pesticide use (health and environmental concerns), trust in food industry, and correlate these factors with demographic variables. They find that women, younger adults and the well-educated are slightly more anti-pesticides than their counterparts, that women and lower-income earners are more concerned about safety, and that respondents with higher education are more likely to see pesticide use as necessary.

A similar method, even if simpler because it is designed to assess preferences specifically for pesticide-free products, is adopted in Cranfield and Magnusson (2003): they derive two factors, pesticide and sustainability, from a list of five questions. The first is aimed at assessing concern about the impact of pesticides on health and the

environment, the second captures consumers' feeling about sustainability as a broad concept. Not surprisingly, the impact of the first factor on WTP for pesticide-free certified products confirms that respondents who are concerned with the negative effects of pesticides on the environment and health would pay higher prices to avoid pesticides. However, the second factor is not significant.

Gil *et al.* (2000) apply principal components to extract two factors from a list of statements: environmental conservation, which reflects consumers' active interest in reducing the effects of environmental degradation, and environmental concern, that considers consumers' awareness about negative effects of development on the environment.

In the case of ERPs, indirect environmental concern can be associated with the use of pesticides, eliciting the consumer's perception of the negative effect of pesticide use on the environment. Consistent with expectations, Govindasamy and Italia (1997) found that respondents who believed that the use of pesticides was damaging the environment were more likely to purchase IPM produce.

Animal welfare and environmental concerns together contribute to determine the "ecological motivation": the more concerned people are with environmental and animal rights issues, the more positive attitudes they have towards organic food (Honkanen *et al.*, 2005). However, it is not clear that animal welfare is a relevant concern for consumers of organic meat (O'Donovan and McCarthy, 2002; Verhoef, 2005).

In conclusion, the most common methods employed to elicit environmental concern in food consumers can be summarised as the following:

- Direct elicitation of environmental concern with single questions/statements usually based on a Likert scale.

- Environmental concern elicited as trade-off between the environmental factor and some other positive social aspect: for example trade-off between environment preservation and job creation.

- Extraction of environmental factors from a list of statements.

- Pesticide concern indexes calculated from a pool of statements/questions.

- Choice among products with different environmental risk levels: for example choice between organic and conventional produce.

3.3.2 Health risk (food safety) concern

If consumers associate their food safety concerns with the presence of chemical residues in what they eat, then those who show a higher degree of concern should also have a stronger preference for ERPs, particularly towards organic produce. Therefore, the expected sign of the effect on ERP consumption and on WTP is positive.

Perception of health risks can be assessed by using a very simple "perceived risk" variable, usually defined over a Likert scale: Eom (1994) defines an index of health risk from consuming commercial produce on a 10-point scale: the impact of the perception of health risks on the intention to buy safer produce is positive. In conjoint analysis one way

to elicit health concerns is to offer alternative product varieties with lower health risk, for example those obtained by reducing pesticide usage (Baker, 1999; Ara, 2003).

Explicitly addressing the trade-off between food safety and appearance is important for the assessment of the positive and negative effects of ERPs. The study by Loureiro *et al.* (2001) is the only one which approaches the problem using a "net balance" method. In line with expectations, the probability of purchasing organic apples increases when consumers have a strong food safety concern.

Several authors aggregate health and safety statements into a unique health index, allowing for a reduction in the number of parameters in the model and the aggregation of different and complementary opinions about health aspects of the food. Misra *et al.* (1991) calculate a pesticide concern index based on a pool of six questions: including the ranking of pesticide concern within food concerns, the comparison of pesticides risk with other health risks, opinion statements about the use of pesticides. Their results suggest that as the degree of concern increases, the probability of a higher WTP for pesticide-free produce also increases.

Similarly, Boccaletti and Nardella (2000) found a residue concern index positively affecting WTP for pesticide-free produce, although the size of the impact was quite small. In Batte *et al.* (2004) a health index and a food safety index were also positively related with the consumer's choice to buy organic produce.

If the objective of the research is to evaluate the reduction of a particular health risk, such as pesticide-residue risk, as in the case of ERPs then the response to a single question may suffice, and consumers may simply indicate if they believe that the use of synthetic pesticides poses a serious health risk. Buzby *et al.* (1995) and Govindasamy *et al.* (2001) found that attitude towards pesticide residue was an important indicator of consumers' WTP for food safety: consumers with high risk aversions towards pesticide were more likely to pay higher prices for pesticide-free produce in the first study and for IPM produce in the second study. With a similar methodological approach, Ara (2003) shows that consumers who are more averse to pesticide risks have stronger preferences for organic rice.

As in the case of environmental concern, Durham and Andrade (2005) define four synthetic factors for health concern obtained from a list of 13 questions drawn from an earlier study on wellness orientation (Kraft and Goodell, 1993). They are *i)* personal health self-responsibility, *ii)* nutrition and stress management, *iii)* physical fitness, *iv)* health environment sensitivity, where only the second and the fourth are related to the concern about food risk, while the other two refer to overall health and wellness concerns. Results indicate that concern about food nutritional characteristics is a factor that strengthens the preference for organic produce and increases the probability of this choice, and the same is true for respondents with a higher health concern and who feel more responsible for their health.

One of the factors identified by Gil *et al.* (2000) as "lifestyles" refers to health concern, *i.e.* to the consumer's attitude to keep himself healthy (see also Galloway and Bailey, 2005, for elicitation of wellness) and another factor, "natural food consumption", indicating attitudes towards good foods (fruit and vegetables), indirectly captures health concerns. In all these studies, health concern favours the choice of ERPs.

Few studies specifically address the analysis of risk preference, and elicit an overall risk perception measure: Lusk and Coble (2005), following previous work by Pennings and Leuthold (2000) and Pennings and Wansink (2004), elicit general risk in consuming GM foods by asking four 9-point Likert scale questions and adding the results to obtain an overall measure: the results show that respondents who indicated that they had consumed GM foods were more risk-loving than those who had never consumed GM foods. Nganje *et al.* (2005) model the consumer's awareness of food risk as a function of several perceived risk characteristics, indicating that outrage and personal health influence affect consumers' risk perception.

Summarising the results and independently from the selected elicitation method, the expected effect of perceived health risks from pesticides or other sources of risk on the demand for ERPs is clearly positive: the higher the perceived risk (the more health-conscious is the consumer), the higher the preference for products cultivated with environment-friendly practices, *i.e.* the probability of incurring health problems is perceived to be lower as a consequence of reduced chemical use in cultivation.

Govindasamy and Italia (1998) also assess the effect of socio-demographic factors on the consumer's concern about pesticide residues, and find that concern is higher for women with children located in suburban areas and with medium-low incomes.

3.3.3 Knowledge

The use of environment-friendly techniques in agriculture is not easily signalled to final consumers, unless they have some previous knowledge about these production methods or the benefits stemming from alternative agricultural practices. Sometimes even the use of certification and labelling is not a satisfactory solution to the problem: the assurance that a product is organic may not be enough to convince a consumer that his satisfaction will increase if he consumes that product, unless he has some direct knowledge about the production methods. On the other hand, when consumers are informed, their degree of risk awareness could be lower, because they may be aware of the fact that the use of chemicals at the production level does not necessarily mean that the final product will contain residues. From the literature the dominant relationship between knowledge and consumption of (WTP for) ERPs seems to be positive.

In the literature several different methods to elicit the degree of consumer's knowledge are employed. Often respondents are asked if they have ever heard of a particular ERP, with reference to environment-friendly production methods: Govindasamy and Italia (1999) found that those who had knowledge of IPM methods were more likely to pay a premium for organic produce. Rimal *et al.* (2001) asked questions related to food safety issues and found that higher knowledge implied lower concern about food safety.

Self-reported knowledge defined over a point scale from "no knowledge" to "very knowledgeable" is also commonly employed in papers aimed at explaining WTP. Gifford *et al.* (2005) found that knowledge of GM foods significantly lowered the bids for organic products, but had no significant effect on bids for non-GM products.

When the focus of the study is to ascertain the effect of informing consumers in general, such as in models which include some sort of informational factor, for example

the willingness to purchase a particular type of certified label with some information attached about the certification (Underhill and Figueroa, 1996), then knowledge variables are not included in the analysis. In this case, respondents gather new precise information when they are interviewed, and therefore past information should not play a relevant role.

3.3.4 Other concerns and attitudes

Novelty: Trends in food consumption usually show a conservative inertia: most consumers stick to their "consumption history" and change food habits very slowly and not very often. Nevertheless, some individuals are more prone to try new foods than others. To capture this attitude, some authors introduce a variable for novelty. Consumers are generally asked to self-rate themselves as to whether or not they like to try newly introduced food products (Govindasamy and Italia, 1999). Cranfield and Magnusson (2003) found that innovators are more likely not to pay a premium or to pay a very modest premium for pesticide-free products compared with those who do not try new food products. But in Govindasamy and Italia (1999), respondents who indicated that they were among the first to try newly introduced food products were also the most likely to pay a premium for organic produce.

Ethical concerns: Political concern (measured with a self-reported indication of political belief) as well as religious concern (measured for example with the self-reported level of worship) have some sort of impact only for the choice involving GM food products (Hossain and Onyango, 2004). In many countries environmentalists are usually identified with a specific political part, and this could justify the inclusion of political concern as an explanatory variable for the demand for ERPs.

Emotions: According to Verhoef (2005) goal-directed emotions (fear) and self-conscious emotions (guilt) might influence consumption of organic meat. We can extend the idea saying that consumption of ERPs may induce some emotional reactions in food consumers, linked to the fear of health and environmental negative consequences from eating conventional foods, or to the guilt of contributing to environmental degradation. The expected impact of these emotions would be clearly positive on the demand for ERPs.

Shopping attitude: Some consumers would switch stores in order to find what they want, for example pesticide-free products (Magnusson and Cranfield, 2005; Cranfield and Magnusson, 2003; Govindasamy and Italia, 1997; Shuzzler *et al.*, 2003). The habit to visit a farmers' market may also indicate some propensity for natural foods (Govindasamy *et al.*, 2001; Eom, 1994). When significant, this variable sustains the consumption of ERPs.

3.4. Policy and marketing variables

3.4.1 Certification and labelling

The attitude towards labelling and certification reveals the trust of consumers in private or public agencies as regulators of the certification system behind labels. The overall attitude towards regulations of risky sectors like GM and organic represents an important factor influencing the consumer's decision to buy these products. The degree of trust can be measured by simply asking the respondent's level of agreement with the (importance of) identification of organic food (Anderson *et al.*, 2005; Byrne *et al.*, 1992;

Misra *et al.*, 1991) by means of testing and certification (Hu *et al.*, 2005) and with the involvement of public regulatory institutions (Chakraborty, 2005). Expectations of a positive relationship between ERP consumption and policies like certification and labelling aimed at turning credence quality attributes (food safety and environmental preservation) into search attributes (labels) are confirmed in many studies and the level of significance is also quite high (Cicia *et al.*, 2002; Wang and Sun, 2003).

Misra *et al.* (1991) found that a higher individual rating of testing and certification increases the probability of being willing to pay a higher price. In Anderson *et al.* (2005) a high percentage of consumers indicated that they would prefer certified products (IPM or organic) after hearing a clear definition of the production methods and of the environmental and health benefits. This result provides a clear feedback to policy makers, showing that certification strategies should be paired with other complementary marketing strategies based on credible and understandable information to final consumers.

Several studies include measures, usually evaluated on a Likert scale, of the level of confidence in public and private institutions, although these variables often come out not significant (Gifford *et al.*, 2005; Johnston *et al.*, 2001). Consumers' support for mandatory labelling is also a proxy for trust; for one particular food safety attribute (BST-free) Chakraborty (2005) shows that consumers would be willing to pay a higher price if they believe strongly in mandatory labelling.

The use of choice models allows us to model the preference towards different certification systems (organic or GMO-free, in Hearne and Volcan, 2002; not certified, in Wang and Sun, 2003) or different labels, such as organic, conventional or eco-labelled products (Loureiro *et al.,* 2001; Blend and van Ravensway, 1998; Johnston *et al.*, 2001; Roheim *et al.*, 2005), therefore modelling the degree of influence of different factors on choice. The results provide insights into the relevant features that a certification system should have and the consequent information that a label should report.

The trust in the certification system has a direct influence on the consumer's preferences, and therefore to ask if consumers prefer to buy certified products indirectly reveals the trust in certification systems (Anderson *et al.*, 1996; Ara, 2003). Galloway and Bailey (2005) elicit the consumer's perceived importance for certification of credence attributes for coffee, which includes organic and fair trade features.

In WTP models for ERPs, the perceived importance of labelling as a source of information contributes to the size of the expected marginal utility from consumption (Cranfield and Magnusson, 2003, Gifford *et al.*, 2005). In models with continuous variables, label perception is also measured through the frequency of use (Nayga *et al.,* 1999). Alternatively, the consumer simply indicates if labels help to make purchase decisions (Rimal *et al.,* 2001; Shuzzler *et al.*, 2003).

Perception of labelling as a useful instrument to "differentiate" products is elicited in Rimal and Moon (2005), by asking consumers if they feel uncomfortable about the fact that conventional foods are not labelled differently from GM foods. If the interest is in the costs and benefits of labelling, then a hedonic model could provide a measure of the marginal effect of organic labels on product price (Boland and Schroeder, 2002), which could be compared to the cost of implementing a quality certification system.

Preferences for products labelled organic can also be modelled as endogenous by estimating (single equation) models with choice (reliability) of labelled products as the dependent variable, sometimes distinguishing among different labels; for example in terms of content in organic ingredients. Underhill and Figueroa (1996) show that informed consumers prefer "organic" over "certified organic", and "certified pesticide-free" over IPM, indicating that individuals assume that organic produce is guaranteed free of residues and therefore do not need certification for organic, while IPM is not sufficiently self-guaranteed. Armah (2002) suggests that a majority of consumers of organic produce use eco-label standards to purchase their organic produce.

3.4.2 Advertising

Few studies try to measure the respondents' use of advertising and reports from the media as a source of information (Govindasamy and Italia, 1999; Govindasamy *et al.*, 2001). This is probably due to the fact that, for ERPs, and particularly for organic and IPM certified products, the most reliable information available to consumers is from labelling and certification. The direction of the advertising effect on consumption (WTP) is positive, confirming that those who are most likely to purchase ERP (organic) produce for a premium are more likely to look for new information by reading food safety reports in the media. The reliability of comments from several sources can be easily tested: for example Rimal *et al.* (2001) calculate three indexes to measure consumers' confidence in the media, in scientists (universities) and in supermarket representatives and find that respondents generally trusted independent laboratories and universities but not supermarket representatives, and only chemical manufacturers and growers' associations had enough influence to convince them to alter their food habits.

3.4.3 Other marketing variables

The non-availability of ERPs in groceries increases search costs for consumers, leading to a lower purchase probability (Verhoef, 2005). A small assortment of ERPs will make them less attractive to consumers (Huang, 1991).

4. Policy implications

In the literature, food products have usually been considered experience goods in Nelson's definition (Nelson, 1970), the reason being the dominance of experience attributes, detectable only after consumption. Consumers are often unable to inspect the product in depth and to assess its intrinsic quality before purchase. Moreover, the growing concern of individuals towards product/process attributes difficult to detect, such as nutritional characteristics, food safety, environmental impact (organic, IPM practices) has increased the number of credence attributes, *i.e.* those characteristics not detectable even after consumption.

Steenkamp (1997) reports that the most important evaluation criteria in the choice of a food product are: product quality, price, brand name/reputation, freshness and guarantees. Guarantees make it easier to interpret and process information in the presence of hidden quality attributes. Some examples of guarantees are: brand name itself, quality labelling and geographic origin.

The increasing liberalisation of international trade has aggravated the problem of asymmetric information: if on the one hand it improves consumers' welfare by increasing

the variety of food products available, on the other hand, consumers' bounded rationality and the lack of familiarity with several products accrues to the informational problems between producers and consumers. At least initially, the introduction of a product in a foreign market causes most of the problems that new products imply: the solution to these problems requires, among other things, an adaptation of the consumer's perception of the product as well as a reformulation of the producer's strategic behaviour and some kind of institutional regulation of the market, for example the definition of common standards and certification procedures for process attributes.

Whenever the information asymmetry present in food markets is not at least partially solved with an institutional intervention by means of specific regulations, then problems of adverse selection and moral hazard can occur. With adverse selection, an *ex ante* opportunism due to hidden information, there is a progressive reduction of the quality until only the bad-quality products remain on the market. In other words, if only products with quality attributes below what consumers would expect, for example a conventional product labelled as organic, are sold, then the market fails to deliver "high-quality" products. A second problem arising from information asymmetry is moral hazard, caused by *ex post* opportunism, when the producer does not try to achieve a predefined quality level. In both cases, the market will not fully reward high-quality producers or penalise low-quality producers.

Taking as an example ERPs, if there is not mandatory certification for a particular type of "low pesticide use" product, then both adverse selection and moral hazard will emerge. Even with mandatory certification, as in the case of organic produce in most developed counties, if certification is not fully effective in screening for proper agricultural practices, then moral hazard may still exist. As Grolleau and Caswell (2005) correctly underline, moral hazard "may be mitigated to some extent by the need for producers to make significant initial investments in knowledge, skills, materials, and time to become certified", and therefore the effect of these transaction-specific assets would be a higher degree of commitment to the certification standards.

4.1 Policy remedies to market imperfections

Several policy remedies can be suggested as a possible solution to the market imperfections emerging from the empirical studies reviewed above. Here we do not consider policy remedies for moral hazard, but rather we consider the policy instruments that are aimed at solving the information asymmetry between producers and consumers, *i.e.* the adverse selection problem. The mechanisms aimed at solving the asymmetry observed at the lowest level of the marketing channel are basically reputation, quality signalling and advertising.

4.1.1 Reputation

Reputation refers to the capacity of a particular brand or trademark to inform final consumers about an overall quality level, and usually its effect is a reinforcement of the informational effectiveness of some other quality signal. For example, the reputation of a producer's brand or a distributor's private label may give further strength to claims regarding credence attributes, such as "cholesterol-free", "GMO-free", but also "organic" or "obtained from IPM methods". Clearly, this supportive role of reputation will be more effective for the first two examples, because there is no mandatory certification to make

those claims, and less effective for the other two cases, at least whenever a mandatory certification system exists.

4.1.2 Quality signalling

The simplest way to turn an experience or credence attribute into a search one is through labelling. Nutritional labelling provides information about nutrients, while organic labelling identifies the product as obtained from organic agricultural practices. Clearly, the effectiveness of labelling depends on the reliability of the certification system in assuring that the practices adopted at the farm level are in line with the claim made on the label. McCluskey (2000), using a game theoretical approach, shows that both a repeat-purchase relationship and credible third-part monitoring are required for high-quality credence goods, *i.e.* organic products, to be available on the market.

The necessity to provide information in the organic sector stems from the consumer's willingness to pay a premium for organic products: in such a situation, a profit-maximising producer would clearly try to falsely claim that his product is organic as long as the probability that he will not be discovered is sufficiently high. Governments have some advantages over third party in regulating certification: they can standardise the term "organic" and ensure coherence with international standards, and they have the power to prosecute violators under criminal law. As such, it is expected that consumers would show more confidence in governments rather than in private agencies.

4.1.3 Advertising

Advertising represents another way for consumers to gather information, although for credence goods advertising is usually not informational. Nevertheless, supermarket chains sometimes use advertising to make statements that help clarify their position with regard to credence attributes such as use of biotechnologies and of environment-friendly production methods. Standard consumer protection laws related to advertising are required to ensure that the claims made are not false.

4.2 Effectiveness of certification and labelling as informational signals

Reliability of labels as a source of information for ERP consumers depends significantly on the effectiveness of the certification system in assuring the promised levels of environmental and health attributes. The level of most of these attributes is determined in the upstream phases of the food supply chain, well far away from retail markets. Contractual arrangements, co-ordination and controls contribute to assuring the final quality. The institutions in charge of the certification/labelling scheme must assure segregation of the products with and without the desired characteristics throughout the supply chain (Caswell, 2000).

Another source of uncertainty in evaluating labelling policies is the complex relationship between consumer information and behaviour (Caswell and Mojduszka, 1996). The variability of the results obtained in studies that assessed the impact of different labels/certifications on the purchase of organic and other ERPs provides some evidence of the fact that these signals interact with several other factors, such as the levels of understanding and the overlapping of different labels and certifications.

As Grolleau and Caswell (2005) rightly emphasise, "a high level of search and experience attributes detectable by consumers before or after the purchase can support the credibility of environmental claims…" Joint product differentiation with respect to environmental and health credence attributes, together with "private" search or experience attributes, appears quite difficult to implement. In the previous discussion, we found some evidence of perceived superior quality for organic products, but we also reported some evidence of a negative perception of attributes such as appearance and size. Research aimed at the development of process and product innovations to improve quality of environment-friendly products may play an extremely relevant role in the near future, although the negative perception towards GM products may slow this trend down.

Credibility will strictly depend also on the level of the standard imposed: the higher the standard, the more difficult will be its implementation throughout the supply chain (Jahn *et al.*, 2005). From a strictly economic point of view, the quality level should be increased as long as there is a net welfare improvement, *i.e.* the benefits of a further increase in quality exceed the additional benefits.

The fact that the demand for organic products is slackening after a period of consistent growth may indicate that in many cases the costs are higher than the benefits; other less "costly" products may serve the cause in a better way, for example with a reduction in monitoring costs, and a smaller difference between effective and perceived quality, generating greater benefits for final consumers.

4.3 Some clues from the literature: the consumer of ERP

Any policy intervention should take into account the relevant market imperfections which are going to be addressed as well as the characteristics of the consumer targeted by these policies. Although the results described in the literature are not always comparable or address the same set of hypotheses, it is possible to draw a sufficiently precise picture of the consumer showing a preference for ERPs *vs.* conventional alternatives.

Summarising, highly-educated women under 50 years old in higher-earning households with children, with some knowledge about environment-friendly production methods as well as environmental and health risks, show stronger preferences for ERPs in terms of higher WTP over conventional products.

Uncertainty about the benefits and risks of both conventional and ERPs is probably the most important factor against a proper product differentiation, which compromises a clear separation between the two product categories in terms of expected utility. Higher education levels contribute to a better understanding of the information available, and a possible explanation could be that the current dissemination of information about risks may be too technical for less educated persons. Public institutions (government agencies and universities) could indeed play a relevant role by distributing easy-to-read information about research findings (risks) to the general public.

Risk attitude, technically definable as the degree of individual risk aversion, is also an extremely relevant variable in consumers' food choice. The individual concern about risk is strictly related with individual socio-demographic characteristics: women show a higher degree of risk aversion, especially when they are the prime shopper in the family

and the household includes children. Older consumers seem to be less concerned about health risks and generally show a weaker preference for ERPs.

Food safety concern, a proxy of the perception of health risks from food, depends also on the consumer's trust in food safety regulations and enforcement by public institutions: the negative relationship between the two variables implies that credible institutions and good food safety regulations contribute to reduce food scares (Rimal *et al.*, 2001). This may have different and controversial policy implications. On the one hand, a reduced food risk concern may imply that consumers perceive conventional food as free of risk, and therefore may be averse to switching to ERPs, usually sold at higher prices. In this case, the expected net utility from ERP consumption would be negative. On the other hand, certified ERPs may be perceived as effectively reducing food risks, and therefore the utility gain from the consumption of these products may turn out to be positive. The first effect could explain why the fact of being concerned by risk does not necessarily imply a change in consumption habits.

The significance of the income variable in consumers' decisions to purchase ERPs may be explained in part by their higher price: people with higher incomes are more oriented towards ERPs, especially certified organic products, where this category usually represents the most expensive alternative. Price differentials between organic and conventional may vary depending on the product category but can be as high as 30-40% of regular price. Most of the studies indicate that individuals are willing to pay a premium not higher than 15-20% of regular price for organic products, although some studies report values well above 20%. This provides an important threshold for the definition of proper marketing strategies. For example, if producers of pesticide-free products intend to sell through mass marketing channels, *i.e.* supermarket chains, then the price difference with respect to conventional produce should not exceed this range. The high price elasticity found from the application of classic demand models, more than twice the elasticity for conventional products, indicates that organics should be priced carefully if the objective is to increase their market share.

On the other hand, there is a relatively small niche of very concerned consumers with higher WTP, and it may be targeted by selling through specific and specialised marketing channels, such as specialty outlets for organic products. Sensitivity to prices and income may vary substantially between consumers buying from mass markets and those buying from specialty outlets.

Not surprisingly, the lower the degree of perceived "environment-friendliness" of the product, the lower the price that the consumer is willing to pay. Methods like IPM are usually perceived as having a higher negative impact on the environment than organic techniques, while certification and trust in public institutions improve the perception of the positive effects. Current studies seem to indicate a stronger preference for organics compared to other products obtained from less environment-friendly techniques, such as IPM, although those studies specifically addressing the consumption of IPM products provide some evidence of consumer support for IPM.

In drawing conclusions, one should also consider that most empirical studies use hypothetical market situations, and that there may thus be some upward bias in their results. In addition, because of the difficulties associated with the enforcement of rules concerning organic agriculture, this may reduce the significance of the results in favour of

less drastic production methods, such as IPM or other emerging certification methods, for example "controlled procedure agriculture" employed by several supermarket chains. The amount of information required for an informed food choice is smaller and technically less complicated for these products, with lower enforcement costs. However, the benefits in terms of environmental impact may be substantially smaller compared to organic agriculture.

5. Final remarks

It is clear from this review that the future of the ERP market relies on the individual perception that these products provide an effective way to reduce health and environmental risks and that there is a net welfare gain at least at the single consumer level. If individuals perceive mainly the health risk component, and much of the relevant literature identifies chemical residues in food as a major issue to consumers, and if they believe that the current regulations and enforcement systems are reliable in guaranteeing safe foods, then it is difficult to foresee a significant increase in ERPs market shares, because risk-averting consumers also may not end up buying ERPs. In fact, conventional foods may not represent an actual risk.

However, the preference for ERPs, and organics in particular, may be strengthened, with marketing communication stressing the use of fewer chemicals. Although both environmental and food safety improvements are sources of added value to consumers of ERPs, food safety appears to be more important than environment. As such, it is most probable that private communication should focus on health aspects, while public information may fill the gap in providing proper information about environmental aspects. Who should invest in communication depends on the degree of informational market failure, on the extent of public social benefits, and on the truthfulness of the information given. Moreover, it is important that the design of effective label standards meet the values and behaviour of all market participants, satisfying all levels of the marketing chain: the presence of gaps along the supply chain may impair the effectiveness of the certification system and therefore the acceptance by final consumers.

If environmental concerns grow among consumers, then a reliable institutional framework may not be enough to keep individuals loyal to their current food habits. In this case, consumers' needs would change in favour of ERPs. Factors like prices, as well as certification to assure that environment-friendly practices are actually used, may play a relevant role in the consumer's food choice and should be addressed in the policy design. In particular, policies aimed at reducing production costs -- and the current Common Agricultural Policy in the European Union seems to go in this direction -- may help to reduce the price spread between conventional and organic produce.

The cost of public intervention should also be compared to the cost of private initiatives, as those employed by large grocery chains, and to the net social welfare gains in the two cases. Indeed, whenever a particular food safety or environmental policy issue is addressed, a cost-benefit analysis, although partial, aimed at measuring welfare gains for the different categories of economic agents should be provided, but unfortunately only few studies try to do it (Buzby *et al.*, 1995).

One last point regards the fact that both private and public actors have different reasons to promote and differentiate ERPs: producers may find a way to alleviate the

competitive pressure, while institutions want to avoid future environmental and health costs. In order for these two different views to converge, a common path is necessary. A proliferation of standards and certification systems would only confuse consumers, who generally already have problems in evaluating the benefits from ERPs. Moreover, managing costs for harmonised certification systems would be substantially lower. Higher costs and the coexistence of different process standards for the same product definition would clash with consumers' limited WTP and with their difficulties in assessing the benefits from ERPs.

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6. Residential Water Use

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1. Introduction

Although 72% of the earth surface is covered by water, less than 1% of the world's fresh water is directly accessible for human uses. Given humans' water consumption patterns and the world population growth rate, these fresh water reserves have been shrinking all over the world at an alarming rate. There are currently more than 800 million people facing water scarcity and the United Nations project that approximately 2 to 7 billion people will be left without water by 2050; moreover, in the next 20 years, the average global supply of water per person will drop by one-third (see United Nations, 2003 and 2006).

There are essentially two broad issues of concern for policy makers in the analysis of residential water consumption. The first issue relates to water pricing in the absence of environmental considerations, and whether existing prices are reflective of water scarcity as well as marginal costs of production and supply. The second issue relates to water pollution or degrading uses of water (Khan, 2005). Socially optimal pricing of water entails a per-unit price that encompasses the opportunity (or user) cost of water as generated by its scarcity, the marginal cost of producing/supplying water, and the marginal environmental cost of water use. In instances in which water is an exhaustible resource, water pricing requires adjustments over time to reflect the increased water scarcity and thus increased opportunity cost of water use. Socially optimal pricing of water also requires that the social costs and benefits associated with water use be properly measured. And even if an accurate assessment of these costs and benefits is possible, there are often political considerations that prevent water use from being appropriately priced. One such consideration is equity.

The effectiveness of water pricing depends on household responsiveness to price changes. The impact of a price increase on the demand for any good can be decomposed into an income effect and a substitution effect. The income effect results from a decrease in purchasing power (or decrease in real income) following the price increase; the substitution effect results from substitution possibilities which enable consumers to switch from more expensive goods to cheaper alternatives. At low price levels, the income effect of a given percentage change in price will be minimal. However, when the price of water is high, the income effect can be important. In response to a price change, individuals may start using more water-saving technologies or repairing leaks and replacing water-using laws with other paving materials. Appropriate estimation of the

demand for water thus entails that consumers' responses to high price levels (or to significant price increases or price increases at high price levels) be taken into account.

In addition, studies on residential water use conclude that the demand for water at low levels of consumption is inelastic as water has no close substitutes so that the substitution effect is practically next to zero for basic needs. However, when this minimal level of consumption is satisfied, the marginal use of water may be more readily substitutable. As such, price elasticities may increase with consumption levels.

Households' response to water pricing depends not only on the initial price level but also on the pricing structure. In most countries, water supply services are typically financed through a two-part tariff involving a fixed fee and a variable (per-unit) charge. Consumers pay a fixed fee to be connected to water services which is charged, in most cases, to recover the investment cost and to ensure equity. Additionally, consumers pay a charge per unit of water consumed. This additional amount can be non-linear, that is, the cost per additional unit varies when consumption reaches certain thresholds. Thus, in different consumption blocks, the tariff structure has different marginal prices. These block rates can be either increasing or decreasing. In the increasing block-rate scheme, the price goes up for each successive block of water usage; in the decreasing block scheme, the opposite applies. Under the decreasing price structure, consumers tend to use more water; under the increasing block rate, they pay a penalty (in the form of higher price) for overusing water.

When estimating the price elasticity of demand, using only average prices in the presence of a block-rate system produces upward biased estimates. In increasing block-pricing schemes, a quantity of water (first block) is supplied with a fixed nominal fee, beyond which (the second block) the price level goes up. Once consumers move into the second block, they face a higher marginal price (MP) and a higher average price (AP). The increase in AP is however smaller than that in MP as AP includes the lower rate charged for units in the first block.

Concerns over the accuracy of estimates of price effects also exist when only marginal prices are considered and a block-rate system is in place (Howe and Linaweaver, 1967) as the income effects of a change in intra-marginal rates cannot be properly accounted for with constant marginal prices (within each block). The empirical formulation employed in Howe and Linaweaver (1967) allows for the estimation of a price elasticity of demand that includes both the income and substitution effects resulting from a change in the marginal price and a second elasticity measuring the income effect of changes in intra-marginal rates. This second price variable is referred to as the Nordin's difference variable (Nordin, 1976) and is defined as the difference between consumers' actual water bill and the water bill that would result if each unit of water were purchased at the marginal price.[1]

The relationship between marginal and unit prices depends on the level of consumption, whether it is below or above the allowance level (if there is one), and

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1. This "difference" variable and the income variable both measure income effects only. Therefore, in a linear demand equation, their coefficients are expected to be equal in magnitude but opposite in sign.

whether the rate structure is increasing, uniform, or decreasing. The marginal price is zero for consumption up to the allowance level; for the first unit beyond the allowance level (and any additional unit in the first block), the marginal price is equal to the unit price for the first block. For units of consumption above the allowance, the marginal price exceeds, equals, or falls short of the average price, depending on whether the block rate is increasing, uniform, or decreasing.

Besides measures relying on water price increases, other instruments can be used by governments to induce a reduction in residential water use, which are particularly useful when changes are needed in very short periods of time. These non-price policy measures include: restrictions on certain water usages, rationing, public information campaigns, labeling and metering, and subsidies for using water-efficient technology. In several studies that consider these non-price demand management policies, the empirical evidence points to their being highly effective at reducing water demand.

In addition to policy variables, the demand for water use is likely to depend on a host of other factors, including socio-demographic (*e.g.* age, income, type and size of house) and attitudinal characteristics, and responses to a given policy are likely to vary with these characteristics. In light of the increased awareness of the environmental problems associated with water usage and the alarming projections of water scarcity over the next few decades, water-related conservation issues are bound to be high on the policy agenda. For policies to be efficiently and effectively designed, it is then necessary for those involved in policy-making to have an accurate understanding of the factors influencing households' water consumption decisions, the direction and magnitude of influence of each of these factors, and whether the effects of policy incentives tend to be independent of socio-demographic and attitudinal characteristics or are more pronounced in particular segments of the population.

Section 2 provides a review of the empirical literature on residential water use structured around two themes: (2.1) factors determining the demand for water and (2.2) willingness-to-pay for water, which is essential to the estimation of the benefits of water use. In section 3, the policy implications that arise from the discussion of the empirical literature are presented.[2]

2. Literature review

Firstly, the main findings on the determinants of residential water use are presented. Four types of explanatory variables are considered: socio-demographic characteristics, attitudinal factors, pricing policy measures, and non-pricing policy measures. The sub-section on socio-demographic characteristics also includes a discussion about weather variables, whenever applicable. Secondly, the results of the literature reviewed on the willingness-to-pay for water services are summarized.

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2. The results of the studies are summarized in the three tables presented in the related online report, "Household Water Consumption: Summary of Empirical Results", at *http://dx.doi.org/10.1787/482525215830*. Table A.1 gives a summary of the evidence on the policy instruments considered in the literature. Table A.2 summarizes the effects of socio-demographic, weather, attitudinal, and policy variables. Table A.3 provides the price elasticity and income elasticity estimates available to date.

2.1 Determinants of the demand for water use

In the majority of the studies reviewed, the estimation of a water demand function almost always includes some socio-demographic factors and policy variables (either pricing or non-pricing, or both). Questions about the role of attitudes are less frequently examined; this is clearly an area where more research is needed, especially in consideration of the difficulties with relying on incentive-based initiatives (either because of low price elasticities or because of equity concerns).

2.1.1 Socio-demographic characteristics and weather variables

In Headley (1963), the impact of family income on residential water demand is studied on the basis of data from 14 cities in the San Francisco-Oakland metropolitan area. Income is the only variable included in the model as it is thought to be a good proxy for all those factors that induce consumers to demand more water (*e.g.* dishwasher ownership, number of bathrooms). The relationship between the average percentage change in water purchase associated with a given percentage change in the median family income is estimated for 1950 and 1959. The results translate into income elasticity estimates of 1.49 and 1.24, respectively, suggesting that water consumption is very responsive to changes in income. In the analysis of the data over the ten-year period (1950 to 1959), the income elasticity estimate is much lower, although more plausible, with a weighted elasticity for the entire population reported at 0.19, suggesting that a 10% increase in income results in a 2% increase in water use. The study concludes that there is a significant positive relationship between family income and residential water consumption.

In Wong (1972), the demand for municipal water is estimated with data from Chicago and nearby communities over the period from 1951 to 1961. Two analyses are carried out: a time-series analysis involving Chicago and 59 neighboring communities; a cross-sectional analysis involving 103 public water supply systems. In the former analysis, average per-capita municipal water demand is expressed as a function of price per 1 000 gallons, average household income, and average summer temperature; in the latter analysis, temperature is excluded and sample communities are divided into four groups according to size. In both cases, income is found to be a statistically significant variable for Chicago (in the time-series analysis) and for the two largest groups of communities (in the cross-sectional analysis). The time-series model provides a lower estimate of the income elasticity (0.2 for Chicago versus 0.48 in the cross-sectional model); however, income does not seem to have any significant impact on per-capita water consumption in suburban or small communities. Average summer temperature is significant in both suburban and urban centers.

In Nieswiadomy and Molina (1989), the demand for water use is estimated based on microdata time-series (monthly) observations for the same group of consumers facing a decreasing block-rate pricing for the first half of the time series and an increasing block-rate schedule for the second half of the time series. Out of the 60 000 households living in the city of Denton, Texas, 101 consumers are randomly sampled, with their monthly water billing records obtained from the city's water department from 1976 to 1980, under a decreasing block-rate system, and from 1981 to 1985, under an increasing block-rate system. Only summer months are considered; furthermore, the sample data are screened in such a way that the sample only includes houses with lawns and without swimming

pools and owned/occupied by the same families over the entire time period. The model also includes income and weather as explanatory variables. Independently of the type of block-rate pricing scheme in place or of the estimation technique employed, households with higher incomes, bigger houses, and/or bigger lots are found to demand more water; furthermore, the effect of hotter temperatures on water consumption is significant and, as expected, positive.

In Renwick and Archibald (1998), data are collected through various sources (households' monthly utility bills and telephone interviews) to estimate the demand for residential water in two Californian communities, Santa Barbara and Goleta. Aside from policy variables, other variables covered in the study include the size of the household and household income. Results suggest that household size, as expected, has a positive effect on water consumption and that a 10% increase in income leads to a 3.6% increase in water use. The income elasticity estimate is similar to that in Howe and Linaweaver (1967), Jones and Morris (1984), Nieswiadomy (1992), and Renwick *et al.* (1998).[3] Furthermore, income is found to negatively affect households' responsiveness to price changes; in particular, a 10% increase in the price of water leads to a 5.3% reduction in water use for the low-income group, a 2.2% reduction for the moderate- to high-income group, and a 1.1% reduction for the wealthy people. The fact that low-income households are almost 5 times more responsive to price increases than the high-income households suggests a shifting of the financial burden of conservation through higher prices onto low-income households, and thus poses a serious concern for policy makers from an equity point of view.

In Espineira (2000), data are gathered from 132 towns in north-west Spain[4] for the period from 1993 to 1999 to estimate a water demand function that includes average number of members in the household, per-capita disposable income, average monthly temperature, number of days with precipitation in a month, number of water units charged regardless of actual use (in m^3), number of billing periods in a year, percentage of population over age 64, percentage of dwellings regarded as main residence, and a variable, referred to as the Nordin difference, that measures the difference between the total water bill and the water bill that would result from pricing total water use at the marginal price. The estimated coefficient of the "difference" variable used in the model is highly significant and has the expected negative sign, which implies that water is a normal good as confirmed by a positive and statistically significant income elasticity estimate. The estimates of the coefficients of the weather variables (average monthly temperature and number of rainy days in the month) are statistically significant with negative signs, although the magnitude of the estimates is rather low, implying that climatic effects do not play a significant role in determining the demand for water, particularly in the north-west area of Spain. Consistent with *a priori* considerations, a higher ratio of the population above age 64 is found to lead to a lower level of water use whereas the number of houses regarded as main residence is found to have a positive effect. The latter variable captures the impact of tourism, which is particularly relevant in

3. The income elasticity estimate is 0.32 in Howe and Linaweaver, between 0.40 and 0.55, for three different marginal prices, in Jones and Morris, ranging from 0.28 and 0.44 in Nieswiadomy, and 0.25 in Renwick *et al.*

4. Most of these towns employ a tariff schedule consisting of a fixed fee for a minimum allowable quantity and a second block charged at a single rate, or several blocks charged at increasing rates.

the area of interest. The larger the number of holiday residences is, the more water is expected to be consumed during the summer and relatively less in the other seasons. However, this seasonal impact is not detected.

In Nauges and Thomas (2000), data are collected from 116 eastern France communities over the period 1988 to 1993. Water consumption is estimated as a function of average water price, proportion of inhabitants over 60 years old, proportion of households composed of one or two members, average income before tax, population density, proportion of single house units in the community, proportion of houses equipped with a bath, proportion of houses in which the owner owns one or more cars, proportion of housings built before 1949 in the total stock of housings, proportion of housings built after 1982 in the total stock of housings, local community economic activity, and average annual rainfall. In France, 85% of the population is supplied water by private operators; furthermore, residential water users face a two-part tariff scheme whereby they pay a fixed fee for access to the supply of water and a variable fee which depends on water consumption. In determining the price of water, the local authority (municipality) negotiates with private operators for the entire contracting term, and the price depends largely on the expected amount that is to be used by the community, socio-demographic characteristics of the community, and possible pressures by lobbying groups. The price of water is thus not only the result of profit-maximizing considerations by the private operators, but also of negotiations between private operators and the local authority. Based on the estimated coefficients of the various non-policy variables included in the analysis, house age has a positive effect on water consumption as older houses are more prone to leakages, a 10% increase in average taxable income leads to a 1% increase in water use, and communities with more seniors (over 60) and/or with more new (built after 1982) houses require less water.

In Domene and Sauri (2005), a sample of 532 households, from 22 municipalities in the metropolitan region of Barcelona, is utilized to investigate the effects of urbanization and demographic, behavioral, and housing characteristics on water consumption patterns. In Spain, the demand for housing in the suburbs of the main cities has been increasing significantly as a result of a number of social and economic factors such as preferences for single condominium units, prevalence of many single-member families, rising affluence levels, and low interest rates. The urban sprawl experienced by Spain and, in general, southern Europe over the last decade gives rise to important concerns over the environment, as low-density urbanization leads to inefficient use of land and energy, and rapid urbanization causes substantial increases in water consumption.[5] In this study, a telephone survey is administered to collect information from each of the 532 households on water use for both indoor and outdoor activities, socio-economic variables, household characteristics, water fixtures, and total water consumption from their water bills for 2003. Three types of housing are used in the analysis: *i)* high-density housing (apartments in a multistory building), *ii)* mid-density housing (apartment blocks with shared garden

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5. Two important transitions witnessed in MRB are: a declining household size (based on the 2001 census, more than 25% of households are single-member households and more than 50% have two persons or less) and the migration of young couples with children to suburbs.

and swimming pool), and *iii)* low-density housing (condominiums and detached housing).[6]

A descriptive analysis of the data reveals that households differing in income do not exhibit significantly different personal habits of water usage (*e.g.* washing hands, brushing teeth, and flushing toilets). The few cases in which significance can be established include showers, which low-income groups tend to have fewer per week, and water use in general, which tends to be higher among women and lower among older people. In terms of water consumption across the three housing types, high-density households are found to use the least amount of water per household and per capita, with an annual average of 120 litres per person per day, possibly because they have fewer indoor water fixtures and fewer members (households are smaller in size), although there is no statistical difference in water usage between low- and mid-density households; furthermore, 72% of water consumed in high-density households is for personal hygiene (shower, bath, and toilet) and 36% of water consumed in low-density households is for irrigating gardens. As for the results of the estimation of the per-capita demand for daily water consumption, housing type, garden necessities, household size, presence of a swimming pool, income, and consumer attitudes towards water conservation are all significant determinants of water usage. Households living in single-family dwellings tend to consume approximately 36 litres more per day, on average, than those living in multistory buildings because of outdoor use of water; households with fewer members and/or without swimming pools tend to consume less water while those with higher income levels consume more through the use of more water-based appliances. Garden size is not significant but garden design is important.

In Mazzanti and Montini (2006), a municipal panel data set from Emilia-Romagna, Italy, covering the period 1998 to 2001, is used to examine the determinants of the demand for residential water. In addition to the price of water, several socio-economic factors are considered, including income, household size, population age, altitude, and share of rural area. Income and altitude are the only variables found to be significant. Results suggest that water consumption decreases with altitude (as temperature drops) but increases with income. According to estimates, a 10% increase in income causes water use to drop by 5.3 to 6.2%.

2.1.2 Attitudinal characteristics

In Domene and Sauri (2005), a telephone survey is administered to 532 households in the metropolitan region of Barcelona to examine, among other factors, the impact of consumers' attitudes towards water conservation on water consumption. A consumer behaviour index is constructed based upon six conservation practices: installing water-saving devices in taps, toilets, and showers (each of them counted individually), turning off running water while brushing teeth, purchasing water-efficient appliances, and comparing water consumption between periods. The descriptive analysis of the data

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6. Of all the houses in the region, 60% are high-density, 30% are detached or semi-detached, and the rest are apartment blocks with communal garden and swimming pool. In MRB, from 1985 to 2000, 35% of new houses are detached or semi-detached, which means that most of those houses have a garden (considered a symbol of social status). Furthermore, smaller households, with one or two members, are usually found in the metropolitan centers while larger households are more common in the suburban areas.

shows that consumer behaviour does not tend to depend on income, with only one exception being shower use, which high-income groups have more frequently. Attitudes towards water conservation are found to have an effect on water consumption.

In Gilg and Barr (2005), a sample of 1 600 households from Devon, UK, is employed to examine how the behavioral patterns of households affect water demand. The data are gathered through a questionnaire in which consumers are asked about their attitudes towards water consumption and their socio-demographic characteristics. More than half of the sample reports having undertaken water-saving actions (such as turning off the tap while brushing teeth, using shower rather than a bath, waiting until there is a full load before using a washing machine). Based on the data collected, four clusters of individuals are identified: *i)* committed environmentalists, *ii)* mainstream environmentalists, *iii)* occasional environmentalists, and *iv)* non-environmentalists. Committed and mainstream environmentalists have a strong commitment to water-saving behaviour, while occasional environmentalists are much less committed and non-environmentalists never undertake water-conserving behaviour. Results indicate that the mean age of committed environmentalists in the highest while the mean age of non-environmentalists is the lowest. Non-environmentalists have significantly lower income levels while committed and mainstream environmentalists tend to have smaller households.

In Hurd (2006), households' landscape choices are examined based on data from a mail survey implemented in 2004 in three New Mexico cities (Albuquerque, Las Cruces and Santa Fe). Four types of landscapes are identified according to the extent to which water conservation considerations have been incorporated. Households' landscape choice is then expressed as a function of water cost, number of children in the household, level of education, and degree of responsibility towards water conservation, all of which but the number of children have effects that are both significant and consistent with *a priori* expectations. In particular, a sense of moral responsibility towards water conservation is found to significantly induce people to choose water-conserving landscape types.

2.1.3 Pricing policy measures

In Wong (1972), the demand for municipal water is estimated for Chicago and nearby communities with data from 1951 to 1961. The price coefficient estimate is found to be statistically significant for the suburban communities outside Chicago in a time-series model, and for all communities but those in the small-size group in a cross-sectional model. In general, the estimates from the cross-sectional analysis (ranging from -0.26 to -0.82) is higher than that in the time-series analysis (ranging from -0.02 to -0.28). In the latter case, the estimated price coefficient for Chicago is insignificant, which is likely attributable to the extremely low water price (22 cents per 1 000 gallons in 1961); water prices tend to be higher in suburban areas (from 25 cents to USD 1.25 per 1 000 gallons) due to greater distance from water supply and, as such, consumers tend to be more price-sensitive. In the cross-sectional analysis, the higher price elasticity detected in larger and more urbanized communities may also be related to the higher water prices consumers face when they use groundwater as opposed to surface water, which is less expensive to supply.[7] In sum, households living in communities outside Chicago tend to be more

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7. The cross-sectional analysis includes 103 municipal systems all supplied by groundwater; the time-series analysis includes Chicago and 59 nearby communities all supplied by the surface water of Lake Michigan.

price-sensitive and, although the proportion of the total variation in water consumption explained by variation in the explanatory variables included in the model (price, income and, in the time-series analysis, temperature) is low, there is some evidence in support of a differential pricing system as an effective tool for reducing water usage.

In Billings and Agthe (1980), the marginal price elasticity of water demand is estimated for increasing block-rate schemes, based on monthly data from Tucson, Arizona, from January 1974 to September 1977, with different model specifications. The empirical formulation employed in the study allows for the estimation of a price elasticity of demand that includes both the income and substitution effects resulting from a change in the marginal price and a second elasticity (difference elasticity) measuring the income effect of changes in intra-marginal rates. Results indicate that price elasticities range from -0.45 (at 21 cents per 100 cubic feet) to -0.61 (at 42 cents per 100 cubic feet) in a linear specification, consistently with findings in Wong (1972) and Young (1973) for the same geographical area. The difference elasticity of demand is instead estimated to be between -0.12 and -0.14, depending on specification. The estimate of the coefficient of the difference variable has the expected sign but is much larger in magnitude than the estimate of the coefficient of the income variable. Possible explanations for this deviation include: *i)* the difference variable absorbs less than 0.15% of income and may be too small to have any significant impact on consumers' perceptions of income; *ii)* the use of aggregate rather than individual data; *iii)* the use of state-level income data. Finally, a comparison of the results with nominal and real figures for prices and incomes reveals that consumers are more responsive to real changes than to nominal changes.

In Chicoine and Ramamurthy (1986), the appropriateness of including either only marginal prices or average prices in the estimation of the demand for water is tested. The data are gathered from a telephone survey conducted in 1983 and involving 100 households living in 59 rural water districts in Illinois which rely on decreasing block-rate systems. As noted, under a block-pricing schedule, price effects can be accurately captured through the inclusion of a marginal price and a difference variable (also referred to as Nordin difference) that measures the lump-sum income effects embedded in a block-rate system. However, consumers are often unaware of the complexities of block-pricing mechanisms and do not have a clear notion about marginal rates; as a result, they tend to respond to average prices rather than to marginal prices. To test this hypothesis, the demand model employed in this study is an average price model with price decomposed into marginal price and a second variable that is equivalent to the difference between average price and marginal price. Monthly water consumption is estimated as a function of the two price components, number of people in the household, number of bathrooms in the household, and monthly income of the household minus the (Nordin) difference variable. The results suggest that the second price variable has a negative impact on water consumption which implies that consumers tend to respond to average water prices when taking decisions about water usage. At the same time, the hypothesis that the average price model with no marginal price is correctly specified is rejected, so that marginal price is necessary to explain consumers' behaviour towards water usage. Furthermore, a model with marginal price but without average price is unable to explain consumers' decisions concerning water consumption, possibly because water expenses represent a small proportion (around 1.3%) of households' income. The analysis thus points to the importance of including both marginal and average prices in the estimation of water demand.

In Nieswiadomy and Molina (1989), a panel of 101 consumers in the city of Denton, Texas, is observed from 1976 to 1985. A decreasing block-rate pricing in place during the first period to 1980 and an increasing block-rate pricing in place during the second period from 1981. Different estimation procedures are employed and each results into a significant and negative price effect for both pricing schemes; in other words, higher water prices induce lower water usage.[8] When the endogeneity of the price variable is accounted for with the use of appropriate estimation procedures, the estimate of the price coefficient is shown to have the expected sign and to be statistically significant, ranging from -0.36 to -0.86, with the only exception being the decreasing block-rate scheme in one of the models estimated. Consistent with other studies which include the Nordin difference variable, such as Schefter and David (1985)[9] and Chicoine and Ramamurthy (1986), no evidence is detected in support of the proposition in Nordin (1976) that the difference variable capturing the income effects of intra-marginal rates has a negative effect on water consumption, corresponding in magnitude to the effect of an income increase. This insignificance may result from the opaque signal provided by complicated pricing structures and confusing billing procedures or, as proposed in Henson (1984), from the small size of water expenditures relative to consumers' monthly budgets.

In Dandy *et al.* (1997), data from 400 households living in the metropolitan area of Adelaide, South Australia, covering the period 1978 to 1992 are employed in the estimation of water demand. In the area of interest, water is priced on the basis of a two-part tariff system consisting of a fixed charge and a uniform fee for each unit above a free allowance of water usage. The period of study includes the 1991-1992 introduction of a constant allowance of 136 kl of water; prior to 1991-1992, water allocation is computed as a percentage of property value. When consumers use less than the free allowance level, they only pay the fixed charge; their marginal price is zero, so that their water consumption depends on their needs which vary only with climate, household size, and other non-price factors. However, when households consume more than the allowance level, they pay the fixed fee plus the uniform unit rate for each unit of water consumed above the allowance level; their water demand becomes sensitive to the marginal price. Consistent with the utility maximizing framework of decision making (Griffin and Chang, 1990), the results suggest that consumption is influenced by marginal prices and not unit (average) prices.

Because of the presence of the free allowance level, marginal prices and average prices do not coincide in spite of the rate uniformity. Marginal prices are used, together with real property value as a proxy for real income, socio-economic characteristics, and physical variables, in both a static model and a dynamic model of water demand. In the static model, the average household is found to reduce its water usage by 21% in response to the introduction of the constant allowance of 136 kl of water. Furthermore,

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8. The IV and 2SLS price effect estimates are argued to be improvements over the ordinary least square estimates which tend to be understated (negative bias) in the presence of decreasing block-rate pricing and overstated (positive bias) in the presence of increasing block-rate pricing because of simultaneity in the relationship between water consumption and water price (under a block-rate system, the price of water both determines and is determined by consumption) or endogeneity of the price level (the price of water is an endogenous variable as it is a function of consumption).

9. In Schefter and David (1985), estimation results are based on aggregate data from 131 Wisconsin communities which rely on multi-part tariff schedules for water pricing.

consumption above the allowance level is more sensitive to income, climatic variables, and swimming pool ownership than consumption below the allowance level, but as sensitive to household size, number of rooms, and plot size. In general, however, free allowance induces people to consume more water. In the dynamic model, lagged annual consumption of water is added as an explanatory variable and its effect found to be statistically significant, suggesting that consumers tend to respond slowly to changes as substitution possibilities are less immediate when water-using durables (*e.g.* washing machines and dishwashers) are involved. The long-run price elasticity of annual water demand is estimated to be between -0.63 and -0.77, which is higher relative to estimates in other studies possibly because of the fact that almost 50% of water used in Adelaide is for outdoor activities (to water lawns and gardens); correspondingly, outdoor use of water is found to be more price-sensitive than indoor use. A 10% increase in real marginal price thus leads to as much as an 8% decrease in water demand and a 1% increase in revenues.

An interesting result within the dynamic model is that consumers above the allowance level adjust their consumption as the price level increases (and other variables change) more slowly than those below the allowance level. The mean lags for consumption above and below the allowance are 1.710 and 0.923 years, respectively; this makes sense as consumers using more water (that is, above the allowance level) tend to have a larger stock of water-using appliances, the use of which requires more time for adjustment.

In the study by Renwick and Archibald (1998) presented earlier which relies on data from two communities in southern California (Santa Barbara and Goleta), evidence is also provided on the effects of the pricing measures introduced during a period a severe water shortage. In June 1989, Santa Barbara implemented its first pricing policy, moving from a fixed per-unit uniform rate to a moderately increasing block-price schedule and, less than a year later, to a steeply increasing price schedule. In July 1990, the city of Goleta moved from a moderately increasing block-pricing schedule to a relatively high uniform rate. Given the context, the short-run price elasticity of water demand is found to be significant (-0.33), which is consistent with the -0.29 estimate in Berk *et al.* (1980) based on data from three communities in the South Coast of Santa Barbara County,[10] and households' responsiveness to price changes is shown to depend on income.

In Renwick *et al.* (1998), residential water demand is estimated based on data from 8 urban communities in California. The estimation incorporates non-price demand-side management (DSM) policies (such as public education campaigns, rationing, restrictions on certain uses of water like landscape irrigation, and subsidies to promote more water-efficient technologies), in addition to block-pricing schedules, weather variables, and selected socio-economic characteristics. The results suggest that a 10% increase in price reduces water demand by 1.6%, but by up to 2% during the summer months. These estimates are smaller than those in Berk *et al.* (1980), Renwick (1996), and Renwick and Archibald (1998), which range from 2.2% to 3.7%. The reasons for the discrepancy may be the exclusion of DSM policy variables in Berk *et al.* (1980) and the significantly larger ranges of marginal prices in Renwick (1996) and Renwick and Archibald (1998).

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10. This estimate is also comparable to the estimates in Agthe *et al.* (1986), Billings (1987), Moncur (1987), and Nieswiadomy and Molina (1989), which range from -0.27 to -0.52.

In Pint (1999), the empirical analysis entails the estimation of consumers' responses to the substantial water price increases experienced during the California drought from 1987 to 1992. The data set used in the study includes a sample of 599 single-family households from the Alameda County Water District. The pricing system is based on increasing block rates. Different models (heterogeneous-preferences and two-error models) are used to estimate price elasticities[11] and the results suggest that the price elasticity ranges in the summer from -0.04 to -0.20 (at a price of USD 0.60 per cubic feet) to -0.47 (at a price of USD 2.00). In the winter, price elasticities range from -0.07 to -0.33 (for USD 0.60 per cubic feet) to -1.24 (at a price of USD 2.20 per cubic feet). Even though the estimated demand elasticities are low (particularly, within the heterogeneous-preferences model which is considered to predict single-family water use more accurately), the relatively large price increases across the blocks did result in a 16% reduction in residential water demand from 1990 to 1991. These price increases also resulted in an increase in revenue, unlike other Californian water systems that relied upon quantity restrictions to reduce water use and suffered from severe loss in revenue, which ultimately forced them to increase water prices in later periods. One interesting conclusion of this study is that, while previous analyses produce low price elasticity estimates for California (possibly because of small price variations), excessive price hikes render water demand relatively elastic. Thus, people who are relatively irresponsive to price changes can become quite responsive when subjected to large price hikes (beyond the usual pattern).

In Espiñeira (2000), data are collected from 1993 to 1999 in 132 north-west Spain towns to estimate water demand as a function of household size, income, temperature, precipitation in a month, Nordin difference, number of water units charged regardless of actual use (in m^3), number of billing periods in a year, percentage of population over age 64, and percentage of dwellings regarded as main residence. Most communities in the sample rely upon a tariff schedule that consists of a fixed quota with a minimum free allowable quantity and a second block charged at a single rate or several blocks charged at increasing rates. Independently of the estimation procedure employed,[12] the marginal price elasticity is found to be quite small, ranging from -0.12 to -0.16, with statistical significance only in one model. For water usage up to the minimum level, consumers effectively face a marginal price of zero so that water consumption decisions are not affected by price changes. At high levels of water use (beyond the minimum level), the demand for water is however expected to be responsive to price changes as consumers are beyond the free allocation. This is indeed confirmed by the estimates; in fact, when only data on monthly average water use beyond the minimum level are used, the price elasticity of demand is estimated to be approximately double, that is, -0.33. Hence, the study concludes that *i)* over and above the minimum level of water consumption, the demand for water becomes elastic; *ii)* the larger the minimum amount of water that is sold for a given fixed fee, the higher the average use is; *iii)* the more water consumers use, the more responsive to price changes they are; *iv)* at lower tariff rates, consumers are less interested in finding out about the true marginal water price that results from the tariff system; *v)* within the minimum water use level, the average price of water clearly explains the quantity of water demanded; *vi)* beyond the minimum water use level,

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11. The heterogeneous-preferences model results in much less elastic water demand curve than the two-error model.

12. Ordinary least squares, Hausman-Taylor, fixed effects, random effects, and between group estimation.

consumers find it worthwhile to invest time in understanding the tariff system and respond to price signals.

In Dalhuisen (2003), a meta-analysis is carried out in an attempt to explain the empirical variation in the price and income elasticities of residential water demand. The meta-analysis sample consists of 296 price- and 162 income-elasticity estimates of residential water demand from 64 studies over the period 1963 to 2001. An important conclusion of this study is that variation in price and income elasticities is due to differences in the underlying tariff structures. Under an increasing block-rate system, price elasticity estimates tend to be relatively high and income elasticity estimates relatively low. On the other hand, the presence of a decreasing block-rate system does not seem to affect price elasticity but does increase income elasticity. Using average prices, as opposed to marginal prices, inflates both price and income elasticities; the inclusion of the Nordin-difference variable only matters for income elasticity while the adoption of a discrete-choice specification only affects price elasticity. Finally, consumers in higher-income areas have relatively higher price and income elasticities (in absolute terms) and, as also found in OECD (1999), price elasticity estimates tend to be larger (in absolute terms) in Europe than in the United States.

In Nauges and Thomas (2003), water demand is estimated with a time-series (1988 to 1993) data set from 116 French communities in which water services are financed by means of a two-part tariff system involving a fixed connection fee and a price per unit of water consumed. A dynamic model is applied to determine whether current water usage is influenced by past water usage and whether households' adjustments in water consumption in response to price changes are immediate or manifest themselves in the long run. In addition to confirming the positive and significant effect that income has on water consumption, with an income elasticity of 0.51, the study concludes that the long-run price elasticity is about 1.5 times larger than the short-run price elasticity (-0.40 versus -0.26) and, accordingly, that consumers start reducing water usage when they believe that the increase in the price of water is persistent (that is, after a permanent increase in the price). Based on the results, it takes more than one year for consumers to respond to price increases as it takes time to identify the sources of excess water usage and, even when these sources are easily identifiable, it takes time to eliminate them as they relate to the use of durable goods such as dishwashers and swimming pools.

In Espiñeira and Nauges (2004), data from Seville, Spain, covering the 1991 to 1999 period during which a severe drought was experienced, are used to estimate a water demand function and obtain an estimate of the minimum consumption level below which water demand becomes insensitive to price changes.[13] The water price schedule examined in the study consists of a fixed fee and an increasing three-block rate. In addition to the marginal price of water, monthly household water consumption is regressed on virtual income per month,[14] precipitation per month, number of daily hours of supply restrictions applied during the worst drought periods, banned outdoor water usage, and population density. Results suggest that, above the minimum threshold consumption level, water

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13. The minimum consumption level can be thought of as the minimum amount necessary to fulfill essential needs such as drinking, cooking, and personal hygiene.

14. Virtual income is the difference between the average salary and the (Nordin) difference variable. Average salary is used as a proxy for household income.

demand, although inelastic, is responsive to price changes: a 10% price increase reduces water use by 1% (a 10% increase in income has exactly the opposite effect, that is, a 1% increase in water use) and a 9% price increase is equivalent, in terms of its impact on water use, to a daily supply restriction of one hour. Hence, as long as water consumption is above this threshold, both pricing and non-pricing measures can be effective policies; however, once the threshold level is achieved, policy makers should focus more on non-pricing tools.

In Taylor *et al.* (2004), data from 34 Colorado municipal water utilities over a two-year period (1984 to 1985) are employed to determine whether marginal price and/or average price should be used to estimate the demand for water. Water demand is defined on a per-connection basis instead of total sales and assessed according to a number of variables: marginal price and/or average revenue, higher annual temperature, monthly precipitation, annual income, water conservation program, water rate schedules (flat-rate pricing, increasing block pricing, decreasing block pricing, and non-metered fixed monthly fees). Different estimations procedures are used, accounting for the fact that the price level depends on the water consumption level under block-rate systems.[15] With a marginal price specification, the elasticity of water demand is found to vary between -0.3 and -0.2. When average revenue is included in the analysis instead of marginal price, the price elasticity reaches -0.4 because of the fixed monthly fee that is embedded in the average revenue but not in the marginal price.[16] When this fee is removed, the average revenue variable fails to have any significant impact on water demand or its coefficient is estimated to have the wrong sign. Hence, in the presence of fixed fees, a marginal price specification is more appropriate. In general, results suggest that, relative to constant rates, increasing block rates result in less water use, and both decreasing block rates and non-metered fixed monthly fees result in more water use; specifically, the consumption of water is 16% lower, 31% higher, and 83% higher under increasing block, decreasing block, and non-metered fixed rates, respectively, when compared to the water use under constant rates. Independently of the type, a pricing mechanism is, however, more efficient than conservation programs which are found to have no significant impact.

In Cummings *et al.* (2005), 50 public water systems across 28 coastal Georgia counties, each with its own water pricing scheme (mostly, based on a block-rate system), are considered over the period 2003 to 2005. Data for residential water use are obtained through a mail questionnaire that includes questions regarding the physical facility of the water system and the amount of water billed per household in the months of January and July 2002. Based on the data, average monthly use of water per household, price paid by the average household per month, and marginal quantity of water used by the average household are derived for the months of January and July.[17] In the water demand model, marginal water quantity is expressed in terms of three variables: median household income, marginal price (per thousand gallons), and a variable referred to as Nordin

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15. A 2SLS estimation procedure is employed, with both a log-log form and a linear form, and its results compared to and contrasted with the OLS estimation results.

16. When fixed monthly fees represent a substantial component of the total water bill, a specification that includes average revenue creates a bias toward unitary price elasticity.

17. The marginal quantity is the extra amount of water beyond the range of the last block.

difference.[18] While income and the difference variable do not seem to be relevant determinants of water consumption,[19] marginal prices do have some impact which tends to increase as prices increase. Consistent with findings in other studies, water demand is inelastic at low prices and elastic at high prices; specifically, water demand becomes elastic in January for marginal prices above USD 2.33, which applies to only 7% of the sampled water systems, and in July for marginal prices above USD 4.00, which does not apply to any of the sampled water systems. Even if the demand for water is inelastic, at least for a certain price range, pricing mechanisms do affect people's conservation behaviour at the margin while having the additional benefit of increasing the flow of funds going into communal activities, including the management of water systems.

In Domene and Sauri (2005), a sample of 532 households from 22 municipalities in the metropolitan region of Barcelona is observed to examine the effects of urbanization and demographic, behavioral, and housing characteristics on water consumption. Through the inclusion of average price, the analysis also allows for an assessment of the effectiveness of pricing schemes. Although the water pricing mechanism in MRB commonly consists of a fixed service fee plus several increasing blocks, average price is used as opposed to marginal price in light of a number of considerations: *i)* almost half of the interviewed households do not look at the water bill or compare it with previous bills, *ii)* most of customers admit that they do not understand the tariff schedule of their municipality, and *iii)* heterogeneous pricing structures exist in the sample area. Hence, based on the estimation results, average price does not seem to play a significant role in households' decisions over water consumption, a finding that is likely attributable to the fact that expenditures on water represent a negligible proportion (around 1% on average) of the total household budget.

In Olmstead *et al.* (2005), 1 082 households in 11 urban areas covering 16 water utilities across North America (Canada and the United States) are considered in an empirical analysis of the effectiveness of increasing block-rate schedules relative to that of uniform rate structures. With 26 price systems included in the study (8 two-tier increasing block-rate structures, 10 four-tier increasing block-rate schedules, and 8 uniform structures), the price elasticity for households facing an increasing block-rate schedule is estimated to be -0.64 in the context of a discrete choice model; the price elasticity for households facing uniform marginal prices is instead computed to be -0.33 in the context of a panel random effects model. These figures, both of which are statistically significant, suggest that increasing block-rate systems are more effective at reducing residential water demand relative to uniform rate systems.

In the study by Hurd (2006) presented earlier, landscape choices of home-owners are analysed in terms of their impact on residential water demand. The data is based on a mail survey carried out in 2004 in three cities in New Mexico. In cities with high per-capita water use, residential areas are dominated by traditional turf grass landscapes and

18. Variable that measures the difference between the total water bill and the water bill that would result from pricing total water use at the marginal price and that is introduced as a way of accounting for income effects.

19. The estimated coefficient of the difference variable is insignificant for both January and July. The estimated coefficient of medium income is significant for January but, contrary to theory and most of the empirical evidence, it is negative.

hydrophilic landscapes; however, 35% to 70% of current per-capita water can be saved if a traditional bluegrass type landscape is adopted, along with improved outdoor water usage. The results suggest that water costs highly affect landscape choice: the use of traditional water-intensive turf grass increases water use, and thus costs, substantially; therefore, increases in water prices induce households to choose water-saving landscapes. It is estimated that a 1% increase in the water rates will result into a reduction of 2.8% in the likelihood for households to choose a landscape with 100% turf grass. Therefore, it is evident from the study that higher water costs influence the landscape choices of households toward water-saving activities.

In Mazzanti and Montini (2006), the demand for residential water in Emilia-Romagna, northern Italy, is estimated with municipal panel data covering the period 1998 to 2001. In 1994, the region of interest, which enjoys a relatively high per-capita GDP, witnessed the implementation of water reform policies amounting to two basic principles: *i)* that water prices be reflective of long-run costs of water provision and *ii)* that water provision be gradually privatized. One of the immediate results of the water reform was a rise in water prices; for the 125 municipalities considered in the study, the nominal increase in water prices was 8.9% from 1998 to 2001. The basic price structure of water in Emilia-Romagna is an increasing block-rate schedule; however, because of lack of data on marginal prices, the price pertaining to the medium block of the tariff structure is instead used in the analysis. Residential water demand is then expressed as a function of water price, municipal income, and several socio-economic variables (such as household size, population age, density of commercial enterprise, altitude, and share of rural area). Based on the results about the price elasticity of demand, water consumption is very responsive to price changes; in particular, a 10% increase in the price leads to an 11% decrease in water consumption when only income is included in the model and up to a 13% decrease when the other socio-economic variables are controlled for in the analysis. The high (and significant) price elasticity of demand is likely the result of the relatively high water pricing structure in Emilia-Romagna.

2.1.4 Non-pricing policy measures

In Creedy *et al.* (1998), the effect of group metering is examined with household data from Western Australia where most households are metered under a group system. Because of free-riding incentives, group metering is expected to result in more water use than single metering, other things being equal. Free-riding occurs as a result of an inconsistency in how the costs and benefits of an increase in water use are shared among households in the same group; specifically, while the benefits of an increase in water use accrue only to the household using the additional water, the costs are borne by every household in the same group, independently of its water use. This problem causes households to use more water than they would otherwise as, effectively, they face a lower marginal price of water. The evidence gathered in the study does not, however, support the notion of excess water consumption or free-riding under group metering; a possible explanation for this discrepancy between theoretical predictions and empirical findings is that water prices are quite low in the sample and it is therefore difficult to identify the variation in water consumption that is attributable to the effect of free-riding.

In Renwick and Archibald (1998), non-price Demand-Side Management (DSM) (*e.g.* low-flow toilets and showerheads, water-efficient irrigation measures) are examined, together with socio-economic factors and pricing measures, within a residential water

demand model with data from southern California covering the 1985 to 1990 period.[20] For each of the water-efficient technologies considered (low-flow toilets and showerheads, water-efficient irrigation measures), households are found to respond positively, thus adopting the technology, to an increase in the price of water and the presence of more non-price DSM policies. Each of the DSM policies considered is found to be relevant. In response to the allocation and irrigation restriction policies in Goleta and Santa Barbara, the average household is shown to consume 28% and 16% less water, respectively. The use of one low-flow toilet induces households to reduce water use by 10% while the use of one low-flow showerhead results in a decrease in household water consumption of 8%. Water-efficient irrigation technologies reduce water use by 11%; traditional irrigation techniques, on the other hand, increase water usage by 9%. It is evident from the study that DSM policies can be as effective as pricing measures at encouraging households to engage in water conservation. The impact of non-price DSM policies is also found to be linked to density, with stronger negative effects among low-density households with larger landscaped areas or in suburban areas.[21] Consistent with this result, adoption of water-efficient irrigation technologies causes a larger reduction in water consumption among low-density households (31% versus 10% among high-density households). An important conclusion of this study is that the effectiveness of policy instruments, both pricing and non-pricing, is not independent of households' characteristics.

In the study by Renwick *et al.* (1998) presented earlier, data gathered from the 8 urban Californian communities, representing 7.1 million people, are used to examine the impact of demand-side management (DSM) programs. The study considers six types of programmes used during the severe drought from 1985 to 1992 to encourage people to save water: *i)* public information campaigns, *ii)* subsidies for adopting more water-efficient technologies, *iii)* distribution of free retrofit kits, which include a low-flow showerhead, tank displacement devices, and dye tablets for leak detection, *iv)* rationing of water among households, *v)* restriction on certain types of water usage, such as ban on landscape irrigation during peak hours, and *vi)* ensuring compliance with the local water department to certain water conservation steps. In addition to incorporating non-price DSM policies, the econometric model employed in the analysis allows for variables commonly covered in empirical studies of residential water demand, namely, price variables, weather factors, socio-economic characteristics, and lot size.

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20. During the period under consideration, California experienced a severe drought which forced policy makers to experiment with various pricing and non-pricing policies. In 1988, Santa Barbara relied on DSM policies and offered free low-flow showerheads and rebates for the adoption of low-flow toilets. In 1989, the city adopted a moderately increasing block-price schedule and, a year later, a steeply increasing block-price schedule. Furthermore, in 1990, the local authority imposed a strict ban on specific water uses, including landscape irrigation. The City of Goleta also adopted several DSM policies such as rebates for low-flow toilets and free low-flow showerheads. In 1989, it introduced an exceptional "mandatory water allocation" policy whereby water usage was to be allocated across households according to their historical patterns of usage, and excessive usage of water was to be penalized with significant marginal prices. In addition, the District moved from a moderately increasing block-pricing schedule to relatively high uniform rates in 1990.

21. Low-density households own large landscaped areas and thus tend to demand more water so that there is more room for DSM policies to affect their water consumption patterns.

The results suggest that the implementation of public information campaigns and retrofit subsidies is likely to reduce the average monthly household water demand by 8% and 9%, respectively. The use of water rationing and restrictions could reduce the average household water demand by 19% and 29%, respectively (from the mean monthly use). The coefficients associated with stringent policies are larger (in absolute values) than those associated with voluntary measures, implying that restrictions on water usage are more effective at reducing water demand than public information campaigns. On the other hand, rebates for adopting water-efficient technologies and compliance policies are found to be insignificant; most probably because of the problem of aggregating water policies over several heterogeneous water systems, it is difficult to detect any measurable impact of these policies on water use. Non-price DSM policies thus provide a very accessible alternative to price policies, which are also found to be effective. In sum, to achieve moderate reductions in water demand (5% to 15%), modest price increases or voluntary DSM policy mechanisms, such as public information campaigns, can be implemented; for a larger reduction in water demand (above 15%), modest price increases and voluntary DSM policy mechanisms, such as public information campaigns, can be introduced. However, to achieve larger reductions in water demand (greater than 15%), large price increases or more stringent compulsory policy measures (*e.g.* water use restrictions) are better instruments.

In Nauges and Thomas (2000), the demand for water is estimated based on time-series (1988-1993) data from 116 municipalities in eastern France. The study points to a very low price elasticity of demand; specifically, a 10% increase in prices is found to result in a 2.2% decrease in water consumption. Because of this poor responsiveness, non-price policies (such as low-flow equipment promotion, awareness campaigns, and education programs about water conservation) are suggested as better means for inducing consumers to use less water. Furthermore, as those living in individual houses, and thus with access to their own meters, are found to consume less water, generalization of water meters to every household is argued to likely induce more awareness about water use and therefore a more effective management of water bills. This is consistent with the conclusion that individual metering is highly effective at reducing household water consumption by providing consumers with proper signals of increased water prices. Other studies that analyze individual metering report a reduction in water use anywhere from 7% to 35% (Herrington, 1997; Edwards, 1996; Mid-Kent, 1997).

In Espiñeira and Nauges (2004), a water demand function is estimated with data from Seville, Spain, during the period 1991 to 1999, which includes the 1992-1995 drought. One of the main results of the study is that water demand becomes insensitive to price changes below a certain water consumption level (this level can be thought of as the minimum amount necessary to fulfill essential needs such as drinking, cooking, and personal hygiene) so that non-price policies are to be considered whenever this level is reached for further reductions in water use. Two non-price policies are considered in the analysis (bans and supply restrictions), in addition to other commonly included determinants of water use such as the marginal price of water, income, precipitation per month and population density. Bans on outdoor uses are not found to have any significant explanatory power while supply restrictions[22] are significant with a daily supply

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22. Water restrictions of the type applied in Seville as part of emergency measures during the worst drought periods.

restriction of one hour amounting to a reduction in water consumption equivalent to that resulting from a 9% increase in the price of water. The substantial influence that supply restrictions can have on water consumption is an important policy result in light of the fact that, below a certain consumption level, estimated to be around 3 cubic meters per month, households become irresponsive to price increases.

In Gaudin (2006), the question about the relevance of providing clear-cut price information to consumers is explored in a study based on data gathered from the American Water Works Association (AWWA) and household interviews. Per-capita annual water consumption is expressed as a function of average water price, income, average household size, population density, and temperature. To identify the presence of different types of information, two types of variables are used. The first type includes billing features that may influence water demand through price responses (*e.g.* price information variables, quantity information variables, and variables related to other billing aspects). The second type includes billing features that may affect water demand by changing consumer preferences through non-pricing measures (*e.g.* water conservation aspect of water usage, which is not related to prices). Aside from confirming the significance of a number of variables included in most of the empirical analyses of residential water use (income, size, density, rainfall, and temperature), this study finds that the inclusion of information variables has a positive impact on household response to water price increases. Specifically, the presence of information about the marginal price on the bill (next to the consumed quantity) serves to increase (in absolute terms) the price elasticity from -0.37 to -0.51, so that, for a given target reduction in quantity, the required price increase can be 30% lower if price information is appropriately included on the bill (assuming constant elasticity).

In Hurd (2006), the impact of consumer awareness about water conservation is studied in relation to households' choice among four types of landscape differing in their mix between turf grass and water-conserving patterns. Based on the evidence gathered from the analysis of a 2004 mail survey conducted in three New Mexico cities, awareness among the population about water conservation is found to be a powerful tool for reducing residential water demand. A 10% increase in awareness is in fact estimated to increase the likelihood of adopting a landscape fully incorporating water conservation considerations by 13%.

2.2 Welfare impacts

In Woo (1994), the welfare implications of various policies aiming at addressing an extreme water supply shortage are compared. Over the period 1973 to 1990, the Hong Kong Water Supplies Department resorted to three service interruptions to cope with severe droughts. Prior to these interruptions, which applied to all residential and commercial buildings, information was widely advertised in order to mitigate their adverse effects. The welfare loss associated with the water service interruptions is computed[23] based on the results of the estimation of a water consumption model. This model has monthly per-capita water usage expressed as a function of temperature and

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23. The welfare loss computed in this study is based on the Hicksian compensating variation notion which gives the additional income that is necessary after the policy change to restore the level of satisfaction of an individual to its pre-change level.

monthly average price of water, per-capita income and water supply in hours. For the same water use reduction, the welfare loss ensuing from a price increase is also computed. The results suggest that the per-capita welfare loss from a service interruption falls in the range from USD 221 to USD 1 607 per month while the per-capita welfare loss from a price increase, and given the same reduction in water use as under the service interruption, is less than USD 1 per month. It is clear from these figures that service interruptions are very inefficient ways of dealing with water supply shortages. In the presence of water scarcity, pricing instruments seem to allocate resources more efficiently, with a minimal welfare loss.

Of all for the studies on residential water consumption reviewed, that by Hensher *et al.* (2005) is one of the very few concerned with willingness to pay (WTP) for water services. In Hensher *et al.* (2005), households' willingness to pay for assurance that water services are not interrupted is estimated with data gathered through an experiment conducted in 2002 in Canberra, Australia. Based upon the results, consumers are found to be willing to pay for a reduction in the number of water service interruptions and length of interruption experienced each year. The marginal willingness to pay for a reduction in the frequency of interruptions does, however, tend to decrease as the number of interruptions per year increases. If, for example, water supply interruptions usually occur twice a year, the average consumer's marginal willingness to pay for a frequency reduction is 41.5 Australian dollars (AUD) while, with monthly interruptions, the marginal willingness to pay drops to AUD 9.6. Consumers seem to be willing to pay for a reduction in the length of interruption and, interestingly, customers are willing to pay an average of 19% of their current bill to receive advance notice for each interruption.

3. Policy implications

A very important feature of residential water use that most of the articles reviewed share is the estimation of households' responsiveness to increases in water charges as captured by the own-price elasticity of demand. Understanding the extent to which water demand responds to price increases has a fundamental policy dimension that is often not fully explored by policy makers because of equity considerations. Although non-pricing mechanisms do exist for inducing a reduction in water use such as restrictions on certain water usage, rationing, public information campaigns, and subsidies for using water-efficient technologies, pricing structures are viewed as being amongst the most effective means of affecting behaviour. The effectiveness of pricing schemes depends upon the own-price elasticity of demand: the higher the elasticity, the more sensitive consumption is to price changes.

In general, water demand is found to be relatively price inelastic; the lowest estimate of the own-price elasticity in the available literature, from Renwick *et al.* (1998), Pint (1999), Espiñeira (2000), Espiñeira and Nauges (2004), and Strand and Walker (2005), averages -0.10, which implies that a 10 percent increase in water prices yields only a 1 percent decrease in water consumption. There are however studies (Wong, 1972; Nieswiadomy and Molina, 1989; Dandy *et al.* 1997; Pint, 1999; Gaudin, 2006; Mazzanti and Montini, 2006) in which higher estimates averaging at -0.91 are obtained. In Pint (1999) and Mazzanti and Montini (2006), water demand is actually reported to be elastic or very responsive, with a price-elasticity of -1.24 in the former and of -1.33 in the latter.

Although the available evidence seems to point to a relatively price inelastic water demand, the existence of elasticity estimates that suggest otherwise highlights the relevance of the reference price range, that is, the range of prices in the data set being analyzed. In other words, the own-price elasticity of residential water demand is likely to be price-dependent with low figures (in absolute terms) corresponding to low prices and high figures (in absolute terms) correspondingly to high prices. This dependence seems to be confirmed in the study by Cummings *et al.* (2005), in which water demand becomes elastic for marginal prices above $2.33 in January and above $4.00 in July, but warrants further investigation within a framework that allows for much greater price variation than has so far been possible. In Brookshire *et al.* (2002), for example, the difficulty of obtaining an appropriate estimate for the own-price elasticity of residential water demand in a comparative analysis of US cities is attributed to the lack of price variation over the previous 40 years.

Understanding whether and how the own-price elasticity of water demand depends on the price of water has important implications for the design of effective and efficient pricing schemes. For most of the data sets considered in the literature, the pricing structure consists of either a two-part tariff or a block system or both (multi-part tariff). A two-part tariff typically includes a fixed fee, intended for cost recovery and to ensure equity, and some variable fee which may be constant (two-part) or vary across blocks (multi-part). Each block corresponds to a certain range of water consumption and the variable fee may increase or decrease from one block to another. In the absence of the fixed fee, the pricing scheme is more accurately labeled as a block system which can be increasing, decreasing, or uniform depending on whether the variable fee increases, decreases, or remains unchanged from one block to another, respectively.

The effects of different pricing structures on water consumption depend upon household responsiveness to price changes at different levels of consumption. If water demand becomes increasingly more price elastic as consumption increases, increasingly smaller price increases are needed, as households reduce their water consumption moving from one block to another, to induce further reduction in water consumption. An increasing block price system may indeed be the price scheme that is most consistent with the features of the relationship between the price of water and the quantity of water demanded.

In general, increasing block rates are found to be effective at reducing water consumption (Billings and Agthe, 1980; Nieswiadomy and Molina, 1989; Renwick and Archibald, 1998; Pint, 1999; Espiñeira, 2000; Cummings *et al.*, 2005; Strand and Walker, 2005; Mazzanti and Montini, 2006) and, based on the evidence from the one study that permits the comparison (Taylor *et al.*, 2004), appear to perform better than decreasing block rates and non-metered fixed monthly fees by resulting in less water use. Increasing block rates may however be more conducive to inequities as water substitution possibilities may involve, once a certain consumption level is achieved, the adoption of water-saving technologies which are likely to be less accessible to low-income households, unless subsidizing programs are in place. It is indeed out of equity concerns, coupled with the fact that water is an essential commodity, that water prices are typically kept at low levels causing households to overuse and misuse water.

Independently of the pricing scheme adopted, pricing mechanisms to regulate water consumption are deemed to be crucial to ensuring the achievement of environmental,

economic, and social goals which, in turn, help achieve "sustainable development" goals (OECD, 1987; OECD, 1999). Accordingly, in many OECD countries, water reforms have been initiated in support of efficient water pricing based on long-run marginal cost considerations, with annual water prices increasing from 1% to 22% (OECD, 2003). These stark price increases have also triggered questions about "affordability" of water, particularly among low-income households, in response to which many OECD countries, including the United Kingdom, France, Australia, Japan, and Poland, have introduced several support measures (such as direct income assistance from the government, capped tariff rebates and discounts, and payment assistance in the form of easier payment plans). To cite some specific examples, funds are in place at local levels to help write off water debts in France; a social fund, financed through a small levy on water charges, is available for needy households in the Belgian region of Wallonia; discount tariffs are provided in Australia and the United States; charitable trusts are set up by private water utilities to pay off water debts in England and Wales.

As emphasized in OECD (2003), subsidizing water services, thus keeping water prices at low levels (and certainly below the marginal social cost of water provision), may not be the best way of addressing the problems of affordability and equity, which are particularly relevant for water given its essential nature. Water prices do seem to provide households with proper signals and should thus reflect water provision costs. At the same time, however, support measures should be devised to assist needy households. Alternatively, or in conjunction with these measures, free (or low-priced) water allowance levels could be established, as they often are, to ensure that households have access to the amount of water necessary to satisfy basic needs (*e.g.* drinking, cooking, and personal hygiene). Up to this threshold level, households would be quite insensitive to price changes so that pricing mechanisms would not be effective and would have significant welfare implications.

Although some attempt is made in the literature to estimate the minimum threshold level of water consumption (Espiñeira and Nauges, 2004),[24] it is not clear how such a level should be determined and whether factors such as persistent characteristics of the environment and historical water use levels should be considered. One of the first challenges of policy makers is to be able to identify, through a better understanding of households' behaviour in a comparative framework of analysis, the elements that are essential to the setting of the minimum threshold level. As pointed out in Dandy *et al.* (1997), OECD (1999), and Espiñeira (2000), the free (or low-priced) allowance level should be set as low as possible to avoid encouraging consumers to use more water than they would have to fulfill their basic needs.

For water consumption above the minimum threshold level of water consumption, that is, at levels where households become price-sensitive, a pricing mechanism could be devised and supplementary programs could be introduced to alleviate inequality problems resulting from the pricing scheme. In order for both the pricing mechanism and the supplementary programs to be properly designed, it is important to have a good grasp of the effects that income has on water use decisions and of how different households, where differences are identified on the basis of any observable economic or socio-demographic characteristic, respond to water price changes.

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24. The estimate is 2.6 cubic meters per capita per month.

The empirical evidence to date suggests that income is a quite significant determinant of residential water use, with income elasticity estimates ranging from 0.10 to 0.71. As wealthier households tend to rely more heavily upon water-consuming durables (such as dishwashers, washing machines, and swimming pools), they are reasonably expected to consume more water.

A better understanding of the sources of differences in water consumption between low- and high-income households may help identify the particular water uses to target with restrictive instruments. Aside from income, of which the effect on own-price elasticity of water demand deserves further exploration, there are other individual characteristics (*e.g.* household age and size, type of dwelling) that may have an impact on price responsiveness but the available literature does not permit any conclusive statement to be made about this impact. Based on the findings to date, there is some indication, for example, that older households, those living in high-density areas, and those living in multistory buildings tend to use less water but whether these groups are less or more responsive to price changes remains an open, still very relevant, question.

In sum, there seems to be support for pricing instruments as constituting an effective means of encouraging households to reduce their water consumption but, as different households may respond differently to a given price change and these differences are still to be carefully scrutinized, it is not clear what the optimal pricing scheme design would or should look like and which other (non-pricing) policy instruments could be introduced, alongside with the pricing program, to realign any inequality in the distribution of the burden of conservation resulting from the pricing program because of income differences and/or differences in responsiveness to price changes.

Furthermore, for any policy to be effective, households need be fully informed about the policy; in the presence of a block pricing schedule, consumers do not seem to have a clear idea about the different blocks and their corresponding prices so that they often fail to realise the price differences across blocks (Chicoine and Ramamurthy, 1986; Nieswiadomy, 1992; OECD, 1999; Nauges and Thomas, 2000; Taylor *et al.*, 2004; Strand and Walker, 2005; Gaudin, 2006). In Gaudin (2006), the presence of marginal price information on the water bill, next to the water consumption figure, is estimated to result into a price elasticity increase (in absolute terms) from -0.37 to -0.51; correspondingly, for a given water use reduction target, the required price increase, under a constant price elasticity assumption, can be 30% lower when proper price information is included on the water bill. For this same reason, that is, to ensure that households see differences in water prices and act accordingly, individual metering can be quite beneficial; several studies do indeed point to the conclusion that individual metering can induce substantial reduction in water consumption, anywhere from 7% to 35%, by allowing households to fully realize the price signal for reducing their water demand (*e.g.* Edwards, 1996; Herrington, 1997; Mid-Kent, 1997; OECD, 1999; Nauges and Thomas, 2000). Many OECD countries (including Germany, Belgium, France, and the United Kingdom) have moved to individual metering systems to ensure that households have access to their own water bills, which, in turn, allow them to more accurately decide about their water usage levels.

Among the various non-pricing policies that are considered in the empirical residential water use literature (public information campaigns, subsidies for households to adopt water–efficient technologies, free distribution of water-saving devices such as low flow showerheads and toilets, rationing of water among households, restrictions on certain

types of water usage such as a ban on landscape irrigation during peak hours, and mandatory installation of several water-saving systems) and that policy makers are becoming increasingly interested in, particularly in the presence of stark water scarcity and when substantial water demand reductions are required in short periods of time, restrictive measures (water rationing and water use restrictions) are shown to be more effective at reducing water consumption than voluntary measures (public information campaigns). Restrictive measures are also found to be quite effective relative to pricing measures: in Espiñeira and Nauges (2004), for example, a one-hour restriction of water supply per day has an impact on water consumption equivalent to that of a 9% increase in the price of water; in Renwick *et al.* (1998), restrictive policies perform better than pricing policies for reductions in water use above 15%. While, on the benefit side, there may be valid arguments for supporting either pricing or restrictive measures, it is not clear that the two types of policies compare in terms of welfare loss. In Woo (1994), in fact, which is the only study to date that attempts to derive the welfare implications of various policies, the welfare loss, which is computed as the additional income necessary to restore an individual's level of satisfaction to its pre-policy level, is estimated to be, in the presence of restrictive water supply policies, approximately 900 times larger than that under pricing policies. With such a large welfare loss gap, restrictive policies may not be reasonable substitutes for pricing instruments, although they may be opted for in conjunction with pricing instruments to alleviate the potential side-effects of higher water prices or when immediate water use reductions are sought as, based on findings in a couple of studies (Dandy *et al.,* 1997; Nauges and Thomas, 2003), it takes households time to adjust their consumption decisions in response to price changes (long-run own-price elasticity tends to be larger, in absolute terms, than its short-run counterpart).

Of other non-pricing policies considered in the literature, low flow showerheads and low flow toilets can have a substantial impact on water use; the adoption of one of each of the two systems translates, in Renwick and Archibald (1998), into a water use reduction of 8% and 10%, respectively, thus suggesting that free distribution of water-saving technologies or programs that provide rebates to households investing in water-saving technologies can be quite effective. Furthermore, as owning lawns increases residential water consumption (Nieswiadomy and Molina, 1989; Dandy *et al.*, 1997; Renwick *et al.*, 1998; Domene and Sauri, 2005), landscape irrigation restriction policies can have significant effects on water demand in low-density areas where households tend to have bigger landscaped areas (Renwick *et al.*, 1998; Renwick and Archibald, 1998). The type of landscape can also affect households' water consumption (Domene and Sauri, 2005; Hurd, 2006): the "Atlantic garden," planted with turf grass, is, for example, more water-demanding than other landscaping techniques and city planners can rely upon public campaigns to ensure that households are made fully aware of the negative effects of turf grass landscape (in Hurd, 2006, a 10% increase in awareness is found to lead to a substantial increase in the likelihood of adopting landscape types with less turf grass).

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7. Conclusions and Policy Implications

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The results of this empirical review of the drivers of environmental behaviour can inform policymakers on how best to design environmental policies targeted at: reducing waste generation and increasing recycling levels; reducing environmental impacts arising from personal transport choices and residential energy use; supporting organic food consumption; and reducing residential water use. What broader policy lessons can be learned from those findings?

This concluding paper first presents the main factors influencing household behaviour in these five policy areas, which are of particular concern to decision-makers given their environmental significance (Section 1). General policy implications are then discussed in Section 2. Lastly, Section 3 highlights the limits of existing studies to inform policy makers, and suggests the way forward for filling the gaps with new work.

1. Factors influencing household consumption and behaviour: main empirical findings

Aside from analysing the effects of various policy instruments on households' behaviour, the empirical literature examines the role of socio-demographic, attitudinal, and contextual characteristics on household decisions over waste generation and recycling, transport choices, energy use, organic food consumption and water use.

1.1 Factors influencing waste generation and recycling

The effect of policy instruments

Dealing with municipal solid waste remains an important policy concern in OECD countries, and some governments have started introducing economic incentives such as unit-based pricing to limit waste disposal. Governments have also turned their attention to recycling programmes, information campaigns and regulatory approaches (*e.g.* bans on non-returnable containers) as a means of reducing the amount of waste generated and diverting some material for recycling.

The literature on waste generation and recycling mainly focuses on the effects of unit pricing, where households pay according to the amount of waste put out for collection. In general, studies conclude that a unit-based fee is effective at reducing waste and/or at

increasing recycling, compared to no fee or to a fixed fee with which generating an additional bag of garbage entails no cost for the household. There is evidence that unit pricing yields the benefits predicted on theoretical grounds (Kinnaman, 2006). In terms of the relative performance of the various unit pricing systems, there is some indication that a volume-based system[1] tends to provide households with stronger incentives than a system where households contract for a specified volume of waste to be picked up at given intervals (subscription programme). The empirical literature is limited on the effects of other types of unit pricing on waste generation and recycling. The few studies which compare the incentives provided to households in volume- and weight-based programs stress the risk of household engaging in "stomping" to reduce waste volume in the volume-based system (Fullerton and Kinnaman, 1996).

Deposit-refund systems are another policy instrument available to policy makers. By attaching a deposit to products (*e.g.* lead-acid batteries, containers) and refunding it after the products are returned, deposit-refund systems provide an incentive to households to divert recyclable and hazardous items from the waste stream. When compared to a waste fee, refundable deposit systems allow policy makers to tax consumption goods according to their potential environmental impacts, and to internalize the costs of illegal forms of disposal. Despite the extensive theoretical work supporting the implementation of refundable deposit systems, very little is known about the impact of such a policy on households' waste disposal and recycling activities.

Municipalities also often implement recycling programmes as a means of diverting waste from landfills. Various waste separation services, door-to-door or drop-off programmes, can be provided to households to reduce the time and inconvenience costs associated with recycling. Findings here suggest that municipalities with recycling programs tend to have higher recycling rates but not necessarily for every type of recyclable material. The few studies that look at the performance of a curbside collection (door-to-door), relative to drop-off centres, conclude that recycling rates tend to increase as collection is made more accessible. In general, households are found to respond favourably to initiatives intended to reduce sorting time (*e.g.* by combining recyclables) and to increased collection frequency. Lastly, it is not clear whether (or how) households' decisions over recycling are affected by the implementation of a mandatory recycling scheme, independently of whether unit pricing for waste collection is in place or not. In addition, the available evidence suggests that curbside recycling is more effective if combined with unit pricing, and vice versa.

The importance of the provision of information to households is supported by empirical findings in a number of studies that look at the impact of knowledge about waste management options and environmental awareness. Information about recycling programs appears to have a positive effect on whether households recycle or not. Educational programmes may serve to change people's perception about the difficulties related to recycling which emerge as important determinants of recycling efforts.

Most studies examine the impact of unit pricing on waste disposal and/or recycling. Very few of them address the question of source reduction or the effect on consumption

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1. For instance, bag or tag programmes require households to either purchase specific waste bags or stickers to fix on their own containers.

patterns. The literature tends to overlook the issue of illegal dumping, although it is often thought to be one of the major adverse side-effects of unit pricing for waste collection.

Differences in households' responses

The literature review suggests that waste generation and recycling activities vary across different segments of the population. Among the characteristics analyzed, income, household size and composition, education, age, and home ownership are almost always found to be significant. However, their influence varies according to whether waste generation or recycling is considered, and the type of material recycled (*e.g.* glass or paper).

The impact of income on waste disposal and recycling is well documented. High-income households tend to dispose of more waste and demand more collection services than low-income households. Findings are less conclusive concerning the effect of income on recycling activities but, in general, recycling decreases with income for selected materials. This may be due to the fact that, as income raises, the value of time increases, making recycling more costly.

Evidence suggests that user charges may be regressive in the sense that low-income households would pay a greater proportion of their income in waste collection charges than do higher income households. However, to determine the distributional effects of measures implemented to limit waste generation, such as unit pricing, policy makers need to take account of both monetary cost and the value of time spent to sort and recycle material, which varies with income. Furthermore, low-income households are more likely to live in multi-family dwellings which are often excluded from unit-pricing, as the benefits in terms of scale economies from the use of common waste containers outweigh the inefficiencies from flat charges.

In general, demand for unsorted waste collection services increases with household size, while the effect of the size of the family seems to have a greater impact for some recyclable materials than others (*e.g.* glass). The literature also reports that recycling efforts tend to increase with education and age. Density appears to have a significant and negative effect on unsorted waste, and the evidence suggests that home owners tend to recycle more.

The role of attitudes and values is more rarely examined in the literature but some findings stress the influence of environmental awareness on recycling behaviour (Guérin *et al.*, 2001). The few studies available on the role of norms also indicate that both moral norms (the wish to increase self-respect) and social norms (the desire to increase respect in the community) can influence recycling decisions (Halvorsen, 2008; Do Valle *et al.*, 2005). Recycling seems to provide benefits to households who are willing to pay to be able to recycle materials (Kinnaman, 2006). The presence of moral motives for recycling is also captured by the willingness-to-pay (WTP) for leaving the recycling to others, which tends to be lower than the time cost of recycling. The literature suggests that public intervention can either strengthen or weaken these norms, and discusses possible sources of "crowding-out" effects which could induce households to reduce recycling efforts like the introduction of economic incentives in the form of differentiated garbage fees (Thogersen, 1994) or the perception of recycling as mandatory.

Most studies assess the impact of unit pricing systems on waste generation and recycling with a focus on volume-based charging. Important policy questions deserving further analysis include:

(i)   the comparative effects of various types of unit pricing systems on household behaviour using a similar methodology (to assess weight- and volume-based systems). The fact that pricing waste by weight eliminates the incentive to compact waste and that a weight-based system can be significantly more costly to administer would need to be taken into account.

(ii) whether the introduction of a deposit-refund system has significant effects on waste disposal and recycling.

(iii) to what extent recycling programmes induce households to increase recycling.

(iv) an improved understanding of illegal dumping would also help policy makers better estimate the effectiveness of user charges at reducing total waste.

(v)   more insights on the effects of policies on source reduction and/or shifts in consumption patterns in favour of less waste-intensive goods would be useful.

1.2 Factors influencing personal transport choices

The literature review suggests that different dimensions of personal transport demand are interrelated. When evaluating the impact of transport policies, decision-makers should therefore consider the interactions between the vehicle ownership decision, vehicle choice, and distance travelled by the different modes.

The effect of policy instruments

Governments use four broad types of environmental policies to influence personal transport demand: pricing measures (*e.g.* fuel taxes, congestion charges, clean car tax incentives); regulatory measures (*e.g.* emission standards, parking restrictions); information (*e.g.* information campaigns, car labelling); and investments in transport services (*e.g.* bus, cycling lanes) or alternative fuel car technologies (*e.g.* hybrid vehicles).

Among the policy measures considered in the empirical literature on personal travel, the effect of economic instruments is well documented. Evidence suggests that taxes and subsidies have an effect on fuel consumption and mode choice, albeit a limited one. Fuel taxes tend to reduce fuel use, but the effects on car use are found to be much smaller, as households adjust to the cost increase of fuel by buying more fuel-efficient cars. Induced vehicle use that results from increased fuel efficiency limits the effect of the tax.

Taxes on the fixed costs of driving (*e.g.* car purchase tax) are also found to reduce fuel consumption and total car use, but to a lesser extent than taxes which depend on the amount of driving. While car ownership will be reduced, the average age of the car fleet will increase, resulting in more pollution. A differentiated tax or a subsidy encouraging the purchase of cleaner vehicles appears to have a significant effect when sufficiently large. Road pricing and congestion charges can also encourage the use of more environmentally-friendly vehicles, by providing reduced charges for such vehicles.

Evidence points to sharp differences in the adjustment of households to transport policy measures in the short run and long run. In the first instance, the means of response of a household to the introduction of fuel-related taxes is limited to reducing the use of motor vehicles (*e.g.* cutting out non-essential trips). However, in the medium run, households may change vehicle and/or travel mode. In the longer run, individuals may decide to adapt to the increased costs of motoring by changing their place of residence and/or employment. While most of these factors cannot be directly influenced by public policy, other factors which influence household behaviour are subject to policy levers like the improvement of public transportation. Thus, some studies suggest that the effect of fuel taxes on fuel use and kilometres driven can be as much as three times greater in the long run than in the short run. A similar time lag exists when introducing other types of policies like regulatory measures (*e.g.* parking restrictions).

The effect of regulatory measures on household behaviour is less well documented than the impact of economic or pricing incentives. The US Corporate Average Fuel Economy (CAFE) standard[2] has received some attention in the literature, with apparently mixed results on its effectiveness at achieving fuel consumption reduction. Few studies examine measures taken to reduce air pollution at the local level such as parking restrictions, car-free residential areas and traffic restraints. Such measures are found to reduce car use (and emissions) in the area of concern, but to have small effects on total car use and travel. Conversely, land-use measures seem to have substantial effects on both total car use and travel, although there is little reliable empirical evidence on individual preferences over land-use options.

The effectiveness of the different public policy instruments reviewed above on vehicle use or mode choice will however vary, depending on the possibilities of using alternative transport options (*e.g.* buses, cycling paths). When considering the provision of public transport services, there is evidence that subsidizing public transport fares can have a substantial effect on both bus and rail use, in the long run. Empirical evidence on the ability of this type of measure to attract car users to public transport, as opposed to increasing the travels of current users or diverting individuals from other modes (*e.g.* walking, cycling), is however ambiguous and more research is needed. The quality of public transport is found to be as important as relative prices in determining public transport use, so that improving the frequency, reliability and convenience of public transport is essential.

Different policy measures can be compared in terms of their effectiveness in changing personal transport choices. However, the efficacy of public policies in changing the individual's travel behaviour in an environmentally-benign manner will depend on a number of factors such as: socio-demographic characteristics, area of residence, and personal values with respect to the environment.

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2. According to the CAFE standard, each car manufacturer is required to meet a sales-weighted average fuel economy of 27.5 miles per gallon (mpg).

Differences in households' responses

The literature also underlines the role of different household characteristics in determining transport choices. These include age, gender, household size, location and income.

Results suggest that the travel behaviour of women, the young, the elderly, the less educated, those living in urban areas and those with lower incomes is more environmentally friendly, in the sense that such groups travel less, and particularly less by car. However, this difference is not necessarily a consequence of conscious environmental choice, but rather primarily reflects differences in their transport needs and the options available to different individuals. Similar patterns are noted for car choice: women, the young, those with lower incomes and those living in urban areas are more likely to drive smaller and more fuel-efficient cars and are more likely to be favourable to the choice of environmentally-friendly vehicles.

The literature documents quite extensively the role of income as a determinant of personal transport demand. Understanding how household income level affects travel choices is valuable for policy makers to assess the distributional implications of different policy measures. Fuel taxation is found to be progressive up to the middle income levels, but when only households with cars are considered, results suggest that such a tax is regressive across all income levels. Other studies point to the positive distributional effects of a tax on car purchases, while a subsidy on a new fuel-efficient car is found to be regressive, given that high-income households are more likely to buy new vehicles. Higher vehicle registration fees for more polluting cars are most burdensome for middle-income individuals. A uniform tax on mileage that does not distinguish between cars appears to be less regressive than an emissions tax (West, 2004). As for public transport pricing policies, subsidies generally appear to be progressive (*e.g.* for bus transport). In most cases, road pricing is also found to be regressive as low-income individuals and part-time workers who use tolled roads tend to have shorter distances to travel and thus pay a larger proportion of their incomes on tolls.

The nature of the distributional effects also hinges upon whether or not a revenue is generated by the instrument being implemented (*e.g.* taxes *vs.* parking restrictions), and how this revenue is recycled to the economy. Results indicate for instance that a fuel tax is highly regressive under income-based recycling (Bento *et al.,* 2005). Distributional impacts may vary between the short and longer term. Individuals' responsiveness to price changes tends to increase over time as more adjustment options become available to them. Whether this change translates into a change in how the burden of taxation is distributed across individuals depends upon whether the responsiveness to price changes for the taxed transport good or service varies across different groups. Individuals living in urban areas are, for instance, found to be twice as responsive to car price changes and fuel price changes as those living in rural areas (Dargay, 2005).

In general, more subjective characteristics such as values and environmental concerns are found to be weakly related to household transport choices. Various studies suggest that transport behaviour can be indirectly affected by attitudes and both social[3] and

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3. Ajzen (1985) defines social norms as "perceived social pressure to engage in the behaviour, based on beliefs about the expectations of relevant reference groups concerning the behaviour".

personal (*e.g.* feeling of moral obligation) norms. The use of public transport means instead of the car appears to be related to norms (Bamberg *et al.*, 2007). While many studies find that individuals who claim to be concerned about the environment (*e.g.* women, younger individuals, high-income and high-education groups) often indicate that they intend to purchase more environmentally-friendly vehicles, there is limited evidence that they actually do so. Further investigation would be necessary to determine if intended behaviour is reflected in actual behaviour but, since few individuals use alternative-fuel vehicles, empirical data analysis is problematic. The literature also underlines the role of non-rational motives such as affective and symbolic aspects (status and power) of car use (Gatersleben, 2007). For this reason, the willingness to pay for using a car may be high and the effect of taxation limited.

The literature on personal transport demand mainly assesses the impact of fuel taxes. Greater insights on the effect of other policy instruments available to governments could be useful to policy makers to help them design effective and efficient policies targeting personal transport demand, while addressing distributional concerns gained. These include: the impact of congestions charges and the role of car labelling.

In addition, a better understanding of the determinants of alternative-fuel vehicle demand (*e.g.* electric, hybrid) (Knockaert, 2005; Ramjerdi and Rand, 1999) would provide useful insights to policy makers for the evaluation of the impacts of different incentive schemes to encourage the demand for clean fuel vehicles. Better understanding the relationship between attitudes (*e.g.* environmental sensitivity) and household transport demand would also be useful.

1.3 Factors influencing residential energy use

The effect of policy instruments

The empirical studies reviewed here on residential energy use examine the effects of a broad range of instruments. These include energy taxes, energy efficiency labelling of appliances and buildings, energy conservation grants and energy efficiency standards. Lessons which can be drawn are summarized below.

From an efficiency point of view, energy taxes are preferred. The impact of energy taxes is well documented and the evidence suggests that individuals respond to energy price increases. Demand for energy is, however, quiet price-inelastic and there is some consensus on the short-run price-elasticity being about 0.3. As energy is needed in support of the consumption of capital goods (*e.g.* air-coolers and dish-washers), the demand for energy is essentially a derived demand. Consequently, and in light of the fact that capital goods cannot be easily replaced in the short run, individuals are more responsive to energy prices in the longer run. An important implication of the dynamic nature of the demand for energy is that it takes time for policies to become effective, and future expectations are important. Furthermore, responsiveness to price changes depends on substitution possibilities (*e.g.* adopting cost-effective heating technology), which tend to vary across households according to individual characteristics such as income, household size and location. The evidence also suggests that energy taxes raise distributional concerns that need to be addressed when designing policies.

According to the studies reviewed, energy efficiency standards which are adopted on several appliances (*e.g.* refrigerators, washing machines) tend to be cost-effective at reducing energy use. The effects on behaviour of energy-efficiency labels, which are quite widespread (particularly, for home appliances), remain unclear. The evidence also suggests that energy conservation grants are quite effective. The main findings on thermal efficiency standards point to a reduction in space heating demand.

In sum, none of the policy instruments reviewed can be defined as superior or inferior, although there is some indication that information-based options (*e.g.* labels) are not very effective, particularly if used in isolation. The question of which policy (or which policy package) to consider requires that the policy objectives be clearly identified. If an incremental efficiency improvement in energy use is sought, then moderate adjustments in standards, along with incentives to purchase more efficient equipment, may be sufficient and appropriate, based on the insights about behaviour and choice available to date. However, if the objective is to maximize the reduction in energy use over a reasonable timeframe, a wider range of policy options must be considered and a deeper understanding of behaviour and choice, which draws from various disciplinary perspectives, is needed.

Differences in households' responses

Even though it is widely documented that energy savings can be achieved through environmental policies targeted at households, and through technological advancements, energy consumption also depends upon individuals' socio-demographic and attitudinal characteristics.

Studies indicate that the household's income level influences both consumer durable goods purchasing decisions and the demand for residential energy. Although the link between the demand for energy and income is sometimes unclear, the evidence suggests that energy consumption increases with income. Estimates of income elasticity tend to vary depending on the characteristics of the data collected and the methodology used, so relying upon average elasticities when trying to estimate responses to income changes may be quite misleading. Little responsiveness to income changes is also detected when the focus of analysis is the demand for electricity, and when heating expenditures represent a significant component of the demand for energy. Given the role played by income in determining residential energy consumption, distributional impacts constitute a significant policy concern.

Empirical studies broadly agree on the relationship between other household characteristics, such as age or household composition, and residential energy use. The effect of an aging population tends to increase energy demand. The impact of household size on consumption is, however, less clear. Other variables which appear to be relevant in explaining household behaviour include dwelling characteristics (*e.g.* apartment *vs.* detached house), as well as status on the property market (landlord *vs.* tenant).

When examined, the effects of attitudinal variables on residential energy use are found, for the most part, to be weak. However, some recent studies suggest that attitudes

play a much greater role in households' energy conservation behaviour[4] (*e.g.* civic concerns) and in the adoption of "green energy" by residential users (environmental awareness).

1.4 Factors influencing the demand for organic food consumption

The effect of policy instruments

When making choices about environmentally-friendly food products, such as organic food, it is important to recognise that some dimensions of product quality are only detectable after consumption (*e.g.* the taste) while other attributes, like environmental aspects, remain unknown to the individuals even after consumption. For goods with "credence" characteristics, in contract to "experience" goods, the utility cannot be exactly determined even after consumption. This characteristic of products creates a situation of asymmetric information between the consumer and the producer. Consumers will therefore tend to buy lower quality products than they would in the presence of perfect information. To address this information problem, and to help the market function better, governments can use information-based instruments such as organic food labelling, which generally signals that organic agricultural practices are followed in the production process, and public information campaigns.

The studies reviewed here indicate that the effectiveness of labelling depends on how reliable the certification system is at assuring that the practices adopted at the farm level are in line with the claims made on the label. Consumers are expected to have greater trust in certification when it is regulated by governments rather than by private organisms; governments can help by standardizing the definition of "organic" and ensuring consistency in standards, in addition to having the power to prosecute violators under criminal laws. On the other hand, the proliferation of standards and certification systems may confuse consumers who already have difficulty in evaluating the benefits of environmentally responsive products. The variability of findings in studies that attempt to estimate the impact of various labels/certifications on the purchase of organic and other environmentally-responsive products suggests that these signals interact with several other factors, including the level of understanding and the overlapping of different labels and certifications.

The main focus of policies concerning organic food seems to be targeted at information asymmetry problems to ensure delivery and reliability of information on environmental aspects. However, environmentally-friendly food products have both public and private benefits. In addition to the public benefits which relate to the expected positive environmental effects compared to conventional products, these food products are expected to have a positive effect on health (*e.g.* lower pesticide use).

Moreover, the literature indicates that consumers care more about personal health than the environment when choosing organic food over conventional food. The literature on the demand for environmentally responsive products (specifically, organic products) lacks a deeper analysis of the inter relation between public and private benefits, as well as

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4. For instance, recent analysis suggests that energy demand reduction that followed the 2001 crisis in California was triggered by changes in behaviour caused by civic concerns and altruistic motives, rather than by responses to price increases.

a review of the effect of a wider range of policies, particularly in relation to the public benefits organic products are believed to provide.

Differences in households' responses

Aside from policy measures, the determinants of the demand for organic food include socio-demographic characteristics, such as income, age and attitudinal and behavioural variables (*e.g.* environmental concerns).

The literature suggests that age has a negative effect on organic food consumption, possibly because older people are less concerned about health risks. Gender also has a significant effect - with female consumers preferring organic food and showing a higher willingness to pay. Household size is generally found to have a negative effect on the consumption of environmentally-responsive products, because disposable income per person tends to be lower in larger households. The presence of children has contrasting effects: positive if the concern for safety dominates, and negative if the budget constraint is a priority. The probability of buying organic food (relative to conventional food) seems to be higher with children below 18 years of age. In general, individuals with higher income levels tend to be more oriented towards environmentally responsive products. The effect of education is unclear.

Among attitudinal and behavioural variables considered in the literature, the most relevant ones relate to the environmental impact and the health risk of food consumption. The literature review suggests that emphasising health aspects in information campaigns to promote organic food consumption could be more effective than focussing only on environmental concerns.

In the literature on the determinants of organic food consumption, important policy questions to be further examined include: (i) whether consumers buying environmentally responsible products do so out of health concerns or because they care about environmental preservation; (ii) the impact of organic food labels on household decisions; (iii) whether consumers who seem interested in buying organic products choose not to buy them because their price level is perceived to be too high.

1.5 Factors influencing residential water use

The effect of policy instruments

The policy instruments available to governments to influence residential water demand range from water pricing structures (*e.g.* fixed rate *vs.* increasing block tariff) or grants for using water-efficient technologies, to non-pricing mechanisms (such as water restrictions), water efficiency standards for appliances or information campaigns, and water efficiency labelling. The nature of water-related services provided to households can also have an impact on water demand at home (*e.g.* metering of water consumption *vs.* unmetered water supply).

Pricing structures are viewed as being among the most effective means of affecting behaviour and an abundant literature examines the impact of different pricing structures on residential water consumption. In general, increasing block rates, where the variable fee increases from one block to another, are found to be effective at reducing water consumption. In the scarce evidence which allows for comparison between different

water pricing systems, this approach appears to result in less water use than non-metered fixed monthly fees and decreasing block rates (Taylor *et al.*, 2004). Increasing block rates may however be inequitable, which is of particular concern to policy makers.

The evidence on households' responsiveness to increases in water charges, as captured by the price elasticity of demand, points to a relatively price inelastic water demand. The lowest estimates in the literature average at -0.1, which implies that a 10 percent increase in water prices yields only a 1 percent decrease in water consumption. There are, however, some studies suggesting a greater responsiveness to price changes (more than a 10 percent decrease in water use). This variation in the results highlights, in particular, the impact of the reference price of water on households' behaviour. Water demand tends to be relatively irresponsive to water price increases at low prices; however, it becomes more elastic at high water prices, so that the effect of a price increase is likely to be greater for marginal water prices above a certain level.

The results also suggest that household responsiveness to price changes varies with water consumption levels. Water demand is found to become insensitive to price changes below a certain level of consumption, corresponding to essential needs such as drinking, cooking and personal hygiene (Espiñeira and Nauges, 2004). In addition, water price elasticity tends to vary with income (see discussion below).

There can also be significant differences between the short-term and the long-term reaction to water price changes, as households may need some time to adjust their consumption decisions in response to price increases (*e.g.* investments in water efficient appliances). Some studies conclude that it takes more than a year for consumers to change behaviour after a permanent price increase (Nauges and Thomas, 2003). Recent analysis suggests that the response to a price change could be up to 5 times greater in the long term than in the short term (Martínez-Espiñeira, 2007).

Among the various non-pricing policies considered in the literature, restrictive measures such as restrictions on certain water use (*e.g.* landscape irrigation) are shown to be more effective at reducing water consumption than voluntary measures like public information campaigns. Restrictions also appear to be quite effective relative to pricing measures. This is particularly the case in the presence of stark water scarcity and when substantial water demand reductions are required in short periods of time. Some results indicate that a one-hour restriction of water supply per day has an impact on water consumption equivalent to that of a 9 percent increase in the price of water (Espiñeira and Nauges, 2004). However, restrictive water supply policies may entail significant welfare losses that need to be taken into account by decision-makers when designing policies (Nauges and Thomas, 2003).

Among other non-pricing policies considered in the literature, the installation of water-saving devices (*e.g.* low-flow showerheads and toilets) is found to have a substantial impact on water use. Some results indicate that the adoption of these systems translates into water savings of up to 9 percent (Renwick and Archibald, 1998), suggesting that free distribution of water-saving technologies or programs that provide rebates to households investing in water-saving technologies can be quite effective.

The literature also points to the significance of information issues in policies targeting reductions in water demand. In addition to the provision of information to consumers on

the volume consumed, evidence suggests that the clarity of the price signal matters. The inclusion of proper price information on water bills could significantly increase the effectiveness of water pricing as consumers seem to have an unclear idea about the different blocks and price differences across blocks. For this reason, households appear to react to the average price of water, rather than to the marginal price. Recent analysis suggests that if proper price information is included on the water bill (price of the final unit of consumption), the price increase necessary to encourage a given reduction in water use can be up to 30 percent lower (Gaudin, 2006).

The nature of public services seems to matter as well. The provision of individual metering for residential water supply increases the awareness of households about their water use and gives them stronger incentives to save water. By having access to their own water bills, consumers fully experience water price signals. They are induced to act accordingly and to reduce water demand.

Differences in households' responses

In order for both the pricing mechanism and the supplementary programs to be properly designed, it is important to have a good grasp of the effects that households' socio-demographic characteristics have on water use decisions. The literature broadly examines differences in households' water consumption.

Evidence to date suggests that income is a quite significant determinant of residential water use. As wealthier households tend to rely more heavily upon water-consuming durables (*e.g.* washing machines, swimming pools), they tend to consume more water. Estimates of the income elasticity of demand for water indicate that a 10 percent increase in income induces an increase in the quantity of water demanded ranging from 1 to 7 percent.

In addition, household responses to water price increases may differ across income levels.[5] Under certain circumstances, water substitution possibilities may involve the adoption of water-saving technologies which are likely to be less accessible to low-income households, unless subsidy programs are in place.

Addressing distributional effects arising from the implementation of policies aimed at reducing residential water demand is a challenging task, given the complexity of the relationship between income, water consumption levels, price level and price elasticity of water demand.

For water consumption above the minimum threshold level (basic needs), a pricing mechanism could be devised and supplementary programs could be introduced, to alleviate inequality problems resulting from the pricing scheme, without removing the incentive to reduce water consumption. A better understanding of the sources of differences in water consumption between low- and high-income households may help differentiate measures between "basic needs" and "luxury use" (*e.g.* swimming pools).

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5. In addition to varying with the level of consumption level, as pointed out earlier.

Apart from income, studies reviewed here examine other individual characteristics that may have an impact on price responsiveness such as age, household size and type of dwelling. However, the available literature does not permit any conclusive statement to be made about these impacts. There is some indication that households with older members, those living in high-density areas, and those living in multi-story buildings tend to use less water, but whether these groups are less or more responsive to price changes remains an open, yet very relevant, question. The role of attitudes is less frequently examined, although households with stronger attitudes towards water conservation are generally found to consume less (Domene and Sauri, 2005).

2. General policy implications

What general policy implications can we draw from the literature reviewed on the drivers of households' waste generation and recycling behaviour, residential energy and water use, personal transport choices, and organic food consumption?

An improved understanding of households' responses to measures implemented in these five policy areas, and of differences in consumption patterns and according to household characteristics, provides useful insights for the design of effective and efficient environmental policies, while addressing social issues such as distributional concerns. Some key areas where this work is likely to inform policy design include: (i) the choice of alternative instruments and complementarities between instruments; and (ii) the targeting of measures according to different consumer groups.

2.1 Choosing and combining policy instruments

This review guides policy makers on how to choose among different instruments to increase their impact on household behaviour. Clear support is provided for the effectiveness of economic instruments which give an incentive to households to change their behaviour. The implementation of unit-pricing for waste collection services is found to induce reductions in household waste and/or increases in recycling rates, versus flat-fee pricing (which is the most common system used in OECD countries). In a similar way, some water pricing systems encourage reductions in water demand.

Moreover, the literature suggests that some economic instruments have a greater effect on households' behaviour than other instruments. When comparing the relative performance of different residential waste unit-pricing systems, for instance, volume-based systems (*e.g.* bag programmes) are generally found to provide households with stronger incentives than a subscription system under which households are charged according to a specific level of waste collection services, whether or not they use it. When comparing the effects of different water pricing systems, consumers tend to use less water under an increasing price-structure (increasing block).

On the other hand, economic instruments may have a more limited impact on household decisions in some context. The evidence indicates that households' response to pricing measures tends to vary according to a number of other elements, including: (i) the initial price level (*e.g.* energy, water); (ii) the level of consumption (*e.g.* water demand is insensitive to price changes below a certain consumption level); (iii) the nature of the good consumed (*e.g.* water use to meet basic needs *vs.* luxury use of water for swimming pools); (iv) the household income level; and (v) time horizon considered. Better

understanding the role of these various elements, their relative importance, and their interplay can provide useful insights to policy makers.

The impacts of economic incentives may be limited in the short term, but increase with time - as illustrated by households' responses to water or energy price increases. The evidence reviewed in the area of transport also underlines the existence of this time lag, because consumers need to adjust their durable stocks or even their residence location. Households' response to an increase in petrol prices is also found to be much smaller in the short term than in the long run. In the first instance, the means of response of a household to the introduction of fuel-related taxes is limited to reducing the use of motor vehicles (*e.g.* cutting out non-essential trips). However, in the medium run, issues such as vehicle choice and changes in travel mode are raised. In the longer run, the choice of location of residence and/or employment will become important.

The report also emphasizes that relying on policy mixes is likely to increase the effectiveness of individual policy measures implemented to influence environmental behaviour. Because of the needed adjustments over time, and possible weak responses of households to price changes in the short run, there are some limits to relying solely on incentive-based instruments (*e.g.* to change behaviour with respect to residential water consumption or personal transport choices). Important complementarities can exist between instruments (OECD, 2007) and the review provides useful insights on how the effectiveness of economic instruments can be increased in a significant manner by properly combining instruments to affect households' responses.

For example, the impact of economic instruments (*e.g.* taxes, pricing structure) on households' decisions is likely to be increased when applied together with the provision of information. In the area of residential energy use, for instance, it can be preferable to use an economic instrument such as an energy tax in combination with an information-based instrument (energy-efficiency label), rather than applying it on its own. In effect, the label should increase the price elasticity of demand for energy, making the introduction of the tax more effective and economically efficient. The role of information-based instruments in policy-making is supported by empirical studies looking at the impact of knowledge on environmental behaviour. For instance, educational programs may serve to change people's perceptions about the difficulties related to recycling, which is found to be an important determinant of recycling efforts.

More subjective factors influencing environmental behaviour, which can affect the effectiveness of the measures implemented, can also be important. These factors include households' attitudes towards the environment, as well as norms. Their impact seems to vary, however, across the five areas examined. Environmental awareness seems to have a positive impact on the adoption of renewable energy by residential users and on residential water use while environmental concerns tend to be weakly related to personal transport choices. Besides, personal norms are found to influence travel mode choices and more specifically the use of public transportation, and the literature also underlines the role of moral and social norms to explain recycling decisions (*e.g.* household efforts to recycle without economic incentives and legal obligation). Public policies can influence environmental awareness and norms with information-based instruments (*e.g.* information campaigns and education) (Bamberg *et al.*, 2007; Green, 2006).

While the literature points to examples of mutual reinforcement between instruments, the evidence also suggests that there can also be some redundancies and contradictions between instruments. For instance, the adoption of economic incentives can have adverse effects when information tools are geared towards households' non-economic motivations for environmental behaviour, such as personal and social norms. In the case of recycling, given the importance that norms seem to have in the motivation of households to recycle (*e.g.* sense of civic duty, wish to be seen by others as a responsible citizen), the adoption of a pricing system and/or making recycling mandatory may lead to "crowding out" effects.

Environmental "policy packages" tend to have a more significant effect on individual behaviour when implemented in combination with investments in related environmental services (*e.g.* recycling, energy, transport, water). Unit-based pricing, for instance, appears to be more effective in reducing waste generation if implemented in combination with a recycling programme system. In the area of transport, as well, economic instruments such as a fuel tax and congestion charges tend to have a greater influence on car use when implemented in combination with investments in alternative public transport services (*e.g.* bus frequency, cycling paths). Besides, evidence suggests that measures to reduce residential water use (*e.g.* water pricing) are likely to have a more significant behavioural effect when individual water metering is provided to consumers.

2.2 Targeting environmental policies to increase their effect on households

Information on whose patterns contribute the most to environmental problems, and how consumption trends may differ among household groups according to individual characteristics (*e.g.* age, income, household size, rural/urban), provides important insights which can be used by policy makers to target environmental measures. Targeting measures may however entail significant costs that need to be taken into account when assessing the efficiency of a given policy.

Identifying household groups which are less likely to adopt environmental behaviour enables policy makers to take more informed decisions about where and when to implement a particular policy to improve its efficiency and effectiveness. It may not be cost-effective for instance to implement recycling programmes uniformly, if multi-family dwellings recycle less than single-family dwellings. In addition, if population density has a negative effect on recycling, a unit pricing system may provide stronger incentives in denser communities. Besides, information campaigns could be usefully targeted at some specific household groups to improve their effectiveness, in addition to providing information in general so that consumers can make informed choices (*e.g.* labelling schemes). For instance, information campaigns to modify personal transport choices will be most effective if they target those groups which have higher car use and are less supportive of environmental policies: men, the middle-aged, and those with higher incomes and education.

When introducing policies, adverse distributional effects are almost inevitable in the sense that lower income households may spend a slightly higher proportion of their income compared to higher income households. The distributional effects of a given measure will depend upon the importance of the related-expenditures in the total "basket" of expenditures for low-income and high-income households. Another aspect to take into account when looking at distributional effects is that potential behavioural adjustments

will vary among household groups (Salomon and Mokhtarian, 1997) and fewer adjustment options may be available to low-income individuals in response to a particular policy. Better understanding how household behavioural adjustments may differ among income groups allows policy makers to better target measures to address distributional concerns (Serret and Johnstone, 2006).

Water pricing, for instance, is expected to raise particular distributional concerns for policy makers, because water is such as an essential good. Evidence also suggests that waste unit pricing is likely to be regressive. While there seems to be evidence that the demand for garbage collection increases with income, the evidence also indicates that low-income households are not as responsive as high-income ones to recycling programmes. Besides, the distributional implications of transport-related taxation tend to vary across pricing instruments. A tax on car purchases is found to have positive distributional effects, while a subsidy for new fuel-efficient cars tends to be regressive, given that high-income households are more likely to buy new vehicles. Fuel taxation is found to be regressive, as is an emission tax. Subsidies for public transport generally appear to be progressive. In most cases, road pricing is also found to be regressive. The transport literature tends to focus on the distributional impacts of economic instruments, in particular taxes, which are often found to be mildly to weakly regressive. However, the few studies available on alternative policy instruments suggest that distributional concerns may also arise when using standards (*e.g.* energy efficiency standards), because low-income households may be forced to purchase more expensive appliances than would otherwise be the case.

A broad range of instruments is available to governments to address possible disparities between income groups, including targeted grants or tax rebates. However, not all means of compensation and mitigation are equivalent. In introducing these measures, policymakers therefore need to ensure that the economic efficiency and environmental effectiveness of the policy remains intact. In terms of efficiency, it will usually be preferable to address distributional impacts outside the context of the design of the environmental policy itself, in order to retain the incentive to improve the environmental problem. Different channels may be used like the reduction of other taxes or the provision of direct financial support to low-income households (Serret and Johnstone, 2006).

The evidence also suggests that some household groups may be less likely to adopt an environmentally friendly behaviour because they do not face the same incentive due to, for instance, their home occupation status (*e.g.* landlord or tenant). "Split incentives" tend to exist between investors in energy-efficient equipments and end-users and this is a significant barrier to energy efficiency (IEA, 2007). The same barriers exist for investments in water efficient equipments or water conservation devices. Landlords will have few incentives to invest in energy/water efficiency equipments - which will mainly benefit the tenant. On the other hand, the tenant will have few incentives to make investments in a property (*e.g.* house, flat) they do not own. Governments may therefore need to adopt targeted measures, such as tax incentives for landlords, to account for the fact that households' decisions might not be the same according to home occupation status.

3. Moving forward

A number of gaps emerged in the review done for this report including:

- Most studies available cover a very narrow geographical area, typically one country or a region within a country. As a result, there is little policy variability and household heterogeneity embodied in the literature, that would allow for a more comprehensive and reliable assessment of different policy frameworks.

- Studies available generally focus on one policy area (*e.g.* waste) and even only a particular aspect of it (*e.g.* waste generation or recycling levels). They do not allow for the comparison of household behaviour and households' responses to policies across environmental areas.

- Existing studies tend to focus on the effects of economic incentives (*e.g.* taxes, pricing structure) and further insights on the impact of other types of instruments on individual behaviour would be useful. These include the provision of information to consumers (*e.g.* energy labelling) and regulatory instruments (*e.g.* standards, restrictions).

- The role of attitudes and environmental awareness has received less attention so far in the literature, and could also be examined more fully.

- While available evidence deals extensively with how different segments of the population (*e.g.* income, household size) differ in their environmental behaviour and in their consumption decisions, it is equally important to know whether and how these different household groups respond to policies. The interplay between such socio-demographic characteristics and policy instruments is often neglected.

To help policy makers identify further ways to influence household environmental behaviour, the framework of analysis of household decision-making in these key environment policy areas needs to be broadened by:

- Applying a common framework in different countries to collect comparable primary data on household environmental behaviour and individual response to environmental policies, while existing evidence rests on studies using very different methodological approaches.

- Adopting a wide geographical coverage to have cross-country results and, in particular, to show trends across different regions (North America, Europe and Pacific).

Such a framework would allow refinements of policy lessons, building on experience gained from comparisons across policy areas and across countries.

As a contribution to address some of the gaps identified, the OECD has implemented a Household Survey on Environmental Behaviour in selected member countries representing different OECD regions. The same questionnaire has been administered in the 10 countries taking part in the survey and a similar means of implementation has been used (*i.e.* Internet-based survey). The questionnaire designed by the OECD, with inputs from a number of experts, simultaneously addresses the same five environmental policy issues examined in this report: reducing environmental impacts of household waste

generation, energy and water use, food consumption and transport choices. This unique set of household-level data will allow the OECD to carry out comparative analysis across countries, and to eventually refine its policy conclusions.

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ANNEX A

In the following Tables, the empirical results reviewed in this report that relate to the *household waste management* sector are summarised. Table A.1 provides a brief overview of the findings related to the effectiveness of various policy instruments: if the instrument is effective at reducing waste and/or at increasing recycling, the bold font style is used and any additional note is added in brackets. Table A.2 summarises findings related to the effects of other variables, especially demographic characteristics: if the effect of a variable is significant, the bold font style is again used and the direction of the effect (positive or negative) is indicated in brackets. Table A.3 includes the various "own-price" elasticities of demand for garbage collection services that were found in the review.

TABLE A.1: Econometric studies of the effects of policy variables on waste generation and recycling

Authors (year)	Dependent variables	Independent policy variables	Data and country
Ando and Gosselin (2005)	• recycling participation of multi-family dwelling households for total waste, paper, and containers • propensity to recycle of single- and multi-family dwelling (SFD and MFD) households for total waste, paper, and containers	• **distance to bin** (– for container recycling propensity)	survey data, 214 households, Urbana, Illinois (USA)
Callan and Thomas (1997)	• recycling rate	• **unit pricing** (more effective if combined with curbside recycling) • **curbside recycling** (more effective if combined with unit pricing) • **free recycling at state's materials recycling facility** • **educational grants** • equipment grants • curbside trash disposal	324 communities, Massachusetts (USA)
Dijkgraaf and Gradus (2004)	• total waste • unsorted waste • compostable waste • recyclable waste	• **bag-based pricing for unsorted** (with composting increasing) • **bag-based pricing for both unsorted and compostable** (with composting decreasing) • **weight-based pricing** (with composting decreasing) • **volume-based pricing** (only for unsorted and total) • **frequency-based pricing** (with composting decreasing)	community-level, panel data, the Netherlands

Authors (year)	Dependent variables	Independent policy variables	Data and country
Ferrara and Missios (2005)	• probability of recycling newspaper, glass, plastic, aluminum, tin/steel cans, cardboard, and toxic chemicals	• **unit price** (with the exception of toxic chemicals as they are not subject to the fee) • **weekly recycling** (only for glass, aluminum, and toxic chemicals) • **free units** (intensity of recycling declines) • **unit limit** (intensity of recycling declines for plastic and toxic chemicals) • **mandatory recycling** (with the exception of glass)	survey data, 1 409 households, Ontario (Canada)
Fullerton and Kinnaman (1996)	• garbage weight • garbage volume • garbage density (weight per can) • recycling (weight)	• **bag-based user fee** (but density increases)	actual measurements of garbage and recycling over 8 weeks, mail survey for demographic information, 75 households, Charlottesville, Virginia (USA)
Hong (1999)	• total waste • recyclables	• **bag-based user fee** (only for recyclables)	survey data, 3 017 households, Korea
Hong and Adams (1999)	• probability of contracting for larger volume • non-recyclable waste • recyclable waste • recycling rate	• **payment difference** (no effect on choice of container size)	actual measurements of recyclables (2) and non-recyclables (8), face-to-face survey for demographic information, 944 households, Portland, Oregon (USA)
Hong *et al.* (1993)	• frequency of recycling participation • garbage	• **disposal fee under block payment system** (for recycling)	survey data, 2 298 households, Portland, Oregon (USA)
Jenkins (1993)	• quantity of discarded waste	• **user fee**	community-level, panel data (USA)

Authors (year)	Dependent variables	Independent policy variables	Data and country
Jenkins *et al.* (2003)	• probability of recycling newspaper, glass bottles, aluminum, plastic bottles, and yard waste	• disposal price • **curbside program** (more effective than drop-off program) • **drop-off program** (less effective than curbside program) • **number of curbside collected materials** (only for newspaper) • mandatory curbside recycling • **experience with recycling program** (only for newspaper; for yard waste only if program is over 2 years old)	survey data, 1 049 households, USA
Judge and Becker (1993)	• diversion (number of bins of recyclables)	• **frequency** • **commingled** • **accessible pick-up location** • special recycling education	controlled field experiment, with actual measurements of recycling volume of participating households over 6 months, door-to-door survey of households for demographic information, Rice County, Minnesota (USA)
Kinnaman and Fullerton (2000)	• garbage • recyclable waste	• **user fee per bag** (ineffective with subscription programs) • **free curbside recycling** (only for recycling) • refundable deposit system • **yard waste ban** (only for recycling) • **mandatory recycling** (only for garbage)	959 communities, USA
Linderhof *et al.* (2001)	• compostable waste • non-recyclable waste	• **marginal price** (larger reduction in compostable waste) • **lagged dependent variable** (larger long-run effects) • **annual indicators** (lower waste in post-implementation years)	3 437 households surveyed between 2 and 42 times, Oostzaan, the Netherlands

Authors (year)	Dependent variables	Independent policy variables	Data and country
Nestor and Podolsky (1998)	• total waste • waste set out at curbside • waste disposed of on site • waste transported off site • recyclables set out at curbside • recyclables disposed of on site • recyclables transported off site	• **can-based user fee** (+ for recycling and total waste; - for trash) • **bag-based user fee** (+ for curbside recycling but less effectively than bag-based system; - for curbside trash but more effectively than can-based system) • **indicator for presence of garbage disposal** (+ for trash)	284 households surveyed twice, city of Marietta, Georgia (USA)
Podolsky and Spiegel (1998)	• quantity of solid waste disposed of per capita	• **unit price** • **quantity of recycling per household** (recycling is mandatory; effect is independent of whether unit pricing is in place)	149 communities, five New Jersey counties (USA)
Reschovsky and Stone (1994)	• probability of recycling (in terms of whether households recycle) newspaper, glass, plastic, cardboard, metal, and food/yard waste (composting)	• **knowledge of drop-off center within 5 miles** (for glass, plastic, cardboard, and metal) • lack of knowledge about nearest drop-off center (metal recycling decreases) • **knowledge about recycling programs** (but no effect on composting) • **trash-tag fee** (only for composting) • **curbside pick-up** (only for cardboard) • mandatory recycling • **mandatory recycling and curbside pick-up** (for newspaper and glass) • mandatory recycling and trash-tag system • **curbside pick-up and trash-tag system** (for glass, plastic, and cardboard) • **mandatory recycling, curbside pick-up, and trash-tag system** (for newspaper and glass)	survey data, 1 422 households, Tompkins County, USA

Authors (year)	Dependent variables	Independent policy variables	Data and country
Sterner and Bartelings (1999)	• recycling of various materials (glass, paper, refundable, batteries, hazardous waste, household machines, and textiles)	• **indicator for municipality with weight-based fee** (only for glass) • **indicator for municipality with frequency-based fee** (only for glass)	household survey data from three Swedish communities with different fee structures (weight- or frequency-based fee and flat fee)
Van Houtven and Morris (1999)	• mixed waste • probability of recycling • total waste (mixed plus recyclables)	• **bag program dummy** (stronger effect than can program for mixed and total waste) • **can program dummy** (weaker effect than can program for mixed and total waste) • **interaction between unit pricing and home ownership** (smaller effect among home-owners) • **interaction between unit pricing and number of residents** (larger effect in households with many residents)	survey data with eight actual measurements of mixed waste and recyclables per household, 398 households, Marietta, Georgia (USA)

TABLE A.2: Econometric studies of the effects of demographic and attitudinal variables on waste generation and recycling

Authors (year)	Dependent variables	Independent variables other than policy variables (mostly demographic characteristics)	Data and country
Ando and Gosselin (2005)	• recycling participation of multi-family dwelling households for total waste, paper, and containers • propensity to recycle of single- and multi-family dwelling (SFD and MFD) households for total waste, paper, and containers	• **house or single-family dwelling** (+) • **floor indicators** (+ for 4th floor; + for 2nd floor for paper) • **storage space** (+ but declining) • **newspaper subscriber** (+ for total waste recycling propensity) • **indicator for recycling when in public** (+ for paper; + for container recycling propensity) • **indicators for less/more than full-time work/study responsibilities** (+ for less than full-time for paper and container recycling participation) • **household size indicators** (+ for containers with 2 adults; + for total waste recycling participation) • **age** (+ for total waste recycling propensity) • **education** (+ for total waste recycling propensity; + for container recycling participation) • **gender indicators** (+ for single-gendered for total waste recycling propensity; + for all female for containers; - for all male for paper recycling participation; + for all male for container recycling participation)	survey data, 214 households, Urbana, Illinois (USA)
Callan and Thomas (1997)	• recycling rate	• **income** (+) • **education** (+ but declining) • housing value • **housing age** (+) • **density** (-) • **population** (- but declining) • suburban/rural economic center • **resort/retirement/small rural community** (+)	324 communities, Massachusetts (USA)

Authors (year)	Dependent variables	Independent variables other than policy variables (mostly demographic characteristics)	Data and country
Dijkgraaf and Gradus (2004)	• total waste • unsorted waste • compostable waste • recyclable waste	• **age** (+ for total and compostable) • **size** (- for total and unsorted; + for compostable and recyclable) • **proportion of foreigners** (- for every waste stream but unsorted) • **city** (- for every waste stream but unsorted) • **village** (- for unsorted; + for compostable and recyclable) • **population density** (+ for every waste stream but recyclable) • **home ownership** (+ for every waste stream but recyclable) • **flat ownership** (- for every waste stream but unsorted) • **income** (+ for total and unsorted)	Community-level, panel data, the Netherlands
Ferrara and Missios (2005)	• probability of recycling newspaper, glass, plastic, aluminum, tin/steel cans, cardboard, and toxic chemicals	• **home ownership** • **education** (+ for glass at any level above high school; + for newspaper, aluminum, tin cans, and toxic chemicals at undergraduate or post-graduate level) • **income** (- for newspaper, for plastic at low levels, and for toxic chemicals at high levels) • **household size** • **age of household head**	survey data, 1 409 households, Ontario (Canada)
Fullerton and Kinnaman (1996)	• decrease in garbage weight • decrease in garbage volume • increase in garbage density (weight per can) • increase in recycling (weight)	• **number of newspapers delivered daily** (+ for garbage weight and volume and for recycling) • **fraction of household less than 3 years of age** (+ for garbage weight and volume) • college • **income** (- for garbage) • **indicator for adult married couple** (+ for garbage) • **indicator for white household** (- for recycling)	actual measurements of garbage and recycling over 8 weeks, mail survey for demographic information, 75 households, Charlottesville, Virginia (USA)

Authors (year)	Dependent variables	Independent variables other than policy variables (mostly demographic characteristics)	Data and country
Hong (1999)	• total waste • recyclables	• **income** (+ for total waste) • **size** (+ for total waste) • **education** (+ for recyclables) • **opportunity cost of time** (- for recyclables) • **recycling rate** (+ for total waste) • **waste generation** (+ for recyclables)	survey data, 3 017 households, Korea
Hong and Adams (1999)	• probability of contracting for larger volume • non-recyclable waste • recyclable waste • recycling rate	• income • **household size** (+ for non-recyclables and probability of larger volume; - for recycling rate) • home ownership • education level • **presence of garage** (- for non-recyclables) • **presence of small children** (+ for non-recyclables; - for probability of larger volume and recycling rate) • **seasonal indicators** (relative to winter, + for non-recyclables always; + for recyclables and recycling rate only in the autumn)	actual measurements of recyclables (2) and non-recyclables (8), face-to-face survey for demographic information, 944 households, Portland, Oregon (USA)
Hong *et al.* (1993)	• frequency of recycling participation • garbage	• **number of people** (+) • **education** (+ for recycling) • **non-white** (- for recycling; + for garbage) • **home rental** (- for recycling, + for garbage) • **value of time** (- for recycling) • **income** (+ for garbage)	survey data, 2 298 households, Portland, Oregon (USA)

Authors (year)	Dependent variables	Independent variables other than policy variables (mostly demographic characteristics)	Data and country
Jenkins (1993)	• quantity of discarded waste	• **average household income** (+) • **mean temperature** (+) • **average precipitation** (+) • **average household size** (-) • **proportion of population 18 to 49 years of age** (+) • **population density** (+) • price received for old newspapers	community-level, panel data (USA)
Jenkins *et al.* (2003)	• probability of recycling newspaper • probability of recycling glass bottles • probability of recycling aluminum • probability of recycling plastic bottles • probability of recycling yard waste	• **population density** (- for yard waste) • **income** (+) • **household size** (+ for glass bottles and yard waste) • **age of household head** (+ for all materials but glass bottles) • **single-family dwellings** (+ for plastic bottles and yard waste) • **home ownership** (+ for glass bottles and aluminum) • **education** (+ for newspaper, glass bottles, and aluminum; college education has smaller effect than high school education for glass bottles)	survey data, 1 049 households, USA
Judge and Becker (1993)	• diversion (number of bins of recyclables)	• **household size** (+) • average adult age • home rental • **education** (+ only at college and graduate level)	controlled field experiment, with actual measurements of recycling volume of participating households over 6 months, door-to-door survey of households for demographic information, Rice County, Minnesota
Kinnaman and Fullerton (2000)	• garbage • recyclable waste	• **income** (+ for garbage) • **age** (+ for recycling) • **household size** (+ for recycling) • **education** (- for garbage; + for recycling) • **home ownership** (+ for recycling) • **population density** (- for recycling)	959 communities, USA

Authors (year)	Dependent variables	Independent variables other than policy variables (mostly demographic characteristics)	Data and country
Linderhof *et al.* (2001)	• compostable waste • non-recyclable waste	• **size** (+) • **age** (- but declining for non-recyclable waste) • **share of females** (+) • **children by age group** (+ for compostable waste; + for non-recyclable waste only with infants from 0 to 2 years old and – otherwise) • **temperature** (+) • **seasonal indicators** (- relative to first quarter)	3 437 households surveyed between 2 and 42 times, Oostzaan, the Netherlands
Nestor and Podolsky (1998)	• total waste • waste set out at curbside • waste disposed of on site • waste transported off site • recyclables set out at curbside • recyclables disposed of on site • recyclables transported off site	• **income** (+ for recycling and on site trash) • **fraction of members below 18** (+ for on site and off site recycling) • **fraction of members above 65** (- for on site and off site recycling, for curbside and off site trash, and for total waste) • **size** (+ for curbside trash and recycling and for total waste; - for on site recycling) • **fraction of members working full-time** (- for curbside and off site trash and on site recycling; + for on site trash) • **owner-occupied home indicator** (- for on site recycling and total waste) • **non-minority household indicator** (- for curbside and on site recycling and trash and for total waste)	284 households surveyed twice, City of Marietta, GA (USA)
Podolsky and Spiegel (1998)	• quantity of solid waste disposed of per capita	• **income** (+) • **age** (-) • **size** (- but declining) • **population density** (-) • **rain** (+) • **snow** (-) • **number of employees per household** (+ but declining)	149 communities, five New Jersey counties (USA)

Authors (year)	Dependent variables	Independent variables other than policy variables (mostly demographic characteristics)	Data and country
Reschovsky and Stone (1994)	• probability of recycling (in terms of whether households recycle) newspaper, glass, plastic, cardboard, metal, and food/yard waste (composting)	• **adequate storage** (+ for glass, plastic, cardboard, and metal) • **household size** (- for newspaper; + for composting) • **married** (+ for newspaper, glass, metal, and composting) • **female** (+ for glass and plastic) • **age** (- for cardboard; + for composting) • **education** (+) • **weekly number of paid labour hours** (- for newspaper) • **income** (- for glass and plastic)	survey data, 1 422 households, Tompkins County (USA)
Richardson and Havlicek (1978)	• per capita quantity of 11 waste components	• **average household income** (+ for green glass, aluminum, newspaper, grass, and total; - for textiles, plastics, and garbage/other) • **average household size** (+ for clear and green glass, aluminum, metals, textiles, other paper, plastics, garbage/other, and total) • **percentage of people between 18 and 61 years of age** (+ for clear and green glass, aluminum, metals, other paper, plastics, and total)	aggregated household data (60 to 90 households) in 24 areas of Indianapolis (USA)

Authors (year)	Dependent variables	Independent variables other than policy variables (mostly demographic characteristics)	Data and country
Sterner and Bartelings (1999)	• total garbage • composted kitchen waste • recycling of various materials (glass, paper, refundables, batteries, hazardous waste, household machines, and textiles)	• income • **living area** (+ for total waste; - for composting of kitchen waste) • garden area • gender • marital status • education • **age** (- for total waste; + for recycling of refundables) • **household members** (+ for paper recycling; - for recycling of textiles) • **people staying at home** (- for total waste) • **time spent on waste management** (+ for total waste) • distance to recycling center • **attitudinal/behavioural variables** (+ for total garbage if recycling is perceived to be difficult; - for total waste if there is a positive attitude towards composting and if kitchen waste is composted; + for composting of kitchen waste if garden waste is composted; - for composting of kitchen waste if waste management is perceived to be time-consuming; + for recycling of textiles if there is attitude about importance of waste) • **previous experience with recycling** (+ for recycling) • **ease of recycling** (+ for recycling of glass, paper, and batteries) • **information about waste problems and change in buying behaviour** (+ for paper recycling)	survey data with actual measurements of waste flows, 450 households, residential area of Varberg, Sweden household survey data from three Swedish communities with different fee structures for recycling component of study

Authors (year)	Dependent variables	Independent variables other than policy variables (mostly demographic characteristics)	Data and country
Van Houtven and Morris (1999)	• mixed waste • probability of recycling • total waste (mixed plus recyclables)	• **high school education** (- for mixed and total wastes) • **income** (+ for total waste) • **dummy for white** (+ for recycling) • **dummy for urban** (-) • **dummy for owner-occupied household** (+ for recycling) • **number of residents by age group** (+) • **percentage working full-time** (- for recycling and total waste) • **dummy for importance of waste reduction** (- for mixed waste; + for recycling) • **interaction between unit pricing and home ownership** (+ for mixed and total wastes) • **interaction between unit pricing and number of residents** (- for mixed and total wastes)	survey data with eight actual measurements of mixed waste and recyclables per household, 398 households, Marietta, Georgia (USA)

TABLE A.3: Summary of available price elasticities

Authors (year)	Policy program	Dependent variable	Price elasticity
	Weight-based user fee	Total waste	**-0.47 (-0.40)**
		Unsorted waste	**-0.67 (-0.53)**
		Compostable waste	**-0.92 (-0.81)**
		Recyclable waste	**0.16 (0.12)**
	Bag-based user fee (unsorted + compostable)	Total waste	**-0.43 (-0.36)**
		Unsorted waste	**-0.66 (-0.51)**
		Compostable waste	**-0.97 (-0.85)**
		Recyclable waste	**0.25 (0.20)**
Dijkgraaf and Gradus (2004)	Bag-based user fee (unsorted)	Total waste	**-0.14 (-0.07)**
		Unsorted waste	**-0.71 (-0.58)**
		Compostable waste	**0.29 (0.40)**
		Recyclable waste	**0.14 (0.09)**
	Frequency-based user fee	Total waste	**-0.22 (-0.16)**
		Unsorted waste	**-0.28 (-0.16)**
		Compostable waste	**-0.40 (-0.31)**
		Recyclable waste	**0.08 (0.04)**
	Volume-based user fee	Total waste	**-0.06 (-0.00)**
		Unsorted waste	**-0.12 (0.01)**
		Compostable waste	-0.01 **(0.09)**
		Recyclable waste	0.01 (-0.03)
Fullerton and Kinnaman (1996)	Bag-based user fee	Garbage weight	-0.076
		Garbage volume	-0.226
		Garbage density	0.176
		Recycling weight	0.073
Hong (1999)	Bag-based user fee	Total waste	0.121
		Recyclable waste	**0.457**

Authors (year)	Policy program	Dependent variable	Price elasticity
Hong and Adams (1999)	Block payment	Non-recyclable waste	-0.154
		Non-recyclable waste	-0.013
		Recyclable waste	0.091
Jenkins (1993)	Bag- or tag-based user fee	Total waste	-0.12
Kinnaman and Fullerton (2000)	Bag- or can-based user fee	Garbage weight	-0.28
		Recycling weight	0.22
Linderhof et al. (2001)	Weight-based pricing	Compostable waste	-1.10 (short-run)
			-1.39 (long-run
		Non-recyclable waste	-0.26 (short-run)
			-0.34 (long-run)
Morris and Holthausen (1994)	Unit-based fee	Waste reduction	0.97 to 1.49
		Garbage weight	-0.15 to -0.60
		Recycling weight	-0.00 to -0.59
Podolsky and Spiegel (1998)	Bag- or tag-based user fee	Total waste per capita	-0.39
Strathman et al. (1995)	Marginal cost pricing	Disposed of garbage	-0.45
Van Houtven and Morris (1999)	Bag-based pricing	Mixed waste	-0.15 to -0.20

Note: the figures in parentheses are elasticities from the model with environmental activism

ANNEX B

The following Tables present selected characteristics of relevant studies on environmentally-responsible food choice, classified in five broad categories. Table B.1.1 provides a summary of "general reviews" of the literature. Table B.1.2 presents studies on the perception of environmentally responsible products. Table B.1.3 reviews empirical studies using real market data/experimental economics. Table B.1.4 includes studies focussing on hypothetical markets (*e.g.* willingness to pay). Table B.1.5 presents studies available on the perception of labels.

The next Tables summarise the main results from selected papers on environmentally responsible food choice providing significant contributions in terms of methodology or results. Only the effects of relevant and significant explanatory variables are reported. Table B.2.1 provides results from studies using real market data/experimental economics. Table B.2.2 provides results from studies focussing on hypothetical markets (*e.g.* willingness to pay). In these Tables, the reference product is indicated in bold character and the description of dependent variable is indicated in italics.

TABLE B.1.1: Overview of general reviews of the "environmentally-responsive food choice" literature

Authors	Year	Purpose of the study	Explanatory variables
Brennan C., Gallagher K. and McEachern M	2003	Provides a critical review of the literature on the consumer interest in the UK in organic food, with a particular focus on organic meat	
Harris B., Burress D. and Eicher S.	2000	Reviews articles investigating the characteristics and preferences of consumers of, and demand for, Environmentally Identified Products in the US	Summary of main variables affecting consumers' preferences for EIPs
Midmore P., Naspetti S., Sherwood A.-M., Vairo D., Wier M. and Zanoli R.,	2005	Produced on the basis of a workshop (held in September 2004) convened to discuss the relevance of consumer research to the wider "QualityLowInputFood (QLIF) European integrated project". It has three aims: to report on a survey and analysis of both scientific literature and also recent primary data available to the project team providing insights to consumer attitudes to organic products; to support new empirical investigations of consumer attributes which will be the focus in later stages of Sub-Project 1; and, based on the foregoing, to raise issues for broader discussion	
Parker Wheatley W.	2001	Reviews the literature on consumer preferences and willingness to pay for pork produced through alternative methods such as natural and organic production. Investigates the degree to which such premiums are transmitted to pork producers	Cost of alternative production methods compared to WTP
Thompson G.D.	1998	Reviews consumer demand studies specifying organic products analysed, geographic scope, purpose of the study, survey method, sample size	Price elasticities, income, store effects, age, gender, marital status, education, household size

TABLE B.1.2: Perception of environmentally-responsible products

Authors	Year	Purpose of the study	Survey method	Methodology	Dependent variable(s)	Explanatory variables
Anderson M.D. *et al.*	1996	Examines consumer awareness of integrated pest management (IPM) and the effects of two marketing strategies (active and passive)	Direct interviews (360 questionnaires)	Descriptive statistics Chi-square tests		Socio-demographic Concerns about how food is grown, preference for IPM-certified corn, elicited under different marketing strategies
Anderson J.C. *et al.*	2005	Evaluates students' perception of GM and organic foods and processes	Direct interviews (340 questionnaires)	Respondents indicated their level of agreement (8-point Likert scale)		Consumer perception: health, environment, ethics, regulation, risk
Baker S., Thompson K.E. and Engelken J.	2004	Investigates the underlying values driving food choice behaviour of German and British consumers	Direct interviews on a non-randomly selected sample (32 respondents in each country)	Means-end theory and Laddermap 5.4 software		25 attributes, 24 consequences, 13 values
Buzby J.C. and Skees J.R.	1994	Reveals the opinion of food shoppers on food safety in the United States based on the survey conducted by the University of Kentucky	National phone survey, followed by a mail questionnaire (1671 usable)	Descriptive statistics		Socio-economic (age, gender, race, income, household size, education), attitudes about food safety, WTP to reduce risk
Byrne P.J., Toensmeyer U.C., German C.L. and Muller H.R.	1992	Determines Delmarva consumer attitudes towards food safety, with an emphasis on organically grown fresh produce	Mail survey (1065 usable)	Response types: contingent valuation on a scale of 1 to 7; yes, no, or do not know responses; free choice selection; written comments; only descriptive statistics		Socio-economic (age, gender, income, education) Consumer self-ratings of attitudes, perceptions, and beliefs on various food safety topics
Chang Hui Shung	2004	Examines the arguments for and against the mandatory labelling of organic food in Australia, compares the political and marketing environments in which organic and GMO foods operate, and assesses the appropriateness of the differing regulatory responses		Description of labelling schemes		
Chang Hui Shung	2004	Identifies issues that may hinder or		Focus group		Key research question: who are the organic consumers? Why do they buy

Author	Year	Description	Sample	Analysis	Variables / Questions
and Zepeda L.		promote demand			organic? Are they representative shoppers or a fringe niche? How do consumers feel about the price premiums generally required for organic products? How important is certification to consumer confidence?
Conner D.	2004	Discusses the options for creating and maintaining niche markets by providing information on "process" attributes to consumers who wish to support a more sustainable food system, including labelling alternatives and the role of government		Discussion of sustainability and outlines policy and labeling mechanisms	
Conner D. and Christy R.	2002	Discusses the implications that the prohibition of the use of the "big 3" for foods labelled organic has on consumers' WTP, the policy implications of the results and how firms can use this information for marketing strategies		CV (open-ended WTP elicitation)	Socio-economic (age, gender, education, income) Attitudes and shopping habits
Eerola E. and Huthala A.	2005	Studies policies designed to encourage demand for green products under joint production of a private and public good using organic food products as example		The model considers consumers that differ in income level and preference for organic products	
Fotopolous C. and Krystallis A.	2002	Examines preferences of the Greek consumer of organic products	Direct interviews (random stratified sample, 1612 respondents)	Cluster analysis	Socio-economic (education, income), food purchase behaviour, media use, diet habits, attitudes towards the Greek food origin, attitude towards convenience, innovative behaviour, attitude towards advertisement
Gifford K. and Bernard J.C.	2004	Models the price premium of organic food as a function of the message components and information provided on the product packaging. The sub-components of this goal are to develop a method of recording and quantifying label claims and messages;		Descriptive statistics	Package type, organic price premium
Govindasamy R., Italia J. and Liptak C.	1997	Gains a greater insight into the characteristics and beliefs consumers draw upon while selecting the produce they purchase	Mail survey (656)	Descriptive statistics	Nineteen produce characteristics were ranked by consumers: locally grown produce and country of origin among the least important, freshness, taste/flavour, cleanliness, health value, absence of pesticides, among the most important characteristics

	Year		Survey		
Grunert S.C. and Juhl H.J.	1995	Investigates the applicability of the Schwartz value theory and measurement approach. Relationships between motivational domains of values and environmental attitudes are derived	Survey (174 school teachers)	Smallest space analysis, cluster and discriminant analysis	Socio-economic 56 values Environmental attitudes Buying attitudes towards organic food
Harper G.C. and Makatouni A.	2002	Presents focus group results on consumer perceptions, attitudes and behaviour in relation to two key interrelated food trends: organic food and animal welfare	Focus groups	Discussion of the results from focus groups	Concerns about health, food safety, animal welfare, organic and free-range food
Honkanen P., Verplanken B. and Olsen S.O.	2005	Investigates role of ethical motives in consumers' choice of organic food	Self-administered questionnaire (1283)	Descriptive statistics Confirmatory factor analysis Structural equation model among motives, attitudes and intention to consume organic food	Ethical food choice motives, attitudes towards consumption of organic food, choice of organic food
Lohr L., Factors Affecting International Demand and Trade in Organic Food Products	2000	Describes important markets for organic foods in Europe, Japan, and North America		Description of the factors affecting the demand of organic food in different countries	Factors affecting demand: price premiums, price-quality trade-off, country origin of product, GMO content, social goals
Lusk J.L. and Hudson D.	2004	Provides a short introduction to willingness-to-pay methodology and provides a discussion of several different methods used to estimate willingness-to-pay		Discussion of how much of the work in environmental and experimental valuation literature can be extended to agribusiness applications	
Makatouni A.	2002	Understands in depth the behavioural process of parents with respect to organic food	Laddering interviews (40) to parents with children between 4 and 12	Means-end chain theory	Attributes of organic food Consequences and personal values linked to those attributes
McCluskey J.J.	2000	Models the information asymmetry problems arising for organic foods in a game context. The analysis shows that repeat-purchase relationships and third-party monitoring are required for high-quality credence goods to be available		Game theoretic approach	

McGarry Wolf M., Johnson B., Cochran K. and Hamilton L.	2002	Examines the demographics and category purchasing behaviour of consumers who plan to purchase organic lettuce in the future	Personal interviews (259)	Comparison of conventional vs organic. Variables rated on a 1-5 desirability scale	Socio-economic (age, marital status, gender, education, income, employment status), consumption, types consumed, desirability characteristics (including environmental)
McGarry Wolf M.	2002	Examines the consumer purchase interest in organic grapes and price sensitivity	Personal interviews (342)	Laboratory experiment component of simulated test marketing; respondents rated nineteen product characteristics on a five-point desirability scale to examine the characteristics of grapes that impact a consumer's purchase decision.	Socio-economic (age, marital status, gender, education, income, employment status) Characteristics: freshness, quality, price, impact on the environment
O'Donovan P. and McCarthy M.	2002	Examines consumer demand for organic meat with special reference to consumers' perception of food safety	Direct interviews (250)	Factor analysis, reliability analysis.	Attitudinal statements in relation to health, environment and animal welfare
Radman M.	2005	Gains knowledge about consumer attitudes towards organic products in Croatia	Direct (face-to-face) interviews (179)	Univariate analysis, chi-square test, ANOVA and correlation analysis.	Buying behaviour regarding organic products, willingness to pay extra price for these products, knowledge about supply of organic products in the market, consumers' satisfaction with supply of such products, and future intention to buy ecologically-grown foods
Rimal A., Fletcher S.M., McWatters K.H., Misra S.K. and Deodhar S.	2001	Examines the relationship between food safety concerns and the change in food consumption habits	Mail survey (236)	Regression analysis	Food safety concern index Food consumption behaviour index	Socio-economic (health condition, race, education, employment status, age, gender) Attitudes: enforcement of food safety regulations, use of chemicals, label Confidence in comments: government agencies, universities, supermarkets
Rimal A. and Moon W.	2005	Examines the role of consumers' perceived risks and benefits of agro-biotechnology in shaping the purchase pattern for organic food among US consumers	Mail survey (3060)	Frequency analysis, mean test Ordered probit model	Organic purchase frequency	Socio-economic (gender, age, income, education, race) Perceived risks and benefits for GM and organic food, Food-related attitudes: food safety, price, trust in government GM awareness
Roberts J.A.	1996	Develops a profile of the ecologically conscious consumer	Nationwide mail survey (582)	Hierarchical model of multiple regression	Ecologically conscious consumer behaviour (ECCB)	Socio economic (gender, age, education, income) Attitudinal: perceived consumer effectiveness, environmental concern, liberalism

Robles Robles R., Vannini L., De la Puente T. and Fernandez-Revuelta J.J.	2005	Analyses consumer's attitude versus organic foods, in order to identify the factors that influence the demand	Direct interviews (130)	Descriptive statistics	Factors affecting the purchase of organic products (quality, health, environment, guarantee, chemical waste, origin, scarcity, availability, limited range, possibility of fraud, lack of knowledge) attributes of organic products
Tribl C., Salhoefer K.	2004	Addresses the question of how this environmental benefit can be internalised best assuming that organic farming creates a positive externality		Defines a model to allow the welfare effects of a subsidy on organic production and a demand-side information policy	
Weaver R.D., Evans D.J. and Luloff A.E.	1992	Assesses consumer attitudes towards pesticide use and residues in fresh produce	Face-to-face survey (560)	Descriptive statistics	Characteristics important in purchase decision, consumer concern for chemical pesticide use, perceived benefits of chemical pesticide use, concern in market intended or actual behaviour, perceptions of chemical pesticide-free tomatoes, willingness to pay/to purchase pesticide-free tomatoes.
Zepeda L., Douthitt R. and So-Ye You	2003	Presents a model explicitly linking risk perception (RP) to self-protection actions (SPAs) and to overall demand for milk	Telephone survey (1910)	Equations system: two-stage mixed system	RP SPA Milk demand	RP: outrage, attitudinal and demographic factors SPA: RP, labelling, economic variables, demographics, price of SPA Milk demand:SPA, milk price, price of SPA, income, demographics

TABLE B.1.3: Empirical studies: real market data/experimental economics

Authors	Year	Purpose of the study	Data	Methodology	Dependent variable(s)	Explanatory variables
Boland M. and Schroeder T.	2002	Determines the marginal value of attributes to consumers with respect to natural beef or beef produced with organic grains	Data for natural organic beef sales from producer-owned co-operatives	Hedonic price model	Wholesale primal cut prices Carcass revenue	10 product attributes
Galloway K. and Bailey D.V.	2005	Determines WTP for "cause" coffee	Data from experiment (second price Vickrey style auction)	Regression Analysis (104 obs.)	Average WTP bids	Socio-economic (gender, age, marital status, children, education) Coffee characteristics, personal characteristics (health consciousness, coffee consumption, life/financial satisfaction, happiness, donate money, working hours
Gifford K., Bernard J.C., Toensmeyer U.C. and Bacon R.	2005	Determines consumer willingness to pay (WTP) for non-GM and organic foods relative to conventional foods and to see if WTP differences between the three categories vary between fresh and processed food products	Experimental auctions (Vickrey's sealed-bid nth-price auction) with 133 subjects from three states	Tobit models	WTP bids	Socio-economic (gender, age, race, children, education), attitude and knowledge variables: knowledge of GM crops, opinion of GM foods, opinion of organic foods, confidence in the USDA, label readers, awareness that GM have been recalled, % chance of GM in the product
Glaser L.K. and Thompson G.D.	1998	Models the demand for organic and conventional frozen vegetables	Supermarket scanner data from 3000 stores (Nielsen)	Almost Ideal Demand System (AIDS)	Consumption shares	Prices, expenditure
Glaser L.K. and Thompson G.D.	2000	Models the demand for organic and conventional beverage milk	Supermarket scanner data from 3000 stores (Nielsen) Supermarket scanner data from 13000 stores (IRI)	Almost Ideal Demand System (AIDS)	Consumption shares	Prices, expenditure
Hu Y., Mc Cluskey J.J. and Durham C.A.	2005	Evaluates consumers' WTP for Washington apples	Consumer tasting survey (487 – Gala apple; 290 – Red Delicious)	CV: WTP elicited with double bounded method ML estimates	WTP	Socio-economic (age education, race) Purchase frequency Attributes: firmness, sweetness
Lusk J.L., Daniel M.S., Mark D.R. and Lusk C.L.	2001	Explores two important issues in experimental economics: calibration and auction institution. Consumer willingness-to-pay bids for corn chips made with nongenetically modified ingredients are	Auction experiment First price (18); second price (32)	First- and second-price sealed bid auctions	WTP	Socio-economic (gender, age, population) Consumption, exercise GM: feeling, W. to purchase, concern

				Double hurdle model		Food concerns: cholesterol, bacteria, hormones
		elicited in first- and second-price auctions				
Nayga R.M. Tepper B.J. and Rosenzweig L.	1999	Assesses the importance of health/nutrition-related factors and demographics on food consumption	1994 Continuing Survey of Food Intakes by Individuals (CSFII) and Diet Health Knowledge Survey (DHKS) (US Department of Agriculture, 1996)	Variable preference approach; Seemingly unrelated regression estimates	Average daily intake	Socio-economic (income, race, age, residence, gender, employment status, household size, education, body mass) health self-perception, overweight, special diet, pyramid knowledge, diet-disease knowledge, label use; importance: dietary criteria, nutrition, price, taste
Rae A.N.	2000	Measures the importance of several socioeconomic variables in explaining differences in household food consumption patterns and nutrition	1990 National Socio-economic Survey (Indonesian Central Bureau of Statistics)	Cluster analysis; Discriminant analysis	Household dietary pattern	Socio-economic (expenditure, household size, age, children, teenagers)
Roosen J., Fox J.A., Hennessy D.A. and Schreiber A.	1998	Measures consumers' willingness to pay (WTP) for the elimination of one insecticide and also a whole group of insecticides in apple production	Experimental design (Multiple-round Vickrey auction)	Double hurdle model	Preference for reduced pesticide use; WTP for reduced pesticide use	Socio-economic (gender, age, education, employment, income, children, organic shopping, consumption frequency, apple eaters), attitude towards policy options on pesticides, concern about use of pesticides, food poisoning and food prices, importance of apple attributes (flavour, price, damage, pest use)
Thompson G.D. and Glaser L.K.	2001	Analyses the trends in consumption of organic and conventional baby food during the 1990's	Supermarket scanner data from 3000 stores (Nielsen); Supermarket scanner data from 13000 stores (IRI)	Quadratic almost ideal demand system (QUAIDS)	Expenditure share	Prices, expenditure
Thompson G.D. and Kidwell J.	1998	Measures actual choice that consumers made in retail outlets between conventional and organic produce	Cosmetic defects and prices collected directly in store. Consumers' socio-economic traits collected with a questionnaire (340)	Discrete choice model; Two-equation model	Choice of organic/conventional; Choice of store	Socio-economic (income, education, age, young components, gender, store distance); Attributes: defects, price
von Alvensleben R.	1998	Elicits attitudes towards organic food in Germany	3 surveys (2000)	Factor analysis; Multiple regression	Consumption index for organic food	Attitudes

Wier M., Morch Andersen L., Millock K., O'Doherty Jensen K. and Rosenqvist L.	2005	Investigates the relationships between Danish household purchasing behaviour and stated values, motives and concerns	Household panel data (2000) (GfK Denmark) Purchase data (attitudes, perception, values, habits): survey to the same households (1609)	Almost Ideal Demand System (AIDS)	- Budget share - Average organic budget share - Deviation from the average organic budget share	Prices, consumer budget Socio-economic (education, age, children) Stated values, purchasing barriers (pesticide health concern, trust)
York R. and Hill Gossard M.	2004	Assesses the effects of modernisation and ecological context on per-capita meat and fish consumption for 132 nations	Data: UN, World Bank	Trade balance approach	Per-capita consumption	Land area per capita, water area p.c., climate indicator, GDP p.c.

TABLE B.1.4: Empirical studies: hypothetical markets (Willingness to Pay, conjoint analysis, other models from elicited information)

Authors	Year	Main purpose of the study	Survey method (usable replies)	Methodology	Dependent variable(s)	Explanatory variables
Ara S.	2003	Determines consumers' preferences of multiple attributes in organic rice	Direct interviews (548)	Conjoint analysis Logit estimates	Choice among six experiments	Price, health risk (5-point Likert scale), environmental quality, eating quality, organic quality, certification, fair trade
Baker G.	1999	Evaluates consumer responses to hypothetical apple products in a nationwide survey	Mail survey (510 usable)	Conjoint analysis	Choice among 11 hypothetical products	Price, damage, reduce pesticide usage, very limited pesticide usage, certification
Batte M.T. *et al.*	2004	Evaluates consumers' WTP for multi-ingredient processed foods and investigates the willingness to trade off multi-ingredient foods with varying levels of organic ingredients	Direct interviews (199)	Contingent Valuation (payment card) Random Utility Model multinomial/conditional logit model estimates	- WTP - Discrete choice among four hypothetical multi-ingredient cereal products	Socio-economic (age, income, children, education, health index, race, gender), National Organic Program (NOP) awareness
Boccaletti S. and Nardella M.	2000	Evaluates the potential for organic produce, in particular if consumers would be willing to pay price premiums	Direct interviews (400 usable)	Contingent Valuation (payment card) Multinomial logit	WTP	Socio-economic (age, gender, education, urban, children, income) Knowledge of pesticide-borne risks Pesticide concern index, food borne risk concern index
Buzby J.C., Ready R.C. and Skees J.R.	1995	Evaluates costs and benefits from banning a specific post-harvest pesticide	Mail survey (548 usable)	Contingent Valuation (payment card) Regression analysis	WTP	Socio-economic (gender, income, age, education, number of shoppers in the household), two attitudinal factors about safety of current pesticide use and total ban
Byrne P.J., Toensmeyer U.C., German C.L. and Muller H.R.	1991	Determines which consumers are and are not buying organic produce, and analyses their characteristic relationships between organic and conventionally grown produce, as well as their purchase likelihoods	Mail survey (753 usable)	Multinomial logit Ordered logit	- Organic produce purchase experience - Rating of organic vs. conventional produce	Socio-economic (age, gender, income, education), rating of organic produce compared to conventional, perception of organic costs compared to conventional

Chakraborty K.	2005	Measures consumers' WTP for Recombinant Bovine Somatotropin (BST) -free milk and to explore the factors influencing it	Mail survey (700 usable)	Contingent Valuation Probit	I would/I would not be willing to pay a premium for BST-free milk	Socio-economic (gender, income, age, education, children, household size), support of mandatory information, health risk, mandatory BST label, milk consumption
Cicia G., Del Giudice T. and Scarpa R.	2002	Investigates the preferences of regular consumers of organic food allowing for preference heterogeneity	Direct interviews (198)	Complete ranking and random utility	Eight choices to rank-order nine product profiles	Product attributes included price, origin of production, type of certification and visual appearance
Corsi A.	2005	Assesses consumers' habits concerning beef consumption and their responses to the BSE both immediately and in the longer term; consumers' attitudes and willingness to pay for organic beef	Two random telephone surveys (402÷330)	Probit Parametric estimates	Maintain beef consumption change after BSE Difference in expenditure	Socio-economic (age, education, household size, town size, gender, income), familiar with organic products
Cranfield J.A.L. and Magnusson E.	2003	Determines if Canadian consumers would pay a premium for pesticide-free food products	Mail survey (295 usable)	Contingent Valuation (payment card) Ordered probit	WTP	Socio-economic (residence, children, age, education, income) Try new products, shopping at health food stores, pesticide scale, sustainability scale, heard of pesticide-free production
Dunlap R.E. and Beus C.E.	1992	Investigates the public's view of pesticides use. Individual attitudes towards several pesticide issues are analysed.	Telephone survey (437)	Percentage distributions Principal components analysis regression	Necessity of pesticide use Safety of pesticide use Trust in food industry for pesticides use	Socio-economic (gender, age, education, income, residence)
Durham C.A. and Andrade D.	2005	Evaluates the relative strength of health and environmental motivations in the purchase of organic foods	Direct interviews (257)	Discrete choice model (random utility)	Prefer organic High/low buying	Socio-economic (age, income education, children, gender) Environmental purchasing behaviour Energy conservation and recycling behaviour Nutrition, price, appearance Health environmental sensitivity Fitness, personal health responsibility
Eom Y.S.	1994	Develops a theoretical model integrating consumer-stated behaviour with risk perception about pesticide residues	Questionnaires distributed by trained interviewers with self-addressed envelope	Random utility model Probit estimates	Intention to purchase safer produce	Socio-economic (income, age, education, gender, household size, children) price increase, risk reduction

Author	Year	Description	Data	Method	Results	Variables
			(567)			between the 2 product types, health risk, health consciousness.
Gil J. M, Gracia A. and Sanchez M.	2000	Analyses consumer's WTP for organic food, with consumers segmented according to lifestyles	Direct interviews (400)	Contingent Valuation (elicitation of WTP with closed-ended and follow-up method) Principal components analysis		socio-economic (age, gender, education level, household size, income), consumption level, lifestyles, environmental attitudes (conservation, concern), organic products attitudes
Govindasamy R. and Italia J.	1997	Evaluates which demographic characteristics cause consumers to be more likely to purchase IPM grown produce	Direct consumer survey distributed at 5 grocery retailers and collected by mail (291 responses)	Logit model	-Purchase conventional only -Heard of IPM -Willingness to purchase IPM -WTP >10% for IPM -WTP >10% for organic	Socio-economic (age, gender, education level, household size, income, marital status, urban, primary food purchaser) heard of IPM, pesticide risk, negative environmental impact of pesticides, use farmers' market, own garden grown produce, use of media for information.
Govindasamy R. and Italia J.	1998	Empirically evaluates consumer concern about pesticide residues and analyses the effect of socio-demographic factors on pesticide residue concern.	Mail survey (1195, 656 responses)	Logit model	Adversion towards pesticide usage	Socio-economic (age, gender, education, income, children, marital status, urban, frequent supermarket visitor, household size)
Govindasamy R. and Italia J.	1999	Evaluates which demographic characteristics affect consumers' WTP for organic produce	Direct consumer survey distributed at 5 grocery retailers and collected by mail(291 responses)	Logit model	Pay a premium for organic	Socio-economic (age, gender, education level, household size, income), use farmers' market, purchase organic, heard of organic, pesticide risk, own garden grown produce, use of media, primary food purchaser, try new foods, negative environmental impact of pesticides, shop in many food stores
Govindasamy R., Italia J. and Adelaja A.	2001	Evaluates the demographic characteristics that influence consumers to pay a premium for 1PM grown produce	Direct consumer survey distributed at 5 grocery retailers and collected by mail (291 responses)	Logit model	Pay a premium for IPM	Socio-economic (age, gender, education level, household size, income, marital status, urban, primary food purchaser) heard of IPM, pesticide risk,

Author	Year	Objective	Data	Method	Dependent variable	Explanatory variables
						negative environmental impact of pesticides, use farmers' market, own garden grown produce, use of media for information, shop in many food stores
Groff A.J., Kreider C.R. and Toensmeyer U.C.	1993	Determines the overall probabilities and marginal demographic effects for consumer rating of organics versus conventional produce, and the importance of various factors in consumer organic produce purchasing decisions	Mail survey (6155 households, response rate 12.2%)	Ordered logit models	Rating of organics vs. conventional / Rating of the importance of where produce was grown / Rating of the importance of brand name	Socio-economic (age, gender, education, children, marital status, income) / Factors relevant in organic produce purchasing (not included in estimated models)
Hansmann R., Scholz R.W., Francke C-J. A.C. and Weymann M.	2005	Assesses environmental and economic consequences of food consumption	215 pupils in 6 classes played the game	SIMULME (simulation game)		Economic (unemployment figures, the number of persons employed in agriculture, the average income of farms, and the development of consumers' purchasing power), ecological (the size of the area occupied by agriculture in Switzerland, the ecological state of the agricultural area, the implementation of fair and humane animal husbandry, and the global ecological situation)
Hearne R.R. and Volcan M.M.	2002	Elicits Costa Rican consumer preferences for different attributes of organic and conventional vegetables in a hypothetical market	Direct interviews (432)	Discrete choice model / Logit and conditional logit models	Product alternatives	Blue label, blue and green label, size, appearance, price (demographics in a different model)
Huang C.L.	1996	Analyses simultaneously consumers' preferences and attitudes towards organic produce	Mail survey (580, 381 completed)	Discrete choice model / Maximum Likelihood estimates	Prefer to buy organic fresh produce / Would buy organic even with sensory defects	Socio-economic (gender, age, education, household size, income, race) attitudes: pesticides concern, pesticide ban, certification, nutritional value, appearance, low price

Author	Year	Description	Survey (responses)	Method	Product alternatives / WTP	Socio-economic / Attributes
James S., Burton M.	2003	Examines the conditions under which consumers would purchase GM foods	Mail survey (2080, 370 responses)	Discrete choice model Conditional logit model	Product alternatives	Socio-economic (age, education, income, mean shopping bill, organic food buying habits, occupation, heard of GM, children) Attributes: weekly food bill, production technology (conventional, GM), level of on-farm chemical use, environmental risk, health risk
Jolly D.A.	1991	Elicitation of attitudinal and perceptual responses to questions about food safety concerns; the quality of conventional vs organic produce; and purchasing patterns of organic products.	Mail survey (1769)	Analysis of variance		Socio economic (occupation, age, size of community) Attitudinal factors (levels of concern for chemical residues, additives and preservatives, artificial coloring, radiation byproducts, salt and sugar).
Larue B., West G.E., Gendron C. and Lambert R.	2004	Characterises Canadian consumer response to GM functional food vs. conventional or organic food with the same functional property	Telephone survey (383)	Discrete choice model	Product alternatives (conventional, organic, GM)	Attributes: price, GM, organic, health property, health property (organic), health property (GM).
Lohr L. and Semali A.	2000	Identifies significant factors in the retail decision to sell organic foods and quantifies the effects of retailer attitudes on behaviour	Direct interviews to store managers (90)	Probit model	Sell organic food	Customers characteristics, chain type, sales/sq.feet, manager's education, support for organic, competitive and economic factors, information, price premium, margin
Loureiro M.L. and Hine S.	2002	Elicits consumers' willingness to pay (WTP) for a labelled value-added potato that could be marketed as organic, GMO-free, or Colorado grown (local)	Direct interviews (437)	Contingent Valuation: WTP elicitation with payment card	WTP	Socio-economic (gender, children, income, age, education, upper class), importance of nutrition, importance of freshness
Loureiro M.L. and Lotade J.	2005	Reveals consumer preferences for ethical and environmentally sound labelling programmes in coffee	Direct interviews (284)	Contingent Valuation: WTP elicitation with payment card Weibull model	WTP	Socio-economic (education, income, age, gender); concerns: welfare, environment
Loureiro M.L., McCluskey J.J. and Mittelhammer R.C.	2001	Assesses consumer choice of eco-labelled, organic, and regular apples, and identifies socio-demographic characteristics affecting the choice among those three alternatives. Estimates based	Direct interviews (285)	Discrete choice model Multinomial logit	Product alternatives (organic, eco-labelled, regular apples)	Socio-economic (education, income, age, gender, children, household size, race, main

Author	Year	Objective	Data	Method	Focus	Variables
		on stated preferences are compared with actual purchase behaviour obtained from a market experiment				shopper) Concerns: environment, food safety, quality, quality of eco-labelled apples
Loureiro M.L., McCluskey J.J. and Mittelhammer R.C.	1999	Assesses consumer preferences for sustainable agricultural, organic, and conventional apples. Estimates based on stated preferences are compared with actual purchase behaviour obtained from a market experiment	Direct interviews (289) Scanner data	Discrete choice model Multinomial logit Hedonic price analysis	Product alternatives (organic, eco-labelled, regular apples)	Socio-economic (education, income, age, gender, children, household size, race, main shopper) Concerns: environment, food safety, quality, quality of eco-labelled apples
Lusk J.L. and Coble K.H.	2005	Investigates the effect of risk preferences and risk perceptions on acceptance of GM food	Direct interviews (50 undergraduate students)	Nonhypothetical risk-elicitation preference experiment. Probit model	Eat GM food Purchase GM food	Socio-economic characteristics of interviewed students (race, loan, income, work, age, gender, freshman)
Magnusson E. and Cranfield A.L.	2005	Assesses what food products consumers would purchase if available in a pesticide-free production form and what factors affect demand for PFP food products	Mail survey (2000, 320 usable)	Discrete choice model Probit model	Purchase PFP	Socio-economic (residence, income, education, age, gender, children, marital status) Try new food, health food stores Concerns: pesticide residues, pesticides in the environment, labels Heard of PFP, switch grocery stores to find PFP, WTP for PFP
Misra S., Huang C.L. and Ott S.L.	1991	Analyses consumer preferences for testing and certification of fresh produce and consumers' willingness to pay for fresh produce that is certified as free of pesticide residues (FPR)	Mail survey (580, 389 returned)	CV: WTP elicitation with checklist Ordered probit model	WTP	Socio-economic (residence, income, education, age, gender, race), expectation of financial status, importance of testing and certification, pesticides concern index
Nganje E.W., Kaitibie S. and Taban T.	2005	Evaluates the determinants of food safety risk perception gaps	Direct interviews (363)	Discrete choice model	Consumer risk perception, consumption of bison at/away from home	Socio-economic (residence, gender, age, income) Personal health influence, perceived locus of control, consumption outrage/awareness: food safety risk, safe handling, TV info, magazines, labels
Roheim C.A., Johnston R.J.,	2005	Assesses trade-offs between species, price, and the presence of ecolabels for popular fresh	Mail survey (1414, 368	Conjoint analysis Random utility (discrete	Product alternatives	Socio-economic (age, household size, income, seafood

			usable)	choice)		
Greer J. and Donath H.		seafood species				expenditure, consumption frequency, feel overfishing, member of environmental group) Product attributes (price, label, fish type)
Scarpa R., Spalatro F. and Canavari M.	2003	Investigates preferences for potatoes obtained from different environment-friendly production methods	Stated preference data (2000 households) using Nielsen telematic network	Mixed logit	Product alternatives	Attributes: organic, Integrated Crop Management, quality certification, size, white pulp, appearance, bag, domestic origin, price
Shuzzler A., Govindasamy R. and Adelaja A.	2003	Documents the characteristics of frequent buyers of organic food and the characteristics of those who are willing to pay 10% or more for organic food	Data extracted from different surveys	Logit model	Frequently buy organic Willing to pay ≥ 10%	Socio-economic (household size, residence, gender, age, education, income, marital status) Label concern, farmers market, advertise use, absence of pesticide, switch supermarket, higher quality, higher variety, pesticide risk, fertilizer risk, know IPM, quality affects shopping.
Soregaroli C., Boccaletti S. and Moro D.	2003	Assesses consumers' attitude towards foods obtained from the application of biotechnologies and foods labelled as "GM-free" and measures WTP for GM-free and WTA for GM food	Direct interviews (500, 459 usable)	CV: WTP/WTA elicited with payment card Binomial probit Ordered probit	WTP (premium for GM-free food) WTA (discount for GM food)	Socio-economic (gender, age, household size, children, education, income, employment status, residence, usual shopper) Awareness and knowledge of GMO, confidence in GMO-free label Attitudes towards GMO: risk, trust, useful, agree
Underhill S.E. and Figueroa E.E.	1996	Examinees the potential for marketing fresh fruits and vegetables with labels indicating enhanced food and/or environmental safety attributes as compared to conventional produce	Mail survey (1500, 534 usable)	Ordered logit	Likelihood of purchase (1-5 scale) for organic, certified organic, certified pesticide residue-free label, IPM label, WTP (for the same variants)	Socio-economic (age, urban, gender, income), knowledge

Veenan M. and Adamowicz W.	2000	Assesses Alberta consumers' stated preferences and purchase behaviour for foods exhibiting a range of environmental risks; response of a random sample of consumers to the use of recombinant bovine somatotrophin (rBST) in milk production	Telephone survey for preferences towards food with environmental risk (1240) / Mail survey for response to the use of rBST (400, 294 returned)	Discrete choice model / Multinomial logit models	Choice to restrict pesticide/hormone use / Milk alternatives	Socio-economic (age, gender, children, income, education), rBST knowledge, milk type, rBST presence, price
Verhoef P.C.	2005	Investigatees the impact of economic and marketing variables, emotions, social norms, and environment-related variables on Dutch consumers' preference for, and purchase frequency of, organic meat (OM)	Mail survey (309, 269 usable)	Multinomial ordered probit / Binary probit	Purchase of OM / Purchase frequency of OM among buyers of OM	Socio-economic (age, household size, income, education, gender) Quality perception OM, price perception OM, distribution perception OM, fear, guilt empathy, social norms, environmental concern, green behaviour, perceived consumer effectiveness
Wachenheim C.J. and VanWechel T.	2004	Assesses whether WTP for food products can be motivated by (label) information about environmental effects of the use of GM ingredients	Random n^{th} price experimental auction (112)	Sealed bid		WTP on two variations of each of the three products, one with a standard NutriFacts label and one with an additional label indicating "This product does not contain genetically modified ingredients"
Wang Q. and Sun J.	2003	Assesses the market potential for organic apples and milk, examining consumer evaluation of major product attributes and their trade-offs	Mail survey (1659, 519 returned)	Conjoint analysis / Ordinary Least Squares	Product variants (milk and apples)	Product attributes: production method, location, certification, price, container size

TABLE B.1.5: Empirical studies: Perception of labels

Authors	Year	Purpose of the study	Survey method	Methodology	Dependent variable(s)	Explanatory variables
Armah P.W.	2002	Determines the variables that influence eco-label use in organic produce markets	Consumer intercept direct interviews (512, 212 usable)	Logit estimates	Bivariate variable: Yes/No questions about whether or not respondents (producers, consumers) rely on labels	Socio-economic characteristics Organic consumption behaviour
Blend J. and van Ravensway E.	1998	Examines potential consumer demand for ecolabelled apples and how different types of ecolabel might affect consumer demand	Phone interviews (972 interviews completed)	Simulated market: two scenarios presented to respondents	No model estimated Choice between IPM and ECO labels	Demographics (age, income, education), motivations, buy organic yes/no
Caswell J.A.	2000	Discusses the reasons for the adoption of labelling policies				
Caswell J.A. and Mojduszka E.M.	1996	Discusses the economic rationales for labelling policies and the issues related to how the success or failure of these policies should be judged				
Conner D. and Christy R.	2004	Reports the results of a survey and experimental auction on consumers' preferences for organic standards	Direct interviews (123)	Contingent Valuation (open-ended WTP elicitation) English auction		Socio-economic Attitudes and shopping habits WTP Understanding of organic (auction)
Grankvist G., Dahlstrand U.and Biel A.	2004	Assesses the effect of two labelling schemes on consumers' preferences	Computer-based experiment (40)	Laboratory experiment: choice between pairs of products		Environmental concern
Grolleau G. and Caswell J.A.	2005	Presents a model where the level of search and experience attributes influence the likelihood of production of eco-friendly products	Theoretical paper	Theoretic model of interaction between product attributes in determining the likelihood of eco-friendly production		
Jahn G., Schramm M.and Spiller A.	2005	Analyses the core structure of	Model of audit effectiveness			

		certification systems and tries to evaluate the respective instruments to enhance audit quality				
Johnston R.J., Wessells C.R., Donath H. and Asche F.	2001	Investigates differences in consumer preferences for ecolabelled seafood across the United States and Norway	Contingent choice telephone survey (1640 in the US; 2039 in Norway)	Choice model	Product alternatives	Socio-economic (age, income, gender, education, seafood budget, consumption frequency) Attributes: ecolabelled, unlabelled Attitudes: environment, ecological purchase behaviour, certification
Roosen J., Lusk J.L. and Fox J.A.	2001	Analyses consumer preferences for alternative beef labelling strategies	Mail surveys in France, Germany, UK (1000 in each country, 76,43,and105 usable respectively)	Double bounded logit models Ordered probit model	Demand for mandatory labelling Importance of brand Importance of origin	Socio-economic (gender, age, household size, children, education, income), consumption of different meats Concerns: food spoilage, food production methods
van Ravenswaay E.O. and Blend J.R.	1997	Examines the potential for ecolabelling as a mean to enhance revenues from the adoption of environmental technologies in agriculture: ecolabelling programmes and legal constraints, necessary conditions for an ecolabelling programme to generate revenues sufficient to encourage technology adoption, consumer acceptance for ecolabelled products				

TABLE B.2.1: Main results: Real market data/experimental economics

Authors	Year	Main results	Environmental and health factors	Other factors
Galloway K., Bailey D.V., "A Rose by Another Name: An Objective Analysis of an Established Market for Credence Attributes"	2005	Positive average WTP bids for the cause **coffee**, lowest for organic, greater for fair trade and shade-grown.	*Effects on WTP for cause coffee* donate to environmental causes (-)	*Effects on WTP for cause coffee* Age (+) Married (-) Health consciousness (+), life satisfaction (+), life happiness (-)
Gifford K., Bernard J.C., Toensmeyer U.C., Bacon R., "An Experimental Investigation of Willingness to Pay for Non-GM and Organic Food Products"	2005	Substantial untapped markets exist for GM and organic products, with over half of respondents bidding higher for one or both.	Opinion on organic: 1-neg, 5-pos (+) Opinion on GM (same range): (-)	Organic: Age (+), Income (-), education (+) Non-GM: education (-), read label 1-never, 5-always (-)
Glaser L.K., Thompson G.D., "Demand for Organic and Conventional **Frozen Vegetables**"	1998	Elasticities estimates suggest that consumers were quite sensitive to own price changes in organic frozen vegetables, 2-3 times more than conventional counterparts. Some asymmetry in substitution between organic and conventional is evident		*Effects on consumption* Organic own price elasticities: from -1.63 to 2.268 Expenditure elasticities: from 0.778 to 1.489
Glaser L.K., Thompson G.D., "Demand for Organic and Conventional **Beverage Milk**"	2000	Price premiums for organic milk averaged 60% of branded prices and 75% of private label prices. Own price elasticities suggest considerable response to lower organic prices, although decreasing with expenditure shares. Cross price elasticities indicate substitution between organic and conventional but with asymmetry in response		*Effects on consumption* Organic own price elasticities: from -3.637 to -9.733 Cross-price elasticities: organic and branded (+), organic and private label mostly (-) Expenditure elasticities: from -8.678 to -2.807
Hu Y., Mc Cluskey J.J., Durham C.A., "Consumers' Willingness to Pay for Washington **Apples** with Respect to Sensory Attributes"	2005	Firmer and sweeter apples induce more WTP. Age is an important factor affecting WTP for apples. Education, eating frequency, and race affect WTP in the Gala model but not the Red Delicious. Other variables such as gender, annual household income level, and whether they buy organic food, are not significant		*Effects on WTP* Firmness (+), sweetness (+), age (-), education (+) consumption frequency (+)
Lusk J.L., Daniel M.S., MarkD.R., Lusk C.L., "Alternative Calibration and Auction Institutions for Predicting Consumer Willingness to Pay for Nongenetically Modified **Corn Chips**"	2001	In a small and unrepresentative sample, 70% of student participants were unwilling to pay to exchange a bag of chips made from genetically modified ingredients for a bag of chips made from non-genetically modified ingredients. However, 20% of respondents were willing to pay at least $0.25/oz.	*Effects on WTP for non-GM chips* Exercise on regular basis (1=yes, 0=no) (+) GM concern (+)	*Effects on WTP for non-GM chips* Consumption frequency (-)

Reference	Year	for the exchange	Effects	
Nayga R.M., Tepper B.J., Rosenzweig L., "Assessing the importance of health and nutrition related factors on food demand: a variable preference investigation"	1999	Results of the models show that diet disease, individual's race, region of residence, urbanisation, education, and perceived importance of taste influence the consumption of various food groups	*Effects on average daily intake* Own perceived healthier (+ on dairy and poultry products) Overweight (+ on sugar) Diet disease knowledge (+ on fruit and vegetables)	*Effects on average daily intake* Male (+) Non-metropolitan area (-) Importance of taste (+ on dairies, meat, sugar/sweets)
Roosen J., Fox J.A., Hennessy D.A., Schreiber A., "Consumers' Valuation of Insecticide Use Restrictions: An Application to **Apples**"	1998	Consumer perceptions of product attributes change if pesticides are removed from production, and this is reflected in WTP changes. WTP is shown to be income-elastic	*Effects on WTP for reduced pesticide use* No pesticide (+) Pesticide concern (+ on preference for reduced pesticide use)	*Effects on WTP for reduced pesticide use* Income (+), children (+), consumption (-), price (-)
Thompson G.D., Glaser L.K., "National Demand for Organic and Conventional **Baby Food**"	2001	Results show high own price elasticities for organic baby foods and low for conventional. These two categories are substitutes		*Effects on consumption* Own price elasticities: organic: -2.489/-3.110; conventional: -0.154/-0.165 Cross-price elasticities: Organic/conventional: 1.913
Thompson G.D., Kidwell J., "Explaining the Choice of Organic Produce: Cosmetic Defects, Prices, and Consumer Preferences"	1998	Shoppers at the specialty grocer were sensitive to price differences between organic and conventional items. Cosmetic defects had a small but significant impact on the likelihood to buy organic		*Effects on probability of purchasing organic* Age under 18 (+) Defects (-), store (1= specialty, 0=coop) (-) Effects on probability of shopping at specialty store Income (+), buy certified organic (-)
Wier M., Morch Andersen L., Millock K., O'Doherty Jensen K., Rosenqvist L., "Perceptions, values and behaviour: The case of organic foods"	2005	Household propensity to purchase organic foods increases significantly with the declared importance accorded to 'private good' attributes (*i.e.* taste). The weight that households assign to public good attributes (*i.e.* environment preservation) does not contribute significantly to the explanation of household organic budget share	*Effects on organic budget share* Pesticide residue health concern (+)	*Effects on organic budget share* Stated private good values (+); purchasing barriers (trust in control, knowledge, interest in organic) (-); age (+), children <14 (+); teens (15-18) (-); education (+)
York R., Hill Gossard M., "Cross-national **meat and fish** consumption: exploring the effects of modernization and ecological context"	2004	Ecological conditions in a nation, such as resource availability and climate, influence meat and fish consumption. Additionally, indicators of modernisation, particularly economic development, influence the consumption of both meat and fish.	*Effects on per-capita consumption* Land p.c. (+ for meat) Water p.c. (+ for fish)	*Effects on per-capita consumption* GDP (+)

		However, the effect of economic development on consumption patterns is distinctly different among geographic regions

TABLE B.2.2: Main Results: Hypothetical markets (e.g. willingness to pay)

Authors	Year	Main results	Environmental and health factors	Other factors
Ara S., "Consumer Willingness to Pay for Multiple Attributes of Organic **Rice** : A Case Study in the Philippines"	2003	Health risk is the primary concern for the choice of organic, while organic certification is second.	*Effects on "choice of organic"* Reduced health risk (+) Environmental quality (+) Certification (+)	*Effects on "choice of organic"* Price (-), eating quality (+), fair trade (+)
Baker G., "Consumer Preferences for Food Safety Attributes in Fresh **Apples:** Market Segments, Consumer Characteristics, and Marketing Opportunities"	1999	Consumers expressed a broad preference for reduced pesticide usage. Four market segments were identified corresponding to consumers: (a) who had a strong preference for food safety, (b) who exhibited a more balanced desire for all product characteristics, (c) who were extremely price-sensitive, and (d) who had a strong preference for product quality	*Effects on utility (discrete choice)* Pesticide policy: conventional (-), reduced pesticide (+), organic (+) Certification: monitoring (-), certification (+)	*Effects on utility (discrete choice)* Price (-) Damage (-)
Batte M.T. *et al.,* "Customer Willingness to Pay for Multi-Ingredient, Processed Organic Food Products"	2004	Nutrition and a desire to avoid pesticides were the primary motives for purchasing organic foods, while high price and a perceived lack of variety were the most important reasons for not purchasing. Estimates of willingness to pay for organic foods suggest that consumers are willing to pay premium prices for organic foods, even those with less than 100 % organic ingredients	*Effects on WTP for organic* Health index (-) Effects on discrete choice of **cereals** Health index (+ for 70% organic) Safety index (+)	*Effects on WTP for organic* Age (+), income (+), non-white (+), female (+), specialty grocery shoppers (+), children (+) Effects on discrete choice of organic **cereals** Price (-), children (- for 70% and 100% organic), specialty grocery (+)
Boccaletti S., Nardella M., "Consumer Willingness to Pay for Pesticide-Free **Fresh Fruit and Vegetables** in Italy"	2000	Italian consumers were generally concerned about health risks from pesticides, with only 11% of the respondents not willing to pay higher prices for pesticide-free fresh fruits and vegetables. The most relevant increase in the probability of a positive WTP was given by income and individual perception of risk concern about pesticides, while higher education increased the probability of a zero WTP	*Effects on WTP for pesticide-free* Pesticide concern index (+)	*Effects on WTP for pesticide free* Female (+), education (-), income (+)
Buzby J.C., Ready R.C., Skees J.R., "Contingent Valuation in Analysis: A Case Study Residue Risk Reduction Food Policy of a Pesticide-Residue Risk Reduction"	1995	Estimated benefits of banning a specific post-harvest pesticide used in fresh grapefruit packinghouses outweigh costs: growers would be negatively affected, while consumers' benefit from reduced risk would outweigh the increase in price.\	*Effects on WTP for pesticide-free* Pesticide concern (+) Ban pesticides (+)	*Effects on WTP for pesticide-free* Income (-), age (-),
Byrne P.J., Toensmeyer U.C., German C.L., Muller H.R., "Analysis of Consumer Attitude Toward Organic Produce and	1991	Higher education and males demonstrate negative effects on the organic alternative. While higher-income households do not necessarily favour organic produce purchases, their ability to pay for the higher-priced good is evident from their positive purchase		*Effects on "purchase organic" at higher prices* Female (+), education (-), income (+)

Purchase Likelihood"		likelihood result.		
Cicia G., Del Giudice T., Scarpa R., "Consumers' perception of quality in organic food. A random utility model under preference heterogeneity and choice correlation from rank-orderings"	2002	Consumers who regularly buy organic food belong to a homogeneous segment. Consumers perceive price as a quality signal and prefer the product certified by reliable certification agencies	*Effects on discrete choice of organic olive oil* Certification (+)	*Effects on discrete choice of organic olive oil* Price (+), product origin (-)
Cranfield J.A.L., Magnusson E., "Canadian Consumer's Willingness-To-Pay for Pesticide Free Food Products: An Ordered Probit Analysis"	2003	Over 65 % of respondents would be willing to pay a 1% to 10%premium relative to a conventional food product. Five per cent of respondents would be willing to pay more than a 20 % premium. Health and environmental concerns, willingness to switch grocery stores and youth are important characteristics of consumers who would be willing to pay higher premiums. Distribution channels geared towards health food stores (or health food centres within grocery stores) are likely targets for Pesticide Free Production (PFP) certified food products	*Effects on WTP for pesticide-free production (PFP)* Pesticide concern (+)	*Effects on WTP for pesticide-free production (PFP)* Try new products (-), switch store to buy PFP (+) Age (less than 36, +)
Durham C.A., Andrade D.. "Health vs. Environmental Motivation in Organic Preferences and Purchases"	2005	Both health and the environment are motivations for organic preferences and purchasing, but environmental motivations are more influential in determining higher levels of purchases	*Effects on preference for organic fresh fruit and vegetables* EEPB (+) Health environmental sensitivity (+)	*Effects on preference for organic fresh fruit and vegetables* Age (-), price importance (-)
Eom Y.S., "Pesticide Residue Risk and Food Safety Valuation: A Random Utility Approach"	1994	Results from a pilot survey suggest a clear linkage between perception and behaviour in response to new risk information. Consumers' stated preferences for safer produce were influenced by price differences and perceived risks	*Effects on purchase intention for safer produce* Risk reduction from safer prod.(+) Pesticide health risk concern (+) Pesticide negative effect on env (+)	*Effects on purchase intention for safer produce* Price increase (-), education (-) regularly purchase organic (+)
Gil J. M., Gracia A., Sanchez M., "Market segmentation and willingness to pay for organic products in Spain"	2000	Consumers concerned about healthy diet and environmental degradation are the most likely to buy organic food, and are willing to pay a high premium. Organic attributes are easily identified in perishable products as the premium consumers would pay for organic **meat, fruits**, and **vegetables** is higher.		
Govindasamy R., Italia J., "Consumer Response to Integrated Pest Management and Organic Agriculture: An Econometric Analysis"	1997	Income was found to be the most significant determinant of willingness-to-purchase IPM grown produce. Participants with higher annual incomes were more likely to express an interest in purchasing IPM produce and also appeared less likely to strictly purchase conventional produce. Those who frequently purchase organic produce, those who visit farmers markets and those who live in suburban areas were all found to be more likely to purchase IPM grown produce. The results also indicate that women, those with higher annual incomes, younger individuals, and those who frequently purchase organic produce are all more likely to pay a premium for both IPM and		*Effects on willingness to purchase IPM* Age >65 (-), income (+), shop many supermarkets (-) urban (-), rural (-), primary grocery shopper (+) *Effects on WTP>10% for organic* Female (+), age (+), income (+), education (-

Author/Title	Year	Description	Effects	Effects
		organically grown produce		), regularly purchase organic (+), try new products (-), household size (+), heard of IPM (+)
Govindasamy R., Italia J., "Predicting Consumer Risk Perceptions Towards Pesticide Residue: a Logistic Analysis"	1998	Women, households with several children, and individuals over 35 years old are more likely to have high levels of risk aversion. Households with higher levels of income and education exhibited lower risk aversions towards pesticide residues		*Effects on "highly adverse to pesticides"* Female (+), Age <35 (-), education (-), children (+) suburban (+), income (-)
Govindasamy R., Italia J., "Predicting Willingness-to-Pay a Premium for Organically Grown Fresh Produce"	1999	Results indicate that women, those with higher annual incomes, younger individuals, and those who usually or always purchase organic produce are all more likely to pay a premium for organic produce. The results also indicate that the likelihood of paying a premium for organic produce decreases with the number of individuals living in the household	*Effects on WTP >10%* Use food safety media reports (+)	*Effects on WTP >10%* Female (+), income (+), age (-), education (-) Regularly purchase organic (+), household size (-), heard of IPM (+), try new products (+),
Govindasamy R., Italia J., Adelaja A., "Predicting Willingness-to-Pay a Premium for Integrated Pest Management Produce: A Logistic Approach"	2001	Results indicate that women, those with higher annual incomes, younger individuals, and those who frequently purchase organic produce are all more likely to pay a premium for IPM produce	*Effects on WTP >10%* Pesticides risk aversion (+)	*Effects on WTP >10%* Female (+), age (+), income (+), household size (-), regularly purchase organic (+).
Groff A.J., Kreider C.R., Toensmeyer U.C., "Analysis of the Delaware Market For Organically Grown Produce"	1993	Younger respondents, female respondents, and those with lower education levels were more likely to feel organics are a better produce than conventionally grown produce		*Effects on consumer's better rating of organic vs conventional* Age (-), education (-), female (+)
Hearne R.R., Volcan M.M., "The Use of Choice Experiments to Analyze Consumer Preferences for Organic Produce in Costa Rica"	2002	The study indicates a positive willingness to pay among Costa Rican consumers for certified food safety and organic production practices		*Effects on certified labelled (organic) product* Size (+), appearance (+), price (-), education (+)
Huang C.L., "Consumer preferences and attitudes towards organically grown produce"	1996	Consumers who are nutritionally conscious, concerned about the use of pesticides, and desire residues-free produce have a higher propensity to prefer organically grown produce	*Effects on preference for organic produce* Pesticide use concern (+) Ban pesticides (+), Test and certif. (+) Nutr. value important (+)	*Effects on preference for organic produce* Low price important (-) *Effects on willingness to accept sensory defect* Appearance important (-), low price (+), education (+), household size (+), income (-)
Jolly D.A., "Determinants of Organic Horticultural Products Consumption Based on a Sample of California Consumers"	1991		*Effects on WTP for organic* Concern for artificial colouring (+)	*Effects on WTP for organic* Education (+), married (-), white collar (+), income (+), female (+)

Larue B., West G.E., Gendron C., Lambert R., "Consumer Response to Functional Foods Produced by Conventional, Organic, or Genetic Manipulation"	2004	Results indicate that many Canadian consumers will avoid GM foods, regardless of the presence of functional health properties. For others, the introduction of GM functional plant foods should increase acceptance of GM production methods, but many consumers will likely avoid functional foods derived from GM animals. The organic food industry could also profit from the introduction of organic functional foods	*Effects on utility (discrete choice among conventional, GM, organic)* Health positive properties (+)
Loureiro M.L., Hine S., "Discovering Niche Markets: A Comparison of Consumer Willingness to Pay for Local (Colorado Grown), Organic, and GMO-Free Products"	2002	Willingness-to-pay estimates show a higher premium for the "Colorado grown" attribute. This attribute affords the **potato** producer with the highest consumer acceptance and premium (relative to organic and GMO-free)	*Effects on WTP for organic **potatoes*** Age (-), upper class (+), freshness concern (+), nutrition concern (+)
Loureiro M.L., Lotade J., "Do fair trade and eco-labels in coffee wake up the consumer conscience?"	2005	Consumers are very receptive towards both fair trade and shade grown coffee labels, and consequently are willing to pay higher premiums for these labelling programmes than for the organic **coffee**	*Effects on WTP for organic coffee* Environmental concern vs. job creation (+) *Effects on WTP for organic coffee* Income (+), Age (-), importance of welfare of future generations (-)
Loureiro M.L., McCluskey J.J., Mittelhammer R.C., "Assessing Consumer Preferences for Organic, Eco-labeled, and Regular **Apples"**	2001	Eco-labeled apples are less desirable than organic when food safety, the environment, and children's needs are considered. Characteristics that may be expected to positively affect the decision to buy eco-labelled apples relative to regular apples actually have the opposite effect with the inclusion of the organic alternative. When considering all three choices, the eco-labelled product is found to be an intermediate choice among consumers	*Effects on utility (discrete choice for organic)* Environmental concern vs. job creation (+) Food safety vs. appearance (+) *Effects on utility (discrete choice for organic)* Children (+), income (+), family size (+), female (+)
Loureiro M.L., McCluskey J.J., Mittelhammer R.C., "Willingness to Pay for Sustainable Agriculture Products"	1999	When consumers choose from among organic, sustainable agriculture and conventional **apples**, the sustainable agriculture choice is an intermediate choice when food safety, the environment and children's needs are considered	*Effects on utility (discrete choice for organic)* Environmental concern vs. job creation (+) Food safety vs. appearance (+) *Effects on utility (discrete choice for organic)* Children (+), family size (-)
Magnusson E., Cranfield A.L., "Consumer Demand for Pesticide Free Food Products in Canada: A Probit Analysis"	2005	Consumers show a strong interest in food products containing grains and oilseeds produced with pesticide-free practices. Preference for these products increases with environmental and pesticide concern	*Effects on utility (discrete choice for PFPs)* Health concern (+) Environmental concern (+) *Effects on utility (discrete choice for PFPs)* Age <36 (+), switch store to buy PFPs (+), education (-), income (+), willing to pay premium for PFPs (+)
Misra S., Huang C.L., Ott S.L., "Consumer Willingness to Pay for Pesticide-Free Fresh Produce"	1991	The analysis suggests that the more the consumers were concerned about health effects of pesticide residues on fresh produce, the more likely they would be willing to pay a higher premium for certified-RFP produce. The results also show that consumers' attitudes towards testing and certification and future expectations play a significant role in influencing their willingness to pay	*Effects on WTP for certified pesticide residues-free produce* Pesticides concern index (+) Importance of testing and cert. (+) *Effects on WTP for certified pesticide residues-free produce* Age (+), education (-), income (+), future financial status (+), white (+)
Roheim C.A., Johnston R.J., Greer J., Donath H., "Consumer	2005	Results suggest that consumers are unwilling to choose a less-favoured species (*i.e.* to	*Effects on utility*

Reference	Year	Results		
Preferences for Ecolabeled **Seafood**: Results of a Connecticut Survey"		sacrifice taste) based solely on the presence of an ecolabel		Price (-), eco-label (+)
Scarpa R., Spalatro F., Canavari M., "Investigating preferences for environment friendly production practices: taste segments for organic and integrated crop management in Italian households"	2002	The distribution of taste intensity for organic, integrated crop management and quality certification share a common correlation structure. The largest price differential is commanded by organic **potato** production. Only 23% of the share of households in Italy is not interested in environmentally friendly production practices		*Effects on utility* Age (-), household size (+), large size (+), poor appearance (-), price (-)
Shuzzler A., Govindasamy R., Adelaja A., "A Comparative Evaluation of Organic Produce Consumers in New Jersey to New York and Pennsylvania"	2003	Relevant differences between consumer's preferences for organic produce emerge in the two states		*Effects on "frequently buy organic"* Household size (+), age (+), income (+) Perceived high quality of organic (+) Perceived higher variety for organic (-) Switch supermarkets to buy organic (+) Check labels (+), heard of IPM (+)
Underhill S.E., Figueroa E.E., "Consumer Preferences for Non-Conventionally Grown Produce"	1996	71% of respondents stated they believed that pesticide residues in food present a serious or moderate health hazard to consumers. In addition, 74% believed that pesticides pose a serious or moderate hazard to the environment, and 64% felt there was a serious or moderate hazard to farm workers. Results indicate there is a positive information effect for likelihood of purchasing for all of the labels, and this effect is statistically significant for all of the labels except for "Certified Pesticide Residue-Free". The magnitude of the information effect for the Grown with IPM label was considerably higher than for the other labels, suggesting that there might be substantial pay-offs for informing consumers about this label		*Effects on purchase of organic/certified organic* Information (+), rural/suburban (-), age (-), female (-), income (+) *Effects on WTP for organic/certified organic* Rural/suburban (-), age (-), income (+)
Veeman M., Adamowicz W., "Consumer's Perceptions of Environmental Risks and the Demand for Food Safety"	2000	Albertans were more concerned about pesticide use in food production than about the use of hormones. In contingent valuation questions, more Albertans wish to restrict pesticide use (relative to a base case of not restricting either hormones or pesticides). They tended to persist in these choices in the face of potential increases in food costs, reflecting a higher level of concern with pesticides than with hormones	*Effects on utility (choice of **milk**)* Use of recombinant Bovine Somatotropine (BST) (-)	*Effects on utility (choice of **milk**)* Price (-), freshness (+), age (+), female (+), education (+ for skimmed), BST knowledge (+)
Verhoef P.C., "Explaining purchases of **organic meat** by Dutch consumers"	2005	Consumers' purchase of **organic meat** is based on both 'rational' economic motives and emotional motives	*Effects on choice/purchasing frequency of organic meat* Green behaviour (+) Consumer's effectiveness in changing environment (+/+)	*Effects on choice/purchasing frequency of organic meat* Quality perception (+), price perception (-/-), distribution assortment of OM (+), fear (+), guilt (not significant/+), animal welfare (+)
Wang Q., Sun J., "Consumer preference and demand for organic food: Evidence from a Vermont	2003	Results suggest that there is likely a significant niche market for **organic apples** and **milk** and many consumers, especially people who have purchased organic food products, are willing to pay more for organic apples and milk produced locally and	*Effects on utility (choice of milk/apples)*	*Effects on utility (choice of milk/apples)* Price (-/-)

survey"	certified by Northeast Organic Farming Association (NOFA).	Organically grown (+/+)
		Conventional (-/-)
		NOFA certification (+/+), USDA (not significant/+)
		Not certified (-/-)

ANNEX C

In the following Tables, the empirical results reviewed for this report are related to the *household water consumption* sector are summarised. Table C.1 provides a brief overview of findings related to the effectiveness of various policy instruments. Table C.2 summarises findings related to the effects of other variables, especially demographic characteristics: if the effect of a variable is significant, the direction of the effect (positive or negative) is indicated in brackets (if the effect is insignificant, the direction of the effect is not given). Table C.3 includes the various "own-price" and income elasticities of demand for water.

TABLE C.1: Overview of pricing and non-pricing policies for residential water demand

Authors (year)	Dependent variables	Independent policy variables	Data and country
Billings and Agthe (1980)	monthly water consumption per household	• increasing block rates	Tucson, Arizona, USA (Jan 1974 to Sept 1977)
Chicoine and Ramamurthy (1986)	quantity of water purchased per month	• declining block-price schedule	59 rural water districts, Illinois, USA
Cummings *et al.* (2005)	marginal quantity (amount of water used beyond the level of last consumed block)	• block-rate pricing	aggregate data, 28 coastal counties, Georgia (2003 to 2005)
Dandy *et al.* (1997)	annual water consumption	• marginal price (below free allowance level, marginal price is zero, and above allowance level, it is the unit price of water) • dummy for reduction in free allowance level of water (before 1991-92, annual allocation of water calculated as percentage of property value; during 1991-92, a constant quantity of 136 kl of water allocated to households, which is much less than before for average consumer)	metropolitan area of Adelaide, Australia (1978 to 1992)
Domene and Sauri (2005)	Per-capita water consumption per day	• heterogeneous pricing schemes	cross-sectional data from metropolitan region of Barcelona (2003)
Espiñeira (2000)	monthly average water use per account	• increasing block rate (a fixed quota with a minimum free allowance plus a second block charged at a single rate or several blocks charged at increasing rates)	monthly panel data, north-west Spain
Espiñeira and Nauges (2004)	Per-capita average domestic consumption per month	• increasing block rate • restricted daily water supply hours during severe drought periods • temporary outdoor use bans	Seville, Spain (1991 to 1999)

Authors (year)	Dependent variables	Independent policy variables	Data and country
Gaudin (2006)	Per-capita annual water consumption	• information dummy for marginal price info (unit price of water is given next to units consumed) • information dummy for price info (full price information of water is given anywhere in the bill) • information dummy for quantity consumed info • information dummy for combined water billing with sewerage, gas or electricity, and high-frequency billing • information dummy for increased block rate	cross-sectional data, USA
Krause *et al.* (2003)	percentage of water resource stock drawn	• allowing consumption from a finite stock of water, in presence of explicit scarcity (it shows that consumption of water depends on type of consumer)	classroom experiment o114 people consisting of three groups: students, working adults, and retired people
Mazzanti and Montini (2006)	Per-capita water consumption	• increasing block-rate structure (central price is used in the equation)	Emilia-Romagna, Italy (1998 to 2001)
Nauges and Thomas (2000)	water consumption in local community	• two-part tariff • existence of own water meter in single-unit houses	panel data from 116 communities, eastern France (1988 to 1993)
Nauges and Thomas (2003)	annual consumption of water (intertemporal choice)	• two-part tariff (a fixed charge corresponding to connection fee and a price per unit of water consumed) • lagged consumption	panel data of 116 communities, eastern France (1988 to 1993)
Nieswiadomy and Molina (1989)	monthly water consumption	• increasing block rate (1976 to 1980) • decreasing block rate (1981 to 1985)	monthly data, City of Denton, Texas (1976 to 1985)
Pint (1999)	bi-monthly water use	• increasing block rate	Alameda County Water District, California (Jan 1982 to Jul 1992)

Authors (year)	Dependent variables	Independent policy variables	Data and country
Renwick and Archibald (1998)	water consumption per household	• increasing block-rate pricing • dummy for Santa Barbara's landscape irrigation use restriction policy • dummy for Goleta's quantity-related water allocation policy • dummy for the low-flow toilet and showerhead subsidy programs • adoption of traditional irrigation technologies by the household • adoption of water-efficient irrigation technologies by the household • adoption of low-flow showerheads by the households • adoption of low-flow toilets by the households	household survey data, Santa Barbara and Goleta, California (1985 to 1992)
Renwick *et al.* (1998)	average household monthly water use	• uniform and block-rate pricing • public information campaigns dummy • subsidies dummy for adopting water-efficient technologies (like free low-flow toilets) • dummy for free retrofit kit distribution (distribution of a low-flow showerhead, tank displacement devices, and dye tablets for leak detection) • dummy for rationing of water • dummy for restriction on some types of water use (like bans on landscape irrigation) • compliance dummy for certain conservation measures Note: effects of rationing and restriction are larger than those of public information and free retrofit kit distribution variables]	eight urban water agencies, California, USA (1989 to 1996)
Schefter and David (1985)	total quantity of water delivered to the residential users	• various price schedules	aggregate data, 131 Wisconsin communities

Authors (year)	Dependent variables	Independent policy variables	Data and country
Strand and Walker (2005)	average water consumption	• block-rate pricing • rationing of water through reduced service hours	survey data, 17 Central American cities
Taylor et al. (2004)	quantity of domestic water demanded	• various price schedules (flat-rate pricing, increasing block, decreasing block, and unmetered fixed fees) • water conservation programs	cross-sectional data 34 utilities from Colorado water districts
Whittington et al. (1990)	probability that a household's WTP for a public stand-post (private connection) falls within a specific interval	• installation of private connections when public water supply posts are in place	Laurent, southern Haiti (1986)
Wong (1972)	average per-capita water demand	• flat rate of water per 1 000 gallons (Chicago) • block rates (suburban communities)	Time-series analysis, Chicago and nearby communities, Illinois (1951 to 1961) cross-sectional analysis with four community sizes
Woo (1994)	monthly per-capita water use	• service interruption of water (to save water reserves) • inverted block-rate pricing	Hong Kong (1973 to 1990)

TABLE C.2: Econometric studies on the determinants of residential water use

Authors (year)	Dependent variables	Independent variables other than policy variables (mostly demographic characteristics)	Data and Country
Billings and Agthe (1980)	monthly water consumption per household	• marginal price (-) • difference variable (-) • personal income (+) • weather variable (evapotranspiration – rainfall) (+)	Tucson, Arizona, USA (Jan 1974 to Sept 1977)
Chicoine and Ramamurthy (1986)	quantity of water purchased per month	• income (monthly income of the household – difference variable) (+) • marginal price (-) • decomposed price (-) • number of persons in a household (+) • number of bathrooms (+)	59 rural water districts, Illinois, USA

Cummings et al. (2005)	marginal quantity (amount of water used beyond the level of last consumed block)	• January (winter):
		  - median household income (-)
		  - difference variable
		  - marginal price (-)
		• July (summer):
		  - median household income
		  - difference variable
		  - marginal price (-)
			aggregate data, 28 coastal counties, Georgia (2003 to 2005)

Authors (year)	Dependent variables	Independent variables other than policy variables (mostly demographic characteristics)	Data and Country
Dandy *et al.* (1997)	annual water consumption	- marginal price (-) - difference variable (-) - capital value of property (proxy for income) (+) - plot size - number of residents per household (+) - number of rooms in the house (+) - swimming pool ownership (+) - moisture deficit (= potential evapotranspiration – 0.6 times rainfall) (+) - lagged consumption (annual consumption in previous year) (+) - dummy for change in free allowance level (higher free allowance level prior to 1992 than in 1992) (-)	metropolitan area of Adelaide, Australia (1978 to 1992)
Domene and Sauri (2005)	Per-capita water consumption per day	- average water price - income of the family unit (+) - housing type dummy (high-density; mid-density; low-density) (+) - number of members per household (-) - house size - garden size - garden necessity of water (+) - swimming pool dummy (+) - consumer behaviour index (-)	cross-sectional data metropolitan region of Barcelona (2003)

Authors (year)	Dependent variables	Independent variables other than policy variables (mostly demographic characteristics)	Data and Country
Espiñeira (2000)	monthly average water use per account	• marginal price (-) • difference variable (-) • number of rainy days in the month (-) • average temperature in each month (+) • number of billing periods in the year • average number of members of the households • family disposable income • number of units charged regardless of actual use (takes into account impact of free allowance level) (+) • percentage of population over age 64 • percentage of dwellings statistically regarded as main residence	monthly panel data, north-west Spain
Espiñeira and Nauges (2004)	Per-capita average domestic consumption per month	• minimum threshold level of water (+) • income/price ratio (insignificant with variable threshold level assumption) • outdoor usage bans • average past consumption (with variable threshold level assumption) (+) • supply restrictions (-) • normal value of rainfall (-)	Seville, Spain (1991 to 1999)

Authors (year)	Dependent variables	Independent variables other than policy variables (mostly demographic characteristics)	Data and Country
Gaudin (2006)	per-capita annual water consumption	• average price (-) • income (+) • average household size (+) • density (-) • average annual precipitation (-) • number of days when temperature is above 90⁰F (+) • information dummy for marginal price info (unit price of water is given next to the units consumed) (-) • information dummy for price info (full price information of water is given anywhere in the bill) (-) • information dummy for quantity consumed info • information dummy for combined water billing with sewerage, gas or electricity and high-frequency billing • information dummy for the increased block rate	cross-sectional community level data, USA (1995 to 1996)
Krause *et al.* (2003)	percentage of water resource stock drawn	• price (-) • age (in case of retirees only) (-) • female • Hispanic (among retirees, Hispanics use more water than their Caucasian counterparts) (+) • political or religious affiliation • attendance in religious services (retirees consume more water) (+) • years of schooling • risk preferences (risk-averse working adults and risk-loving retirees use less water) (-)	classroom experiment of 114 people consisting of three groups: students, working adults and retired people

Authors (year)	Dependent variables	Independent variables other than policy variables (mostly demographic characteristics)	Data and Country
Mazzanti and Montini (2006)	Per-capita water consumption	- price (central price of the tariff structure, medium block) (-) - income (+) - population - population density - household size - percentage of population above 65 years - percentage of population below 19 years - altitude (interaction term with population) (-) - elderly ratio	Emilia-Romagna, Italy (1998 to 2001)
Nauges and Thomas (2000)	water consumption in local community	- marginal price (-) - average price (-) - income (+) - rainfall during summer - population density - proportion of inhabitants aged more than 60 years (-) - proportion of households consisting of one or two members - local economic activity (+) - proportion of single-unit houses (-) - proportions of homes with a bath (significant when average price model used) - proportion of households with one or more cars - proportion of housings built before 1949 (insignificant when average price model used) (+) - proportion of housings built after 1982 (-)	panel data from 116 communities, eastern France (1988 to 1993)
Nauges and Thomas (2003)	annual consumption of water (intertemporal choice)	- lagged consumption (+) - price of water (-) - income (+)	panel data from 116 communities, eastern France (1988 to 1993)

Authors (year)	Dependent variables	Independent variables other than policy variables (mostly demographic characteristics)	Data and Country
Nieswiadomy and Molina (1989)	monthly water consumption	• price (-) • difference variable (+) • income (+) • lawn size (+) • weather (+) • house size (+)	monthly data, Denton, Texas (1976 to 1985)
Pint (1999)	bi-monthly water use	• marginal price (-) • difference variable (+) • house size (+) • lot size (+) • precipitation (-) • lagged precipitation (-) • monthly average temperature (+) • lagged average temperature (+)	Alameda County Water District, California (Jan 1982 to Jul 1992)
Renwick and Archibald (1998)	water consumption per household	• lagged marginal price (-) • income (+) • lagged difference variable (+) • dummy for Santa Barbara's landscape irrigation use restriction policy (-) • dummy for Goleta's quantity-related water allocation policy (-) • dummy for low-density households (+) • dummy for medium-density households (-) • number of members in a household (+) • number of faucets in the household (+) • cumulative monthly rainfall • adoption of traditional irrigation technologies by the household (+) • adoption of water-efficient irrigation technologies by the household (-) • adoption of low-flow showerheads by the households (-) • adoption of low-flow toilets by the households (-) • consumer price index (-)	household survey data, Santa Barbara and Goleta, California (1985 to 1992)

Authors (year)	Dependent variables	Independent variables other than policy variables (mostly demographic characteristics)	Data and Country
Renwick *et al.* (1998)	average household monthly water use	• marginal price (-) • difference variable • public information campaigns dummy (-) • subsidies dummy for adopting water-efficient technologies • free retrofit kit distribution dummy (-) • rationing of water dummy(-) • restriction on some types of water use dummy (-) • compliance dummy for certain conservation measures • limited irrigation dummy (-) • irrigation dummy (+) • average monthly gross household income (+) • average household lot size (+) • average maximum air temperature (+) • precipitation	eight urban water agencies, California, USA (1989 to 1996)
Schefter and David (1985)	total quantity of water delivered to residential users	• marginal price (-) • income (+) • difference variable	aggregate data, 131 Wisconsin communities

Authors (year)	Dependent variables	Independent variables other than policy variables (mostly demographic characteristics)	Data and Country

Strand and Walker (2005)	average water consumption	• access to metered tap water:
		  - marginal water price
		  - average price of water (-)
		  - household income (+)
		  - children (+)
		  - adults (+)
		  - with telephone (+)
		  - value of house (+)
		  - dummies for service hours (rationing of water through reduced service hours only affects those households that are not served everyday) (+)
		• no access to tap water:
		  - water price (-)
		  - truck water time hauling cost (-)
		  - other water time hauling cost (-)
		  - household size (+)
		  - household income (+)
			survey data,
			17 Central American cities

Taylor et al. (2004)	quantity of domestic water demanded	• price (marginal price, average revenue) (-) • highest annual temperature (+) • monthly precipitation • income (+) • water conservation program dummy • various pricing dummy [increasing block (-), decreasing block (+), un-metered (+) compared to constant rate]	cross-sectional data, 34 utilities from Colorado water districts

Authors (year)	Dependent variables	Independent variables other than policy variables (mostly demographic characteristics)	Data and Country
Whittington *et al.* (1990)	probability that a household's WTP for a public stand-post (private connection) falls within a specific interval	- household wealth index (+) - dummy for household foreign income - dummy for occupation index (farmer or non-farmer) (significant for private connections) - household education level (+) - distance from existing source (+) - quality index of existing source dummy (quality = 1 if satisfactory) (-) - dummy for sex (male = 1) (insignificant for private connections) (-)	Laurent, southern Haiti (1986)
Wong (1972)	average per-capita water demand	- price of water (insignificant for Chicago) (-) - average household income (insignificant for suburbs) (+) - average summer temperature (+) - price of water (insignificant for smallest community) (-) - average household income (insignificant for smaller communities) (+)	time series analysis, Chicago and nearby communities, Illinois (1951 to 1961) cross-sectional analysis with four community sizes
Woo (1994)	monthly per-capita water use	- monthly average rate of water (-) - monthly per-capita income (+) - monthly supply hours of water (during the supply interruptions) (+) - rainfall – evaporation - average temperatures (+) - quarter dummy (Q1) (-) - quarter dummy (Q2) (+) - quarter dummy (Q3) (+) - number of calendar days per month (+)	Hong Kong (1973 to 1990)

TABLE C.3: Summary of income and price elasticities of demand for residential water

Authors (year)	Policy program	Price elasticity	Income elasticity	Comments
Billings and Agthe (1980)	• increasing block rates	-0.267 (double-log model) -0.49 (linear model)		marginal price used
Chicoine and Ramamurthy (1986)	• declining block price schedule	-0.47 (for marginal price)		
Dandy et al. (1997)	• two-part tariff (free allowance with a fixed charge + unit price of water beyond the allowance level)	-0.28 (short-run) -0.63 to -0.77 (long-run)	0.14 (short-run) 0.32 to 0.38 (long-run) (property value used as a proxy for income)	price elasticities are above free allowance level; under free allowance level, elasticity is zero as marginal price is zero.
Espiñeira (2000)	• increasing block rate	-0.12 to -0.16		various model specifications used
Espiñeira and Nauges (2004)	• increasing block rate • restricted daily water supply hours during severe drought periods • temporary outdoor use bans	-0.10	0.10	on average
Gaudin (2006)	• using clear pricing information on water bills	-0.37 -0.51 (with price information on water bill)	0.30	
Headley (1963)			cross-sectional: 1.49 (in 1950) 1.24 (in 1959) <u>time-series:</u> 0.00136 to 0.4035 (for 14 cities)	water use regressed on consumers' income
Mazzanti and Montini (2006)	• increasing block-rate structure	-0.99 to -1.33	0.40 to 0.71	introduction of time effects or other socio-economic variables reduces significance level of income variable, and sometimes makes it insignificant.

Authors (year)	Policy program	Price elasticity	Income elasticity	Comments
Nauges and Thomas (2000)	• two-part tariff • existence of own water meter in single-unit houses	-0.22	0.1	
Nauges and Thomas (2003)	• two-part tariff	-0.26 (short-run) -0.40 (long-run)	0.51 (long-run)	
Nieswiadomy and Molina (1989)	• increasing block rate (1976 to 1980) • decreasing block rate (1981 to 1985)	-0.36 to -0.86		2SLS and IV techniques used
Pint (1999)	• increasing block rate	<u>heterogeneous preferences model</u>: -0.04 to -0.14 (summer) -0.07 to -0.29 (winter) <u>two-error model</u>: -0.20 to -0.47 (summer) -0.33 to -1.24 (winter)		less elastic demand curve with heterogeneous- preferences model than with two-error model
Renwick and Archibald (1998)	• increasing block-rate pricing • dummy for Santa Barbara's landscape irrigation use restriction policy • dummy for Goleta's quantity-related water allocation policy • dummy for the low-flow toilet and showerhead subsidy programs • adoption of traditional irrigation technologies by the household • adoption of water-efficient irrigation technologies by the household • adoption of low-flow showerheads by the households • adoption of low-flow toilets by the households	-0.33 (short-run) -0.39 (long-run)	0.36	2SLS estimation methods used

Authors (year)	Policy program	Price elasticity	Income elasticity	Comments
Renwick *et al.* (1998)	• uniform and block-rate pricing • public information campaigns • subsidies for adopting water-efficient technologies • free retrofit kit distribution • rationing of water • restriction on some types of water use • compliance for certain conservation measures	-0.16 -0.20 (June to August)	0.25	
Strand and Walker (2005)	• block-rate pricing • rationing of water through reduced service hours	<u>With tap water access:</u> -0.1 to -0.2 (using MP) -0.3 (using both MP and AP) <u>No tap access:</u> -0.10	< 0.1 (same for both groups of households)	
Taylor *et al.* (2004)	• various price schedules (flat-rate pricing, increasing block, decreasing block, and un-metered fixed fees) • water conservation programs	-0.297 (with MP) -0.403 (with AP)	0.38	TSLS estimation process
Wong (1972)	• flat rate of water per 1 000 gallons (Chicago) • block rates (suburban communities)	-0.02 to -0.28	0.20 to 0.26	time series
		-0.26 to -0.82	0.48 to 1.03	cross-sectional
Woo (1994)	• restricted supply of water (service interruptions) • inverted block-rate pricing	-0.4684	0.2354	based on double-log/AR(1) specification

Note: marginal prices (MP), average prices (AP)

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