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Public Policies and Investment in Network Infrastructure

by
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How can public policy influence investment in infrastructure in network industries? Network industries rely mainly on fixed networks to deliver services, with investment being lumpy and largely irreversible. As a result, public policies – such as public provision, the introduction of competition and the regulatory environment – can potentially have an important impact on investment behaviour, with the net effect depending on the extent that policies boost socially-productive investment or reduce inefficient investment. Drawing on responses to a unique questionnaire assessing public policy in the network sectors, the information in this paper presents a systematic picture of relevant policies in place across OECD countries. Econometric analysis – both at the sectoral and firm level – finds that public policies can have significant quantitative effects. In particular, the introduction of competitive pressures through the reduction of barriers to entry and the combination of regulator independence and incentive regulation can promote investment in the sector.

JEL Classification: H40, L90, O40, Q48

Keywords: Infrastructure, growth, network industries, investment, regulation

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How can public policy influence investment in infrastructure in network industries? Over the past few decades, the provision of infrastructure has undergone profound changes. The public sector was often responsible for provision, but over time, given the combination of privatisation, technological change and the development of new contracting techniques coupled with the establishment of independent regulatory authorities, private provision accounts for an increasingly large share of total investment. This raises questions about how the emerging institutional frameworks affect incentives to investment in infrastructure.

In order to address these questions, the analysis in this paper focuses on infrastructure in energy, water, transport and communications. These sectors are chosen not only because of their importance to the economy, but because they rely mainly on fixed networks to deliver their services, with investment in infrastructure assets being lumpy and largely irreversible. As there are elements of natural monopoly and market failure, public policies are often important. Addressing market failure has been a major motive for public intervention in infrastructure provision, intending to prevent the under-provision or non-provision of infrastructure, when externalities or public good features are predominant, or to limit the exercise of market power to the extent to which a natural monopoly is present.

Where supply entails a natural monopoly, as is typical in the network industries, the private sector will usually be willing to provide the service, though normally at a level that is below, and a price that is above, the social optimum. This will often result in some type of arm's length regulation. Investment will depend on standard investment determinants, such as the cost of capital, but due to the often extremely large fixed costs and the irreversibility of investment decisions, investment decisions are also particularly sensitive to the regulatory environment. As a result, direct public provision, the introduction of competition and the regulatory environment can potentially have an important impact on investment behaviour.

Despite the rationales for public provision to counter under-provision of infrastructure, the move towards greater private provision and more independent regulatory regimes does not necessarily imply lower investment levels. By better aligning incentives for investment and reducing uncertainty stemming from regulatory risk, the innovations seen in recent decades could provide a spur for investment.

The empirical literature assessing the impact of policies on investment has faced a number of difficulties. Data limitations on the diversity of policies in place make it difficult to measure the impact of a particular policy on investment for an individual sector yet alone across a number of sectors. Researchers are often better able to examine the impact of a change in policy through case study evidence or for policies (often a single regulatory policy) for an individual sector. For example, Edwards and Waverman (2006) find that greater regulatory independence is important for the telecommunications sector while Cambini and Rondi (2010) find that investment is higher in firms under incentive

regulation. More aggregate empirical studies have sometimes pooled the data for the sectors covered and thus say little about how the measured effects differ across sectors. For example, in time-series regressions using sectoral data, Alesina *et al.* (2005) noted that lowering barriers to entry was found to boost the investment rate. The empirical work in this paper addresses how general some of these types of findings are across different sectors and also considers interactions between policies.

The structure of the paper is as follows. Section 1 discusses the channels through which public policy affects infrastructure investment, drawing on responses to a unique questionnaire on infrastructure investment. Section 2 contains a discussion of the econometric approaches at sectoral and firm level to assess the impact of public policies on infrastructure investment, which is followed by a presentation of the results. Finally, Section 3 concludes.

1. Public policies in the infrastructure sectors

This section describes how public policies can influence investment behaviour in the infrastructure sectors and draws on two principal sources of information to describe actual public policies in OECD countries.[1] The first source of information is derived from responses to the OECD Regulatory Indicators Questionnaires (Wölfl *et al.*, 2009). This is a regular OECD questionnaire, issued every five years, which is much broader in scope than infrastructure but contains specific questions on policies for some network sectors. For example, the questionnaires contain responses on public ownerships, market structure, barriers to entry and regulator independence for energy, telecommunications and transportation.

A second source of information on public policies is an *ad hoc* questionnaire on infrastructure investment (*http://dx.doi.org/10.1787/888932482365*) submitted to the OECD member governments in December 2007. The aim of the questionnaire was to collect comparable cross-country information, complementing and extending the existing regulatory indicators. The questionnaire was divided into three sections concerning regulation (covering regulators and pricing policies), specific questions on concessions and franchises as well as questions on infrastructure planning and financing.[2] The questionnaire covered the energy (electricity and gas), water supply and sewerage, transport (railroad, road, water and air transport), and the telecommunication (fixed line, mobile and internet services) sectors. Respondents were requested to answer reflecting the regulatory settings at the time of response and not to anticipate changes. When appropriate, central governments were asked to respond basing their answers on institutions prevailing in the most representative sub-central governments or a subset of them that best characterised each country's institutional settings. As with the Regulatory Indicators Questionnaire, questions typically required a yes/no response.

The questionnaire was quite detailed and despite the burden it imposed, response rates were relatively good. In total, the questionnaire asked 38 sets of questions, which taking into account the sectoral coverage implied a possible 1 370 separate responses. Of the 30 OECD members at the time, 25 countries responded to the questionnaire (*http://dx.doi.org/10.1787/888932482384*).[3] The section on regulators and pricing policies had the highest response rate, with all respondents answering questions on the existence of sectoral regulators, their mandates and competencies. On average for this section, the response rate for specific questions was 83%. The response rate to the section on pricing

policies was 75%. Three-quarters of countries responded that they used concessions and franchises, though for the specific questions in this section the response rate sometimes dropped to 50%, often due to limited sectoral coverage. Finally, the response rate for the section on investment planning was around 60% while response rates to specific questions on public-private partnerships (PPPs) were around two-fifths, though conditional on the countries having noted experience of using PPPs the response rate rose to around one-half.

1.1. Public ownership and provision

There are a number of different delivery modes involving the public or private sector to a greater of lesser extent. These include public ownership and procurement, which has often characterised the water supply and road networks; concessions and public private partnerships, which are increasingly involving the private sector in the delivery of infrastructure; and fully privately-owned companies, which has often been the case in the energy sector. Until the late 1980s, public ownership was the dominant ownership form for many network industries. According to OECD indicators, public ownership only declined in importance in some of them quite recently (Figure 1). In the water sector, which is not covered by these indicators, public ownership characterised the ownership structure in two-thirds of OECD countries quite recently (OECD, 2004).

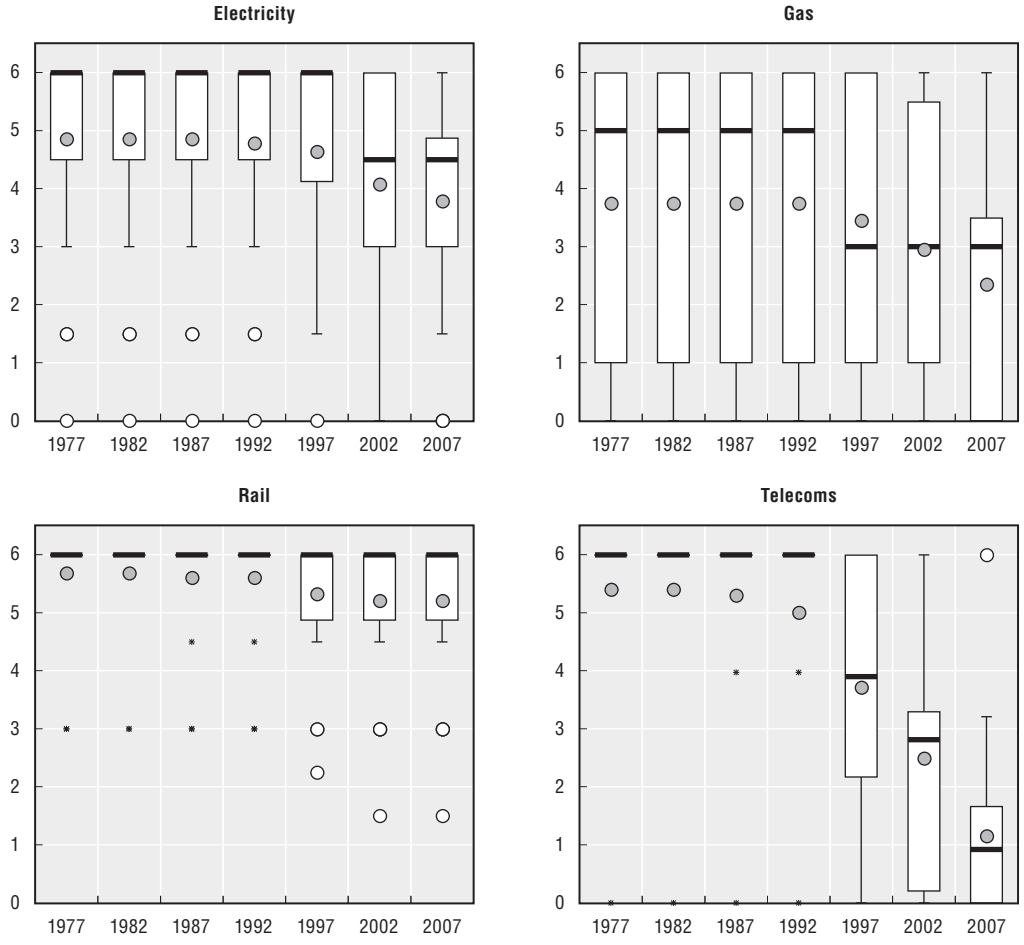
The decline of public ownership partly reflects recognition among OECD governments that it can contribute to inefficient investment in infrastructure. For instance, overinvestment may occur as public managers engage in "empire building" behaviour to strengthen their support with the politicians who appointed them (*e.g.* by expanding capacity and employment in public enterprises). Indeed, some telecom operators cut back ambitious plans to expand fibre-optic networks in the wake of privatisation. At the other extreme, underinvestment may occur, if public authorities pay insufficient attention to the long-term benefits of investment in a context of fiscal pressures. Public investment may also lead to the misallocation of resources across regions and sectors. For example, policymakers may allocate resources to a given region or project at the expense of other potentially higher return investments in more deserving regions or projects (Cadot *et al.*, 2006; Castells and Solé-Ollé, 2005). Investment may also be allocated sub-optimally over time if it is allowed to be influenced by the electoral cycle.

Public ownership can also create disincentives for privately-operated firms to invest in network industries. First, the lack of a level playing field – often due to the state-owned company's soft budget constraint – is a disincentive for private firms to invest. Second, there may be confusion between the role of the state as the regulator and owner, which serves to amplify regulatory discretion and risk (this is discussed below). Finally, state ownership can be a *de facto* barrier to foreign direct investment.

Against this background, private sector provision has become increasingly attractive. First, in some sectors – such as telecoms and electricity – the extent of the natural monopoly element has been redefined, in part as a result of technical progress or as a result of sunk costs having already been incurred, opening the door to competitive private provision. Second, refinements in regulatory techniques (see below) have made "arm's length" regulation of private providers of infrastructure more desirable than direct public provision. Similarly, new contracting techniques were designed, which made contracting out of infrastructure provision more attractive than in the past. Finally, particularly in the presence of mature networks, specific distributional objectives were often found to be more efficiently achieved by other mechanisms, such as targeted social transfers.

Figure 1. **The declining importance of public ownership in network utilities**

Scale 0-6 from lowest to highest degree of public ownership



Note: These plots display the box that covers the observations between the 1st and 3rd quartiles, as well as the median (the horizontal bar) and the mean (the point). The whiskers extending from the box give the range that captures the observations which lie within 1.5 times the inter-quartile range from the 1st and 3rd quartiles. Points outside this range are considered outliers, which are marked by an asterisk.
The sample coverage is the same for each period. For electricity the countries included are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Netherlands, New Zealand, Norway, Mexico, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States. For gas, the country coverage is the same as electricity with the exception of the Slovak Republic. For rail the country coverage is the same as electricity with the exception of Iceland. For telecoms the country coverage is the same as electricity with the exception of Iceland and Luxembourg.
In the rail and telecommunication utilities, public ownership was predominant until the early 1990s in almost all countries.

Source: Regulatory indicators questionnaire.

1.2. Unbundling and market structure

Greater private provision and competitive pressures for efficient infrastructure investment can also be introduced through the unbundling of the natural monopoly elements of networks. The implications of vertical separation and of the ownership of the "core" network (the particular segment that is a natural monopoly also sometimes termed "essential facility") are important for investment. An attraction of coupling entry liberalisation in competitive markets with vertical separation of the network industries is that the private sector will determine the appropriate level of investment in the competitive

segment of the industry. For example, while a vertically-integrated firm may innovate, particularly if there are first mover advantages and the market is contestable, more competition creates incentives to expand capacity and may give sharper incentives to invest in cost-saving technologies and organisational forms (as observed, for instance, in the development of low-cost air transport and innovations in mobile telephony after liberalisation). However, appropriate ownership and regulatory settings would still be needed to ensure an efficient level of investment in the core network.

The argument for retaining a vertically-integrated firm largely depends on the loss of economies of scale and scope and possible co-ordination problems and higher transaction costs in a vertically separated industry. In some sectors, such as mature electricity and gas networks, these factors are not crucial, supporting their unbundling, which was implemented especially in the electricity sector of OECD countries over the past decade. In the case of railroads a large range of options exist across the OECD, running from vertically-integrated public enterprises to vertically-separated private companies. In this sector, the problems created by vertical separation are arguably severe. Train operating companies are relatively unconcerned with lowering high marginal costs for the network operator, and the network operator – not benefitting from higher revenue from train operators – has little incentive to improve its services. Not only may this constellation of incentives lead to under provision of rail track services, some studies suggest that the resulting losses of economies of scope increase production costs by between 20% and 40% when the sector is fully separated (OECD, 2006).

In some parts of the network industries, there may be reasons for maintaining a vertically-integrated firm, such as allowing facilities-based competition to emerge in the long run while allowing service-based competition in the short run to create pressure to increase cost efficiency (in parts of telecommunication networks, for example). In this case, the network operator provides wholesale services to downstream competitors, which may blunt incentives to invest in quality (Auriol, 1998). The resulting regulatory problems are severe, and firms need careful monitoring to prevent the exercise of market power with care also needed in setting the appropriate access regime and price as this is complicated by the firm operating in both regulated and unregulated markets (see below).

When vertical separation is desirable, a central question concerns the ownership structure of the core network. Countries differ markedly with respect to different organisational forms. In the electricity sector, for example, the electricity transmission grid is privately owned and operated in the United Kingdom and Germany, privately owned and operated by an independent company in some parts of the United States, state-owned and run by an independent company in Italy and state owned and operated by a state-owned enterprise in the Netherlands. In some cases, the regulatory authorities have mandated that the "essential facility" be operated by a different entity than a user (to prevent foreclosure). The different types of organisational forms have potentially different consequences for investment (OECD, 2001).[4]

- *Accounting and legal separation:* Formal separation has generally been insufficient to change the behaviour of the incumbent, often amounting to *de facto* vertical integration, and does little to relieve the regulator's burden in determining the appropriate level of investment. For example, in the early 1990s, the UK competition authorities found that a greater degree of separation was desirable for British Gas, then a vertically integrated gas

company. Accounting and legal separation characterises industry structures in energy, rail and telecommunications in many EU countries that implemented the minimum requirements set by EU directives.

- *Operation separation:* This occurs when an independent entity controls the non-competitive component. A key element is whether this entity should be allowed to generate profits. If the governing entity has no interest in the profitability of the non-competitive component it may have little incentive for efficient and innovative investment in the non-competitive activity. Operational separation is a form used in the US electricity industry. But in the United States, electricity retailing companies have complained that (operationally-separate) transmission companies have not been responsive to changes in demands nor innovative (OECD, 2001).
- *Ownership separation:* In this case, the owner of the network will not discriminate among users and thus many of the competition problems that can arise in other organisational structures are mitigated. An example is the National Grid in the United Kingdom. In the absence of co-ordination problems, creating appropriate investment incentives depends on the regulatory framework and the setting of access prices, which are discussed below.
- *Club ownership:* Club ownership – when the core network is owned by a consortium of firms using the network – will help align incentives for network operators and downstream competitors. However, when the number of downstream competitors is small, collusion and foreclosure may result and when the number of competitors is large there may be principal-agent problems. Many EU countries have chosen club ownership between the major airlines and the slot allocation function at major airports or for electricity transmission in Italy.

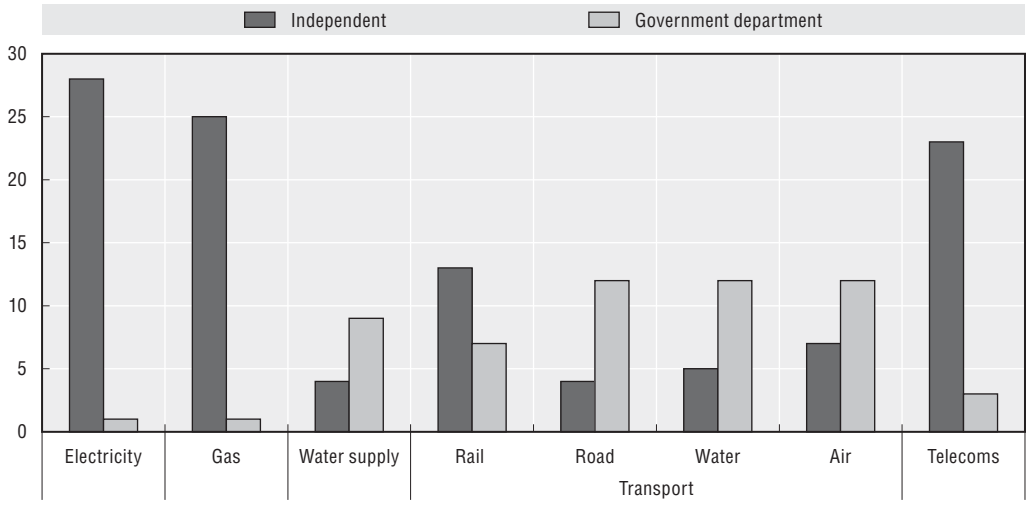
1.3. Regulation and other framework conditions

Regulation – which is prevalent in network industries – and other framework conditions will play an important role in investment decision making through their effect on determining the return on investment as well as ensuring efficient use and expansion of infrastructure through the effects of pricing. This section discusses how these policies can be designed to support such incentives, considering in turn institutional arrangements for the regulator, network access conditions and the pricing regime.

An important factor affecting investment in regulated network industries is the nature of the regulator. The regulator faces potential difficulties both in its relations with the government and the sector it is regulating – including political and private interest pressures – as well as problems related with lack of credibility and asymmetries of information (OECD, 2005). Ensuring the regulator's independence is central to preventing regulatory capture and enhances the stability and credibility of the regulatory framework, in a context where accountability to the government, the legislature and consumers should nonetheless be preserved. To facilitate independence, desirable features for the regulator's operation include providing a legal mandate (including criteria and procedures for over-ruling decisions), ensuring the regulator is separated and autonomous from the government, and defining how appointments and dismissals of regulators are to take place to minimise the possibility for pressure being applied to members. As can be seen in Figure 2, regulator independence across sectors varies substantially.

When it is appropriately designed, regulatory independence should help both improve the quality of regulation and, by holding the regulator accountable for

Figure 2. **Independence of the regulator**



Source: Infrastructure investment and regulatory indicators questionnaires.

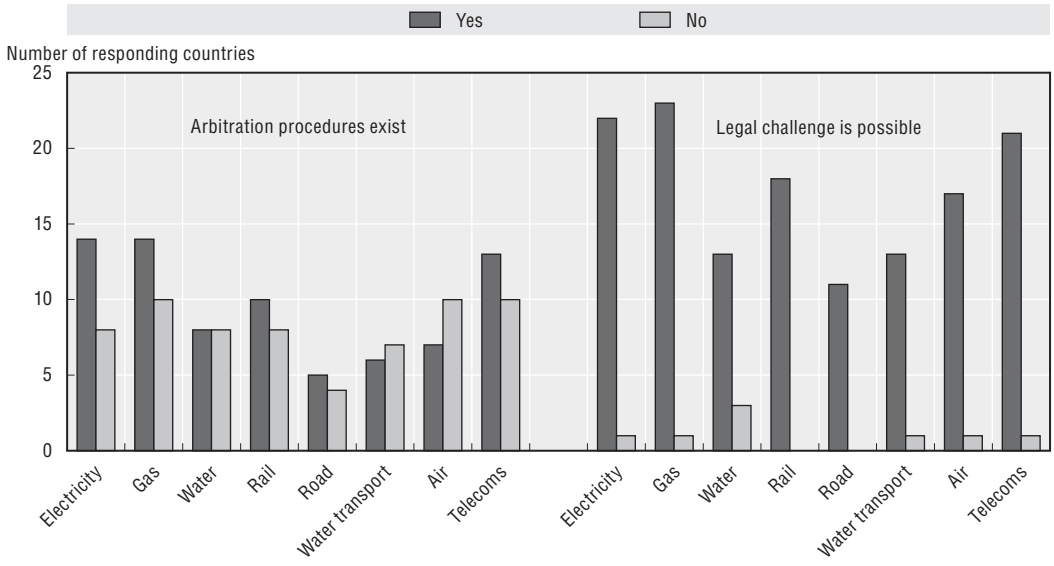
implementing its mandate, reduce the discretion that the regulator can exercise. In this framework, regulated firms will have greater certainty about regulatory outcomes over time (policy consistency) and may also be more willing to share information with the regulator than it would be the case with the government. Excessive use of discretionary powers by regulators can introduce uncertainty, with detrimental effects on investment incentives. Uncertainty may ultimately delay investments and skew them towards less capital intensive projects than is socially optimal (Couper *et al*. 2003).

Policymakers can try to overcome the potentially negative implications of regulatory uncertainty for investment in infrastructure in a number of ways. One approach is to determine the duties of the regulator in legislation, the requirements of the licence holders and procedures for dispute resolution, either through the courts or by appeal to the competition authorities. In other cases, such as the United States, well-defined administrative procedures govern how regulators act, make decision and can be challenged (Newbery, 2000). In both cases, one aspect of the mechanism to counter unexpected changes in regulation is the ability to appeal against the regulator's decisions. In Figure 3, it is apparent that legal challenge is generally more developed than arbitration procedures, although this can be more time consuming. In both cases, country responses report that these mechanisms are more prevalent in the energy and telecommunications sectors than transport and water. Another approach would be to embed regulatory reactions to changes in market conditions in a predictable framework. For example, revenue sharing rules for when firm profits rise above thresholds could mitigate the uncertainty arising due to the fear that high profits could provoke a change in the regulatory regime.

1.4. Access conditions

Barriers to entry and anti-competitive behaviour by incumbents can create obstacles to efficient investment. These issues are in the purview of the competition authorities and sector regulators, which track abuses of dominance and determine access conditions and pricing to existing infrastructure, respectively.[5] Levelling the playing field requires, *inter*

Figure 3. **Dispute settlement with the regulator**



Source: Infrastructure investment questionnaire.

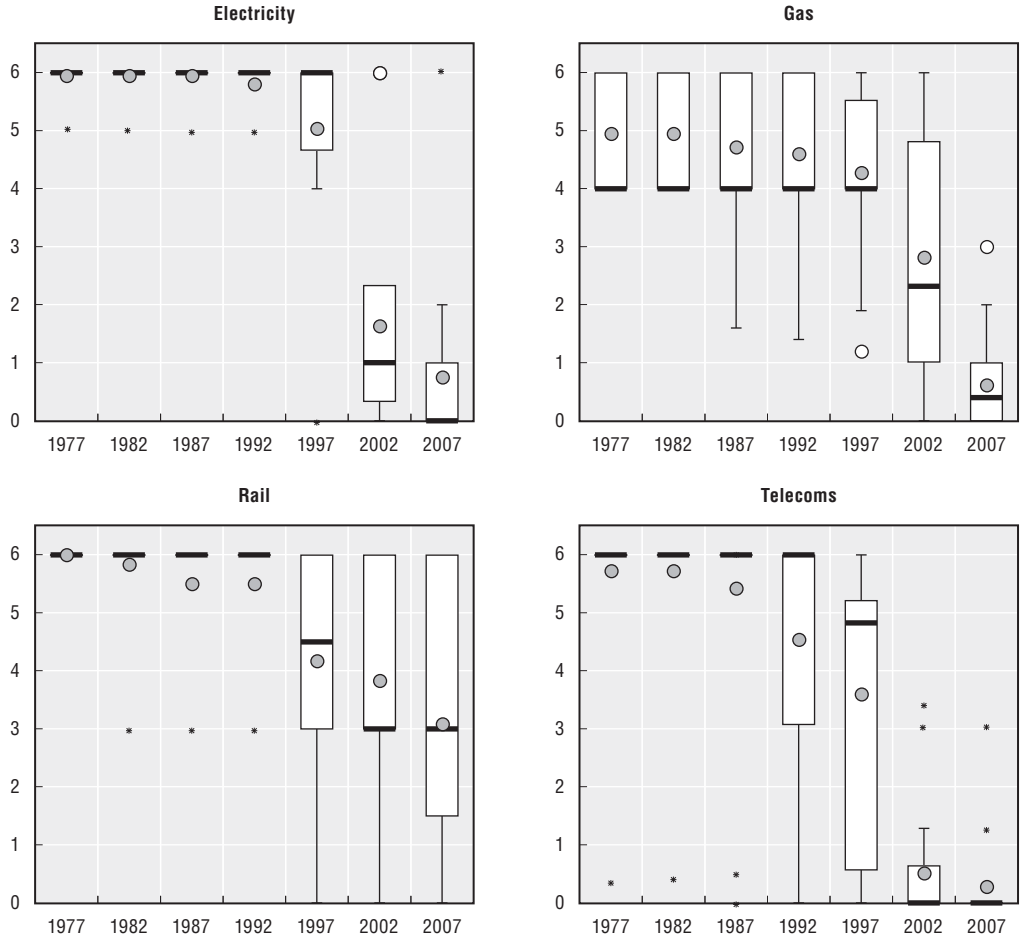
alia, liberalising entry through vertical separation, where appropriate, and introducing regulated third-party access. In OECD economies there has been substantial progress in implementing such policies and removing other barriers to entry (Figure 4).

- This is particularly the case in telecommunications during the 1990s, when most legal restrictions were lifted on both fixed and wholesale services. On average in 2007, the market share of new entrants in mobile telephony exceeded 50%, with only Mexico noticeably lower. For international calls, new entrants' market share was slightly less on average at around two-fifths with progress in opening up this market much slower in some countries, such as Turkey and the Slovak Republic.
- Substantial easing of entry barriers also occurred in the electricity sector, where in 2007 almost all countries had implemented regulated third-party access (TPA), with only Germany and Switzerland using negotiated TPA and Mexico without a TPA regime at all. Furthermore only a handful of countries – Japan, Korea, Mexico, Switzerland and the United States – permit vertically-integrated firms in the electricity sector. However, bottlenecks in interconnection capacity restrain new entry.
- Progress in the gas sector has been less dramatic, but barriers to entry have begun to fall. In the gas sector, both vertically-integrated firms and negotiated third-party access are more common than in the electricity sector. In many countries storage remains largely dominated by incumbents and bottlenecks in interconnection capacity restrains new entry.
- In rail, where reforms have tended to be more recent, few countries have implemented full vertical unbundling possibly recognising the severe co-ordination problems that can arise. Reforms when they have occurred have tended to be for freight rather than passenger transport. However, most countries have imposed legal or accounting separation.

Rules that determine the access conditions to the core network and its pricing have particularly important implications for infrastructure utilisation and investment. Regulated

Figure 4. **Barriers to entry**

Scale 0-6 from lowest to highest degree of barriers to entry



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The sample coverage is the same for each period. For electricity and telecoms the countries included are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Netherlands, New Zealand, Norway, Mexico, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States. For gas and rail the country coverage is the same as for electricity and telecoms with the exception of Iceland.

Source: Regulatory indicators questionnaire.

or negotiated third-party access (TPA) regimes have been established in OECD countries, with regulated access being considered the most favourable to the development of competition in unregulated services. The effects of these regimes on infrastructure investment are intimately related to dispute resolution in the case of negotiated TPA and the terms of access conditions in the case of regulated TPA. In some cases, such regulations have been waived or adapted in energy markets where security-of-supply considerations are important.

Where facilities-based competition is viable, such as with airports and maritime ports and mobile telecommunications, ensuring a level playing field through appropriate competition policy enforcement is crucial to encouraging efficient infrastructure investment. Moreover, when the incumbent remains vertically integrated, but competition

in the unregulated sectors is possible, new entrants can face considerable difficulties with implications for investment:

- Strategic behaviour of a vertically-integrated incumbent can limit access to its regulated infrastructure for competitors in unregulated upstream or downstream markets by either foreclosing practices or insufficient expansion (or retention) of capacity.
- Even when the incumbent does not implement anti-competitive practices, new entrants wishing to invest in infrastructure may still be put at a competitive disadvantage relative to the incumbent, at least initially. This type of outcome has been a feature of telecom liberalisation where the incumbent often enjoyed economies of scale or scope.

1.5. *Pricing regimes*

The decisions of regulatory institutions concerning the desired market structure (reflecting the degree to which competition is possible), access regimes and pricing play important roles in determining infrastructure supply and use. In particular, the regulator often needs to set user costs, access prices or final prices, depending on whether the network provider is vertically integrated and competition is feasible. Under certain conditions, setting the price equal to the marginal social cost would be welfare maximising and when the networks are characterised by constant returns to scale this form of pricing would also cover investment costs. However, marginal cost pricing will not cover capital and operating costs if investment is characterised by increasing returns to scale. In this context, subsidisation or government provision may be warranted when the marginal social benefits arising from additional infrastructure outweigh the marginal social costs. Alternatively, the regulator may adopt an alternative pricing structure to cover investment costs. For example, multi-part tariffs can help preserve pricing that reflects short-run marginal costs while recouping investment costs (Gans, 2001). In other cases, so-called Ramsey pricing, which allows prices to vary in line with elasticities of demand for different services, will minimise the welfare losses arising from deviations from marginal cost pricing. Given the importance of pricing to investment decisions, the credibility and consistency of the regulatory framework are important determinants of infrastructure investment.

The regulator will need to set access prices when there is a vertically-separated firm (such as some electricity transmission grids) and also when service-based competition is feasible with the vertically-integrated firm (such as in telecommunications). In addition, when core network providers have monopoly power, the regulator will need to set the final price (such as in the water sector or operators of toll roads, bridges and tunnels) or a basket of prices (such as for rail). There are two broad approaches to pricing; either basing prices on costs (so that prices may change also to reflect the costs of investment) or using incentive-based pricing policies (where, at least for a period, prices do not vary in response to investment decisions).

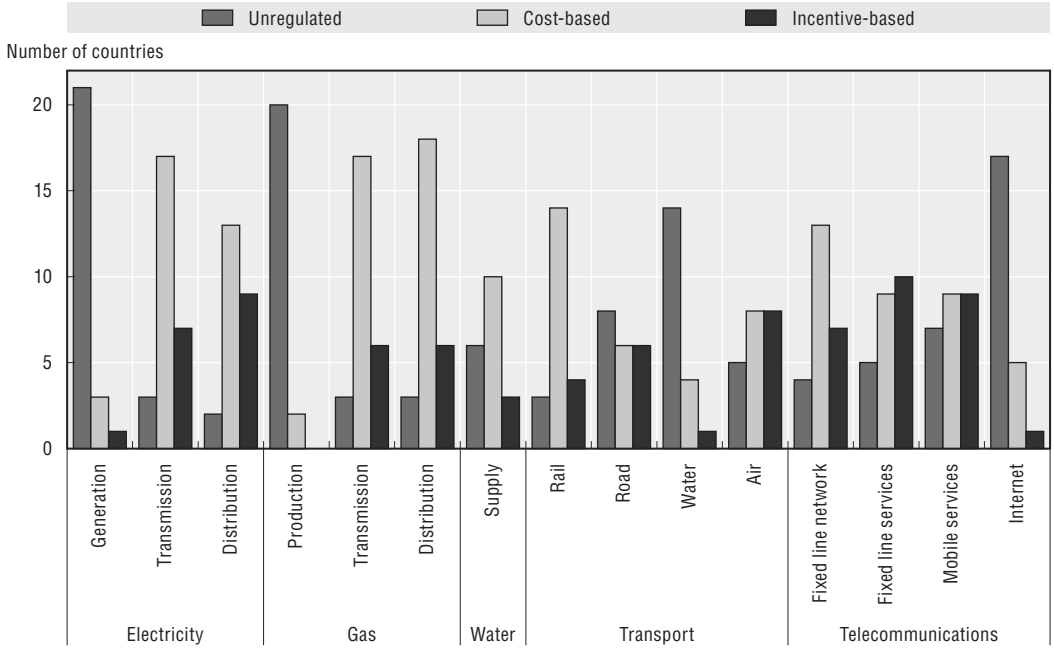
Cost-based pricing – such as rate-of-return regulation – sets prices to cover production costs and allow a permissible margin, which should allow the firm to recover investment costs and can specifically relate to the return the firm is allowed to earn on its capital. In ensuring efficient investment a critical regulatory parameter is the so-called "rate base" on which the rate of return is calculated. However, measuring costs, particularly the common costs that are shared across products, is a difficult task. On the whole, the empirical evidence suggests that the outcome of cost-based regulation has tended to lead to inefficient investment and a slow rate of technological progress. Cost-based pricing provides limited incentives for the firm to

invest in cost-reducing technologies and encourages over-investment if the allowable rate of return exceeds the cost of capital (Averch and Johnson, 1962). Over-investment and the ensuing excess capacity may also be used as a strategic tool to deter potential entrants. Starkie (2006) reports evidence of this happening in the European gas industry and in the UK airport sector. Finally, firms have often continued to depend on government subsidies because of the poor incentives to eliminate inefficiencies.

Against the background of the difficulties in determining costs and the specific rate of return, incentive-based pricing regimes – such as price caps – have gained popularity and often accompanied deregulation and privatisation. In its most basic form of a price cap, prices are set with no explicit consideration of a specific rate of return. The underlying idea is to give firms "high-powered" incentives to invest in cost-saving technology and at the same time simulate competitive conditions which constrain firms' monopoly profits in the long run. To this end, the regulator specifies a price basket that is allowed to increase in line with an exogenous measure of input costs minus a pre-determined factor reflecting expected efficiency gains, possibly allowing as well for expected increases in quality of service. Price cap reviews are made at regular intervals and, when they are not too frequent, this price regime creates incentives for firms to engage in long-term cost-reducing investment.

When prices are regulated, cost-based prices are generally predominant, particularly in the electricity and gas sectors, and to a lesser extent in fixed-line telecommunication networks and rail (Figure 5). Furthermore, in practice price reviews are held frequently in many OECD countries, both for incentive-based pricing and cost-based regimes (Figure 6). In most sectors, countries report that they normally review prices at an annual frequency. Only in the United Kingdom and Italy are prices reviewed less frequently – around 4-5 years – on a systematic basis across sectors.

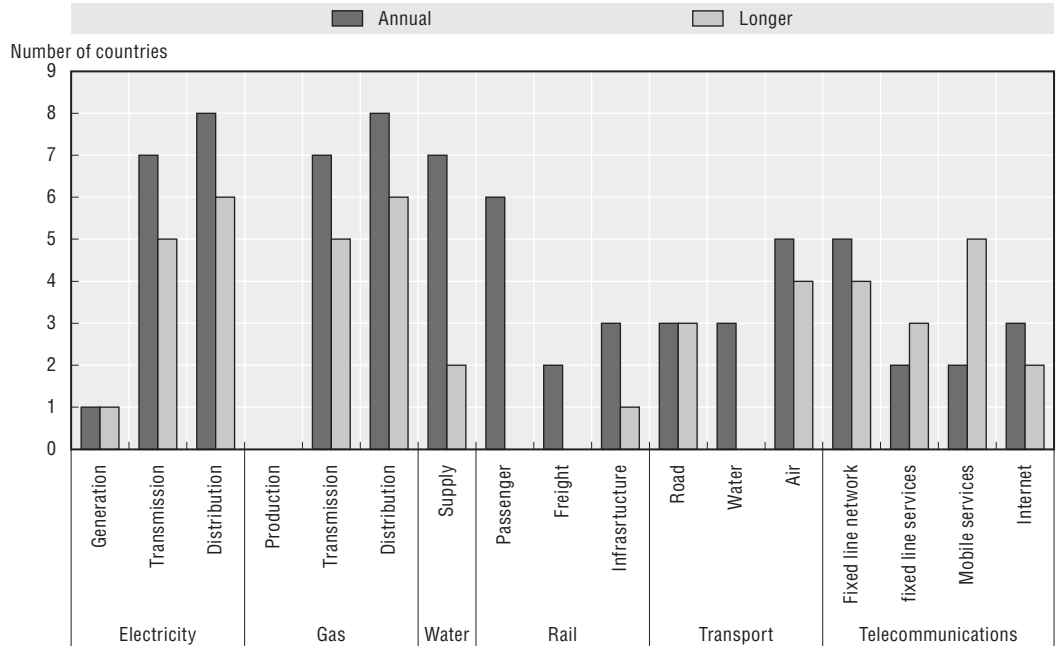
Figure 5. **Pricing regimes**
In late 2007, early 2008



Source: Infrastructure investment questionnaire.

Figure 6. **Frequency of price reviews**

In late 2007, early 2008



Source: Infrastructure investment questionnaire.

In comparison with cost-based regulation, incentive regulation shifts some risk from consumers to the shareholders and consequently raises the riskiness and the cost of capital of the regulated firm. The implications are that if the regulated firm is not allowed to earn a return on its capital that incorporates the higher risk the regulated firm faces, it may tend to under-invest relative to a cost-based regime. Alexander and Irwin (1996) show that a measure of volatility of a firm's returns is higher for firms subject to price caps and imply higher costs of capital of about 1 percentage point than a firm subjected to rate-of-return regulation. An additional problem with incentive-based pricing is that quality may be compromised. A price cap that does not account for quality changes can give incentives to reduce quality (Vogelsang, 2003). Generally, case studies suggest that incentive pricing can help the adoption of cost-saving technology. For example, a review of the effects of incentive regulation on investment reported that price-cap incentive regulation may have spurred investment in the telecommunications sector (Kridel *et al.* 1996; Guthrie, 2006). However, the overall impact on the investment rate is *a priori* uncertain.

With respect to prices set at the price reviews, the central challenge for investment is to ensure that it encourages efficient use of scarce network capacity while at the same time preserving incentives to maintain quality and expand capacity where appropriate. In practice, regulators can adopt a number of approaches to setting access prices. Setting the wrong price and access conditions can run the risk of inefficient utilisation, which in turn can generate either over or under-investment:

- Not only may excessively high access prices induce the incumbent to overspend to develop its own infrastructure, but they may also encourage new entrants to over-invest in alternative networks to bypass the existing infrastructure. While bypass is potentially a serious threat in telecommunications it is less so in other industries such as water and

sewerage and railroads where the sunk costs of duplicating the network are extremely high.

- Setting prices too low leads to underinvestment for opposite reasons and by preventing the incumbent from recovering investment costs, depresses its investment activity. Furthermore, if the access charge is determined without taking into account the option value of delaying investment by potential new entrants, the net present value of using the incumbent's network is higher than building a competing network (Crandall, Ingraham and Singer, 2004).
- Low access prices may also have spillover effects on investment in the upstream or downstream markets. For example, if the services provided by train operators depend on the quality of the railroad network, a lack of investment in the network will tend to depress train operators' investment. Strategic co-operation between the network operator and the train operators may provide a way out.

2. Econometric approach and results

This section first describes the econometric approach and the associated results at the sectoral level and then at the firm level (Egert, 2009; Araújo, 2011). In both cases, the data that complement the responses to the infrastructure questionnaire are also described. The sectoral level analysis concentrates on the importance of regulatory independence and the associated pricing regime, whereas the firm-level analysis looks at other aspects of the regulatory environment.

2.1. Sectoral level

As questionnaire responses only provide a snapshot of regulation in late 2007 and early 2008, the data on the type of regulatory and pricing regime do not have a time dimension. For this reason, only cross-sectional regressions are carried out in the analysis (with sectoral investment being the dependent variable). For the sectoral-level analysis, investment data for energy and water (electricity, gas and water), transportation (rail, road, and water and air transportation) and telecommunications were available for 13 countries (Austria, Belgium, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Portugal, United Kingdom and the United States). Data were available for 1995-2006 and non-overlapping 6-year averages were computed. The investigation of investment determinants uses an investment equation with sectoral investment as a ratio to gross value added. The estimations use both country fixed effects and then industry fixed effects as well as the explanatory variables lagged one period. The structure of the estimated equation is:

$$I_t^{VA} = \beta_1 I_{t-1}^{VA} + \beta_2 OG_{t-1} + \beta_3 RIR_{t-1} + \sum_{i=1}^{2}\sum_{j=1}^{k}\beta_{3+j} X_{j,t-i} + \sum_{l=1}^{country}\delta_l FE^C + \sum_{m=1}^{I}\phi_m FE^I + \varepsilon_t \qquad (1)$$

where (I_t^{VA}) is the ratio of investment to sectoral value added, (*OG*) the output gap to control for business cycle fluctuations, (*RIR*) the real interest rate to capture the impact of the cost of capital on investment and (*X*) variables capturing aspects of the regulatory environment, (FE^C) and (FE^I) denote country and industry fixed effects. The regulatory environment variables include a measure of barriers to entry and public ownership, a measure of regulatory independence and whether the sector had no price regulation as well as a variable that captured whether the sector was subject to incentive regulation. The last variable was also interacted with the regulatory independence variable to assess

whether the consistency in policy stance is important. The regulatory variables as well as the controls are lagged to address potential endogeneity arising between them and the investment ratio. An exception is the variable capturing incentive regulation because observations are only available for the most recent period.

As a robustness check of the simple OLS results, Bayesian model averaging was carried out. Bayesian averaging is a comprehensive analytical tool to check the extent to which any given explanatory variable improves the explanatory power of the estimated models when it is included. In other words, it investigates the probability with which any given variable would be included in the estimated models. This approach requires the estimation of all possible combinations of the candidate explanatory variables (of number K) that is usually quantified as 2^K.

Bayesian averaging of classical estimates (BACE) first determines the posterior probability attributed to each single model M_i that includes the given variable and conditioned on the underlying dataset y ($P(M_i|y)$).

$$P(M_i|y) = \frac{P(M_i)T^{-k_j/2}SSE_i^{-T/2}}{\sum_{i=1}^{2^K} P(M_i)T^{-k_i/2}SSE_i^{-T/2}} \tag{2}$$

where *SSE* is the sum of squared residuals, *T* is the number of observations, k denotes the number of explanatory variables included in the specific model and *K* is the number of all explanatory variables considered. The expression above shows the extent to which any given model contributes to explaining the dependent variable as compared with the other models. These expressions are then summed up for the models that contain the variable of interest to obtain the posterior inclusion probability of this variable.

$$P(X_m|y) = \sum_{j=1}^{n} \frac{P(M_j)T^{-k_j/2}SSE_j^{-T/2}}{\sum_{i=1}^{2^K} P(M_i)T^{-k_i/2}SSE_i^{-T/2}} \tag{3}$$

where $P(X_m|y)$ is the posterior inclusion probability of a given variable. *j* denotes the models that include variable X_m and *n* equals *2k/2*. If the posterior inclusion probability is higher than the prior inclusion probability, one can conclude that the specific variable should be included in estimated models. We estimate all possible combinations of the explanatory variables. In this case, the prior inclusion probability is 0.50.

The posterior mean conditional on inclusion ($E(\beta|y)$) is the average of the individual OLS estimates weighted by $P(M_i|y)$. Note that the unconditional posterior mean considers all regressions, even those without the variable of interest. Hence, the unconditional posterior mean of any given variable can be derived as the product of the conditional posterior mean and the posterior inclusion probability. The posterior variance of ($Var(\beta|y)$) can be calculated as follows:

$$Var(\beta|y) = \sum_{j=1}^{2^K} P(M_j|y) Var(\beta|y, M_j) + \sum_{j=1}^{2^K} P(M_j|y)(\hat{\beta}_j - E(\beta|y))^2 \tag{4}$$

The posterior mean and the square root of the variance (standard error) conditional on inclusion can be used to obtain t-statistics and to determine the significance of the individual variables upon inclusion.

Investment data are obtained from the OECD's STAN and SNA (Sectoral National Accounts) database. These two databases have two serious shortcomings. Firstly, the level of disaggregation is limited to three broad categories: first, electricity, gas and water

supply; second, transportation (road, rail, water, air and associated storage); and third, telecommunications (which also includes postal services). Secondly, the capital stock data needed to calculate the investment-to-capita stock ratio are available only for a limited number of OECD countries and are not fully comparable across countries. In principle, one could compute capital stock series using investment flows and the perpetual inventory method, but these estimates are extremely sensitive to the underlying assumptions. Given long asset lives, one often still needs an estimate of the value of the capital stock to anchor the series, which is not readily available. As a result, sectoral value added is used to construct the investment ratio at the sectoral level. Overall, the sectoral dataset covers 13 countries for the three sectors.

2.2. Sectoral level results

The main findings are presented in Table 1. A simple OLS regression shows that three variables are significantly correlated with investment: these are lagged investment, the measure of barriers to entry and the interaction term for regulatory independence and incentive regulation. Barriers to entry are found to influence investment negatively. The interaction term has a positive coefficient while, when taken separately, regulatory independence and incentive regulation appear to have no effect on investment. This suggests that a consistent policy mix is important in underpinning efficient investment incentives in network industries.

Using questionnaire responses, cross-country industry-level estimations looking at the effects of different types of price regulation on investment were estimated. The results suggest that incentive price regulation has a positive impact on investment in infrastructure only when it is accompanied by an independent regulator. Synergies between the regulator's independence and price regimes, for instance, could be enhanced in the electricity and (parts of) telecommunication sectors if France, Portugal, Spain and the United Kingdom moved to incentive regulation, while greater independence of the regulator in the Danish, Japanese and Norwegian telecom sectors could enhance the effects of the incentive price regulation that is in place.

As a robustness check of the simple OLS results, Bayesian model averaging was carried out. The measures of barriers to entry and the interaction term combining incentive regulation with regulatory independence consistently contribute to a better fit of the model. These results hold both when country and industry fixed effects are used. The results also reveal that the absence of price regulation is correlated with lower investment, however this result is sensitive to the inclusion of observations for the United States.

In terms of the economic significance of the results, the estimated coefficient for the interaction term suggests that reforms can have a large impact on investment. The size of the coefficient estimates for the different subsamples suggests that on average a one-step change in the interaction term (*e.g.* a change that would be slightly smaller than that of fixed-line telecommunications adopting incentive pricing when the regulator is independent) would induce an average increase of the investment ratio of 5.3 percentage points. Given that the observed investment ratios are between 18% and 74%, the impact of such a reform is potentially sizeable. Similarly, a one-step decrease in the measure of barriers to entry (which would be somewhat larger than the impact of introducing regulated third-party access) would be related to an average rise of 1.6 percentage points in the investment ratio. Given the expected influence of barriers to entry to specific sectors, these figures likely masks differences across sectors.

Table 1. **Sector-level results: Investment equations using OLS and Bayesian model averaging**

With country and industry fixed effects

Dependent variable: Investment	OLS	Bayesian model averaging	
		Posterior inclusion probability	Posterior mean and standard error conditional on inclusion
Lagged investment	0.865***	**1**	**0.880**
	(0.161)		(0.166)
Real interest rate	0.009	**0.654**	**0.006**
	(0.006)		(0.003)
Barriers to entry	–0.046***	**0.998**	**–0.043**
	(0.164)		(0.012)
Public ownership	0.004	0.151	0.000
	(0.010)		(0.002)
Regulatory independence	–0.026	0.184	–0.004
	(0.040)		(0.006)
Incentive regulation	–0.003	0.141	0.000
	(0.019)		(0.002)
No price regulation	–0.016	**0.975**	**–0.015**
	(0.010)		(0.008)
Independence and incentive regulation interaction term	0.060***	**0.996**	**0.053**
	(0.017)		(0.014)
Adjusted R-squared	0.741		
Regressions run		256	
Prior Inclusion probability		0.5	

Note: Posterior inclusion probability measures the extent to which any given model contributes to explaining the dependent variable as compared with the other models. Bold figures for the posterior inclusion probability indicate that it is higher than the prior inclusion probability of 0.5. The posterior mean conditional on inclusion is the mean of the individual OLS estimates weighted by the posterior inclusion probability of the individual models including a given variable.

* denotes significance at the 10% level, ** at the 5% level and *** at the 1% level.

2.3. Firm level

For the firm-level analysis, in order to exploit data which varies over time, the concentration is on the importance of the independence of the sector regulator and regulatory indicators (described above). The approach adopted is to estimate the Euler equation. The estimated equation relates yearly firm investment rates (defined as investment-to-capital ratios) to one-year-lagged levels of the linear and quadratic investment rate, cash flow-to-capital ratios, and the user cost of capital. Similarly to Bond *et al.* (2003), we introduce the output-to-capital ratio term to account for either non-constant returns to scale or by monopolistic competition in the product market. The user cost of capital term in the Euler equation is replaced in the empirical specification by time effects and firm-specific effects in the estimated regression similarly to Bond *et al.* (2003). The Euler equation is then augmented to include variables that attempt to capture specific features of the regulatory environment faced by firms:

$$\left(\frac{I}{K}\right)_{icst} = \beta_1\left(\frac{I}{K}\right)_{ics,t-1} + \beta_2\left(\frac{I}{K}\right)^2_{ics,t-1} + \beta_3\left(\frac{Y}{K}\right)_{ics,t-1} + \beta_4\left(\frac{CF}{K}\right)_{ics,t-1} + \beta_5 REG_{cs,t-1} + \gamma_{ct} + \eta_i + \varepsilon_{icst} \quad (5)$$

where I denotes gross investment, K the previous year's capital stock, Y output, CF cash-flow, REG is the set of sector specific regulatory indicators, γ unobserved year fixed effects and η firm-specific fixed effects All variables were lagged once. The analysis does not

evaluate operating cost or service provision. The equation is estimated using the difference GMM estimator to control for biases due to unobserved firm-specific effects and endogenous explanatory variables and is appropriate for dynamic models with many cross-sections and few time periods.

To allow for firm-level analysis, a panel was constructed of companies operating in 18 OECD economies over the period 1983-2005 in the electricity, gas, rail and telecoms sectors. Firm-level variables come from the Worldscope (Thomson Financial) database. The main variables used from the Worldscope database are investment flows, capital stocks, cash flow and output. Investment flows are obtained from uses of funds accounts, which contain primary information on additions to fixed capital stocks. Output is proxied by firm sales and cash-flow by operating profits. The capital stock uses the book value of capital stock which may be flawed, but given the short history available for firms this measure is likely to be preferable to a measure derived from the perpetual inventory method.[6] The final dataset is obtained by merging data from the regulatory indicators with the data on firm-level investment. It results in an unbalanced panel, covering 565 firms operating in the electricity, gas, railways and telecoms sector in 28 OECD countries over the period 1980-2006. Summary statistics are presented in Table 2.

Table 2. **Firm-level summary statistics**

Variable	N	min	p25	p50	mean	p75	p90	max	sd
ELECTRICITY									
Investment-to-capital ratio	2 054	0	0.03	0.05	0.08	0.08	0.12	3.8	0.15
Output-to-capital ratio	2 054	0	0.24	0.33	0.6	0.48	0.77	144.9	4.17
Cashflow-to-capital ratio	1 557	–23.97	0.05	0.09	0.08	0.14	0.21	15.09	0.89
IRA	2 160	0	0	0	0.32	1	1	1	0.47
BE	2 160	0	1	5	3.98	6	6	6	2.35
PO	2 160	0	1.5	1.5	2.6	4.5	6	6	1.81
VI	2 160	0	4.5	4.5	4.59	6	6	6	1.82
GAS									
Investment-to-capital ratio	1 510	0	0.05	0.08	0.11	0.11	0.19	3.24	0.15
Output-to-capital ratio	1 509	0	0.35	0.56	0.71	0.84	1.25	17.81	0.84
Cashflow-to-capital ratio	1 178	–0.28	0.09	0.14	0.16	0.21	0.28	1.33	0.11
IRA	1 550	0	0	0	0.36	1	1	1	0.48
BE	1 550	0	1.4	2	2.44	4	5	6	1.49
PO	1 550	0	0	0	0.43	0	2	6	1.26
VI	1 550	0	0	2.4	2.13	3.3	6	6	2.28
TELECOMS									
Investment-to-capital ratio	1 350	0	0.07	0.11	0.19	0.18	0.37	11.61	0.42
Output-to-capital ratio	1 350	0.02	0.37	0.5	1.76	0.95	2.73	203.84	7.78
Cashflow-to-capital ratio	1 204	–10.55	0.09	0.19	0.56	0.37	0.84	37.09	2.25
IRA	1 375	0	0	0	0.33	1	1	1	0.47
BE	1 375	0	0	0	0.8	0.34	3.75	6	1.76
PO	1 375	0	0	0	1.1	2.57	3.72	6	1.77

2.4. Firm-level results

The results from the first-difference GMM estimations reveal that barriers to entry have a negative effect on investment when all the sectors are pooled (Table 3), consistent with the sector-level analysis and also found by Alesina *et al.* (2005). There is no evidence of other regulatory framework affecting investment rates in the firm-level pooled-sector regressions. The sector-specific regressions show a different picture: legal barriers to entry

act as a deterrent of investment in the electricity sector. In the gas sector, higher levels of public ownership seem to be associated with higher investment rates. The coefficient on the level of public ownership is significant at the 10% level when all the instruments available are used but restricting the number of instruments renders the coefficient insignificant. In telecommunications, the existence of an independent regulator has a positive effect on investment: the coefficient is stable and always significant at the 1% level throughout the regressions making use of different sets of instruments.

Table 3. **Firm-level results: Euler equations using first difference GMM**

Dependent variable: Investment-to-capital ratio	Whole sample	Electricity	Gas	Telecoms
Investment-to-capital ratio (t-1)	0.816***	1.383**	1.242***	0.263***
	(0.164)	(0.579)	(0.249)	(0.100)
Squared investment-to-capital ratio (t-1)	–0.311**	–0.887*	–0.499***	–0.022
	(0.144)	(0.468)	(0.161)	(0.041)
Output-to-capital ratio (t-1)	0.033**	0.062	0.015	0.008**
	(0.016)	(0.045)	(0.010)	(0.003)*
Cashflow-to-capital ratio (t-1)	–0.036	–0.284	0.188	0.034
	(0.088)	(0.282)	(0.259)	(0.021)
Barriers to entry (t-1)	–0.005**	–0.007*	–0.002	0.001
	(0.002)	(0.004)	(0.004)	(0.008)
Public ownership (t-1)	–0.001	–0.007	0.007*	0.004
	(0.006)	(0.010)	(0.004)	(0.008)
Vertical integration (t-1)	0.001	0.004	0.001	
	(0.003)	(0.006)	(0.003)	
Independent regulator (t-1)	–0.008	–0.013	–0.001	0.07***
	(0.009)	(0.015)	(0.014)	(0.026)
Observations	2 274	1 210	926	847
Number of firms	323	173	134	160
Arellano-Bond test for AR(1) (p-value)	0.073	0.024	0.105	0.016
Arellano-Bond test for AR(2) (p-value)	0.483	0.300	0.340	0.311
Hansen test for overidentifying restrictions	0.663	0.472	0.187	0.549

Note: All regressions include year-fixed effects. Standard errors in parentheses are robust to heteroskedasticity and within serial correlation.
* denotes significance at the 10% level, ** at the 5% level and *** at the 1% level.

The results from the firm-level analysis reveal differences in the importance of regulatory variables across the sectors that are masked when the sectors are pooled. To some extent this may reflect differences in samples, but is also likely to reflect the interaction of different market structures with regulation. For example, the telecommunication sector has undergone the largest switch to private ownership and the regulatory environment has moved furthest towards an incentive regulation framework. In this context and consistent with the sectoral results, the independence of the regulator becomes an important factor in reducing uncertainty for potential investors. The differences between the energy sectors may arise due to the greater difficulties in introducing competition in the gas market, where many countries are typically dependent on imported supplies (Newbery, 2000). In the electricity sector, on the other hand, competition can be introduced relatively easily in generation, which may account for the importance of barriers to entry in this sector.

3. Conclusions

The private sector has become increasingly involved in the provision of infrastructure across the OECD. This development has been accompanied by the development of new regulatory and policy environments. Past experience has shown that exclusive public sector ownership and provision can lead to inefficient investment decisions while rate of return regulation could induce firms to overinvest. Against this backdrop, harnessing greater private sector involvement in the provision of infrastructure could be feared to lead to a drop in investment, albeit more investment would be better targeted. However, changes in pricing mechanisms could encourage more investment (especially when sectors are particularly inefficient) and the move towards independent regulators could reduce uncertainty stemming from regulatory risk. In this light, the overall effect on investment is ambiguous.

The findings presented in this article suggest that greater private sector participation in the provision of infrastructure when accompanied by a supporting regulatory environment can boost investment. A number of policies appear to be more conducive to investment, though this can depend on the characteristics of the particular sector. Overall, a competitive environment appears generally supportive of more efficient use of resources. For example, there is evidence that removing barriers to entry – such as requiring vertical unbundling and establishing regulated third-party access regimes – can foster higher rates of investment in the network industries. Such barriers appear to be harmful for investment, especially in the electricity sector. Incentive regulation, such as setting price caps for infrastructure services, can help ensure that investment is cost reducing and mimics a competitive environment. Independence and accountability of the sectoral regulators can help establish a stable and credible framework for investment. Empirically, the evidence presented in this article suggests that price-cap regulation when combined with regulatory independence boosts investment. The importance of an independent regulator is particularly apparent in telecommunications. Policy settings vary considerably across OECD countries, suggesting in some cases scope to improve policy by drawing on the experience of others. The results also suggest that policy interactions are important and as more time series information becomes available further investigation of this aspect of the regulatory regime would be warranted.

Notes

1. Other factors influencing investment decisions are described in the appendix.
2. A copy of the questionnaire and a table giving the responses can be found by clicking on the links in the text.
3. The non-respondents were Greece, Iceland, Luxembourg, Sweden and Poland.
4. There are also organisational forms where the network is separated into reciprocal or smaller parts, which can be introduced with cellular telephony. While this choice can have implications for competition, the direct influence on investment is less clear cut.
5. There are a number of options available to the regulators to restrain *ex ante* such incumbents from abusing their monopoly power on the wholesale market. These include setting quality standards and introducing rewards and penalties or implementing parity standards.
6. Firms needed to have at least 80% of their revenues coming from a single sector. Firms with unusually high investment rates were also dropped from the dataset.

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APPENDIX I

Factors influencing investment in infrastructure

Addressing market failure has been a major motive for public intervention in infrastructural sectors. Governments have intervened to prevent the under-provision or non-provision of infrastructure, when externalities or public-good features are predominant or to limit the exercise of market power to the extent to which a natural monopoly is present. The resulting decisions about ownership and regulation are important factors affecting the supply and demand of infrastructure (these are summarised in the Appendix Figure).

The structure of infrastructure supply depends on the nature of the market failure. Where supply entails a natural monopoly, the private sector will usually be willing to provide the service, though normally at a level that is below, and a price that is above, the social optimum. This will often result in some type of arm's length regulation. Investment will depend on standard investment determinants, such as the cost of capital, but due to the often extremely large fixed costs and the irreversibility of investment decisions, investment decisions are also particularly sensitive to the regulatory environment.

When the government is involved in infrastructure provision, investment decision-making should use the standard criterion of setting the level of provision that equates the marginal social benefit to the marginal social cost, which is related to the marginal costs of public funds and production costs. However, due to the characteristics of networks, the marginal benefits of additional investments are often low and declining, but not always, particularly in well-developed networks.

There are a number of different delivery modes involving the public or private sector to a greater of lesser extent. These include public ownership and procurement, which has often characterised the water supply and road networks; concessions and public private partnerships, which are increasingly involving the private sector in the delivery of infrastructure; and fully privately-owned companies, which has often been the case in the energy sector.

The decisions of regulatory institutions concerning the desired market structure (reflecting the degree to which competition is possible), access regimes and pricing play important roles in determining infrastructure supply and use. In particular, the regulator often needs to set user costs, access prices or final prices, depending on whether the network provider is vertically integrated and competition is feasible. Under certain conditions, setting the price equal to the marginal social cost would be welfare maximising and when the networks are characterised by constant returns to scale this form of pricing would also cover investment costs. Alternatively, the regulator may adopt a different

pricing structure to cover investment costs. Given the importance of pricing to investment decisions, the credibility and consistency of the regulatory framework are important determinants of infrastructure investment.

Infrastructure in the network sectors is also often a congestible public good with congestion-raising production costs and reducing individuals' utility. When pricing is introduced, the optimal toll – determined by the difference between the marginal social cost (reflecting congestion costs and wear and tear of the infrastructure) and private costs – will reduce demand and, by enhancing the efficient use of existing infrastructure, will damp the need for investment in additional capacity. Efficient investment decisions would then equate marginal costs to the marginal benefits of infrastructure capacity and quality, which the revenues from the congestion toll would indicate when additional investment is warranted.

Appendix Figure. **Factors influencing investment in infrastructure**