BACKGROUND PAPER

MONETARY POLICY, FACTOR ALLOCATION AND GROWTH

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Monetary Policy, Factor Allocation and Growth*

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Preliminary

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Abstract

Using a sample of 10 advanced economies observed over the last 15 years, this paper finds that interest rate surprises have been a significant determinant of the sensitivity of factor allocation to productivity growth at the sectoral level. Specifically, when the slope of the yield curve is smaller than had been anticipated one year before, factor accumulation tends to be stronger in sectors where productivity gains are weaker. By contrast, when the yield curve is steeper than had been anticipated, factor accumulation tends to be stronger in sectors with higher productivity gains, thereby delivering an extra-boost to aggregate (total factor) productivity growth. This result suggests that in the aftermath of the financial crisis quantitative easing policies may have contributed to the observed slowdown in productivity growth by hampering the sectoral reallocation of resources.

Keywords: factor reallocation, total factor productivity growth, interest rate surprises.

JEL codes: E24; E51; O47.

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1 Introduction

Almost ten years since the onset of the Great Financial Crisis (GFC), productivity growth has not returned to pre-crisis levels. The reasons are unclear. While tighter credit conditions and a deep recession have led to a significant drop in investment, these factors no longer seem relevant today, at least in a majority of advanced economies. Credit conditions are very loose by historical standards, backed by low interest rates and buoyant financial market valuations, global growth is picking up and, with the exception of some European economies, most banks have repaired their balance sheets. Instead, other factors seem more significant, including an apparent slowdown in technological progress, ongoing population ageing and numerous long-lasting structural impediments to investment and entrepreneurship (eg Adler et al (2017)).

Little attention, however, seems to have been paid to the possible adverse effects of monetary policy. There is no doubt that easier monetary policy is essential in stabilising aggregate demand in the immediate aftermath of a financial crisis or, more generally, in the face of adverse demand shocks, but its effects on the allocation of resources are less certain, especially after a long period of exceptionally low interest rates. On the one hand, looser monetary policy may alleviate credit constraints, thus helping highly productive firms to expand. On the other hand, looser monetary policy may reduce the contribution of factor reallocation to productivity growth by slowing the normal competitive process whereby weak firms lose market share and shed workers and inefficient or non viable firms are kept alive (Caballero and Hammour (1994)). Moreover, this "congestion effect" could also reduce the profits of more productive firms, discouraging investment and entry (Caballero et al (2009) and Adalet-McGowen (2017)). Whether these adverse effects overturn the positive effects of monetary policy on aggregate productivity growth is an empirical question and may depend on changing circumstances such as the availability of credit, the phase of the business cycle or whether the economy is experiencing a financial boom or bust.

Against this backdrop, our study contributes to the literature on factor allocation by investigating how unexpected changes in monetary policy affect the intensity of sectoral allocation and its contribution to aggregate productivity growth. Our dataset, drawn from the EU-KLEMS database, covers 10 OECD countries and 13 sectors over the period 2000-2015, allowing us to examine whether the allocative effects of monetary

policy have changed since the onset of the GFC. Additionally, our study contains a methodological innovation. To the best of our knowledge, it is the first to exploit the fact that the covariance term between sector productivity growth and resource allocation in standard productivity decompositions is proportional to the estimated coefficients in sector-level panel regressions (see below).

Our key finding is that sectoral allocation is closely linked to the slope of the yield curve, rather than either the short- or long-term interest rate alone. Specifically, we find that shocks that flatten the yield curve tend to reduce the contribution of sectoral factor reallocation to aggregate productivity growth, both pre- and post-crisis. But, while this result holds over time, the different ways monetary policy has been conducted in the pre- and post-crisis periods suggest that its effects on sectoral allocation might be state dependent. Pre-crisis, a flattening of the yield curve is normally associated with rising short-term interest rates and a tighter monetary policy, given the smaller variability of long-term interest rates. Thus, our result implies that, pre-crisis, tighter monetary policy tended to reduce factor allocation's contribution to aggregate productivity growth. By contrast, in the aftermath of the GFC, a flattening of the yield curve is normally associated with a monetary expansion, as long-term interest rates fall in response to Quantitative Easing (QE) policies and short-term rates hardly moves once policy rates have reached their effective lower bound. Therefore, our result suggests that, unlike in the pre-crisis period, monetary accommodation has reduced aggregate productivity growth post-crisis.

Our analysis proceeds through two main steps. In the first, we present a method that can be used to analyse the contribution of factor reallocation to aggregate output, labour, capital and total factor productivity (TFP) growth (Section 2). With sector-level data, a standard approach is to decompose aggregate output or productivity growth into at least two components: a first moment, capturing growth common to all sectors; and a covariance term, capturing the contribution of sectoral reallocation.[1] Each component can then be used as a dependent variable in a panel regression to separately assess the relevance of potential explanatory variables approach (eg Borio et al (2015)). Yet, this two-stage approach might not be the most efficient one to exploit the cross-sector, cross-time and cross-country information available in the data. By

[1] This decomposition essentially boils down to a dynamic version of the Olley and Pakes (1996) decomposition. The method described in Section 2 can also be applied to firm-level data.

contrast, the alternative approach we propose combines all information in one stage. Specifically, we first show that the contribution to aggregate labour (capital) productivity growth from factor reallocation can be estimated by running a panel regression of the growth rate of sectoral employment (capital) on the same sector's labour (capital) productivity growth rate (weighed by sector's size). That is, we show that the OLS coefficient in this regression is proportional to the covariance between productivity growth and factor growth in the productivity growth decomposition used in Borio et al (2015), after controlling for changes in sector demand and other potential confounding effects that affect resource allocation at cyclical frequencies. Similarly, we show that the contribution to aggregate TFP growth from factor reallocation can also be related to a panel regression.[2]

In the second step, we assess how unexpected changes in monetary policy alter the sector-level relationship between factor accumulation and productivity growth. That is, we extend the regression estimated in the previous step by adding a monetary policy shock and by interacting it with sectoral productivity growth and other control variables. Monetary policy can influence factor accumulation directly by reducing firms' borrowing costs and easing their credit constraints. In this case, firms may respond by increasing employment and/or investment for a given level of sectoral demand and productivity growth.[3] Additionally, monetary policy can affect factor accumulation indirectly by altering the rate at which factors are accumulated in response to changes in productivity growth. As measures of monetary policy surprises, we consider one-year ahead forecast errors in the 3-month interest rate, which is very closely related to the policy rates. In addition, we consider one-year ahead forecast errors in the 10-year government bond rate. Two reasons motivate this choice. First, the long-term interest rate can be as relevant as the short-term rate in determining the effective cost of borrowing faced by firms. Second, in the post-crisis period policy rates have been at their lower bound prompting central banks to influence long-term rates through large-scale bond purchases (eg Gagnon et al (2011), Joyce et al (2011)).

[2] In deriving the TFP growth decomposition, we assume that aggregate TFP is well approximated by a weighted average of sectoral TFPs. The TFP decomposition has two advantages. First, in decompositions using productivity growth computed with output per unit of labour (capital), there is by construction a negative correlation with labour (capital) accumulation which creates empirical challenges. Our TFP decomposition allows us to circumvent this potential problem when estimating the relationship between factor reallocation and productivity growth. Second, our TFP decomposition provides a direct link between the micro-level evidence on factor reallocation and aggregate TFP (**see Autor et al. 2017**).

[3] Such direct effects will in practice be absorbed by the fixed effects of the regression.

Our paper is closely related to the literature that measures factor reallocation and productivity growth over the business cycle. This literature shows that gross job flows tend to be large and countercyclical and occur both within and across sectors (eg Davis and Haltiwanger (1992), Campbell and Kuttner (1996), Davis et al (1996), Haltiwanger and Schuh (1999)). The intensification of reallocation in a recession is normally found to enhance productivity by forcing the least efficient firms to exit the market and freeing resources for more efficient uses (eg Baily et al (2001), Caballero and Hammour (1994, 1996), Hall (2000), Mortensen and Pissarides (1994)). But other studies show that not all exiting firms in a recession are the least productive and that some of them are disproportionately young (eg Baden-Fuller (1989), Dunne et al (1989), Eslava et al (2010)). As a result, the cleansing effects of recessions may be reduced or even overturned. The intensity of reallocation may also vary over time and across countries. For example, there is evidence that the reallocation in the 2008-9 recession in the United States has been less intense and less productivity-enhancing than in previous recessions (Foster et al (2016)). Our work extends this literature by examining the effects of monetary policy before and after the GFC, finding that post-crisis monetary policy may be partly responsible for the lack of business dynamism.

From a methodological viewpoint, our paper shows and exploits the equivalence between a dynamic version of the Olley and Pakes (1996) decomposition and panel regressions of factor accumulation. It also provides an alternative to the standard Baily, Bartesman and Haltiwanger (2001) decomposition of productivity growth (BBH in short). In our approach, the dispersion across countries and time in the covariance between factor reallocation and productivity growth amounts to around one third of the aggregate productivity growth volatility. In contrast, the BBH 2001 decomposition generates a 16 to 1 volatility ratio, which we view as implying an unrealistically large degree of sectoral reallocation from one year to the next.

The rest of the paper is organised as follows. Section 2 provides output and productivity growth decompositions into a common and a reallocation component and show how the latter is related to the slope coefficient of a panel regression of sectoral factor growth and productivity growth. Section 3 discusses the data and empirical strategy in detail. Section 4 provides a first pass at the data using our decompositions. Section 5 presents the regression results. Section 6 concludes.

2 Methodology

2.1 Decomposing growth

In this section we make use of a number of identities to decompose the rate of growth of aggregate output, labour productivity, capital productivity and TFP into a common component – capturing average growth across all sectors in the economy – and an allocative component – measuring the contribution of factor reallocation. We then show how each of these decompositions are related to the estimated OLS coefficients of sector-level panel regressions of factor accumulation over changes in productivity and other control variables.

2.1.1 Output

Let us write aggregate output Y and aggregate input x as the respective sum of sectoral outputs Y_s and inputs x_s: $Y = \sum_s Y_s$ and $x = \sum_s x_s$. The input x may, for instance, be headcount employment l, hours worked h or the capital stock k. Aggregate output growth can then be written as

$$\frac{Y_{t+1}}{Y_t} = \sum_s \frac{Y_{st+1}}{Y_t} = \sum_s \frac{x_{st+1}}{x_{st}} \frac{(Y_s/x_s)_{t+1}}{(Y_s/x_s)_t} \frac{Y_{st}}{Y_t} = \frac{1}{S} \sum_s \left(1 + \frac{\Delta x_{st+1}}{x_{st}}\right) \left(1 + \frac{\Delta (Y_s/x_s)_{t+1}}{(Y_s/x_s)_t}\right) y_{st} \qquad (1)$$

where S denotes the number of sectors in the economy, Δ is the first difference operator, ie $\Delta x_{t+1} = x_{t+1} - x_t$ and $y_{st} \equiv Y_{st} / (Y_t/S)$ is sector s relative output size at time t.

For any variable z, let us denote $\overline{z_t}$ as the time-t unweighted (simple) average of the sectoral components $\{z_{st}\}_s$. With this notation, aggregate output growth between time t and $t+1$ can be written as the sum of two terms:

$$1 + \frac{\Delta Y_{t+1}}{Y_t} = \underbrace{\left(1 + \overline{\frac{\Delta x_{st+1}}{x_{st}}}\right) \left(1 + \overline{\frac{\Delta (Y_s/x_s)_{t+1}}{(Y_s/x_s)_t} y_{st}}\right)}_{\text{com-x}} + \underbrace{cov\left(\frac{\Delta x_{st+1}}{x_{st}}; \left(1 + \frac{\Delta (Y_s/x_s)_{t+1}}{(Y_s/x_s)_t}\right) y_{st}\right)}_{\text{alloc-x}} \qquad (2)$$

The first term – denoted com-x – is the product of average growth in sectoral input x and average size-weighted productivity growth, while the second term – denoted alloc-x – is the cross-sectoral covariance between growth in input x and size-weighted productivity growth. This latter term measures the extent to

which the input x is reallocated to sectors with high or low productivity gains, or equivalently, the extent to which productivity gains are taking place in sectors with expanding or shrinking input x.

2.1.2 Labour and capital productivity

Similar decompositions into common and allocative components for labour and capital productivity growth can be derived by noting that (2) can be applied to decompose growth in the productivity of input x. Specifically, we can growth in output per unit of input x as

$$\frac{Y_{t+1}/x_{t+1}}{Y_t/x_t} = \sum_s \frac{Y_{st+1}/x_{t+1}}{Y_t/x_t} = \sum_s \frac{(x_s/x)_{t+1}}{(x_s/x)_t}\frac{(Y_s/x_s)_{t+1}}{(Y_s/x_s)_t}\frac{Y_{st}}{Y_t} = \frac{1}{S}\sum_s \left(1+\frac{\Delta\left(x_s/x\right)_{t+1}}{(x_s/x)_t}\right)\left(1+\frac{\Delta\left(Y_s/x_s\right)_{t+1}}{(Y_s/x_s)_t}\right) y_{st}$$

And using similar notations as above, growth in output per unit of input x decomposes as

$$\begin{aligned} 1+\frac{\Delta\left(Y_{t+1}/x_{t+1}\right)}{(Y_t/x_t)} &= \left(1+\overline{\frac{\Delta\left(x_s/x\right)_{t+1}}{(x_s/x)_t}}\right)\left(1+\overline{\frac{\Delta\left(Y_s/x_s\right)_{t+1}}{(Y_s/x_s)_t}y_{st}}\right) \\ &\quad + cov\left(\frac{\Delta\left(x_s/x\right)_{t+1}}{(x_s/x)_t}; \left(1+\frac{\Delta\left(Y_s/x_s\right)_{t+1}}{(Y_s/x_s)_t}\right) y_{st}\right) \end{aligned} \tag{3}$$

As is clear, the key difference with the decomposition of output growth (2) is that the decomposition of productivity growth depends on the growth rate in the sectoral *shares* of input x as opposed to the growth rate in the sectoral *amounts* of input x (all the rest remaining unchanged).

2.1.3 Total factor productivity growth

To decompose aggregate TFP growth, let us *define* the level of aggregate TFP at time t in the aggregate economy A_t^x as the average of sector-level TFP levels A_{st} at time t weighted by their respective shares in aggregate input x:[4]

$$A_t^x \equiv \sum_s \frac{x_{st}}{x_t} A_{st} \tag{4}$$

[4] Total factor productivity growth, -whether at the sector or at the economy-wide level- is usually computed assuming a Cobb-Douglas production function and constant returns to scale. As a result, unless output, capital and employment shares are constant across sectors, there is no direct relationship between TFP growth at the economy-wide level and TFP growth at the sector-level. By computing these weighted average TFP indexes, we can decompose TFP growth in a similar way to output, labour and capital productivity growth. In addition, we can test the extent to which this assumption is accurate by comparing TFP growth computed using aggregate data and TFP growth re-computed under the weighted average assumption.

Hence, for any production factor $x = \{h; k; l\}$, we can write aggregate TFP growth as

$$\frac{A^x_{t+1}}{A^x_t} = \sum_s \frac{A_{st+1}}{A_{st}} \frac{A_{st}x_{st}}{A^x_t x_t} \frac{x_{st+1}}{x_{st}} \frac{x_t}{x_{t+1}} = \sum_s \frac{A_{st+1}}{A_{st}} \left(\frac{A_{st}}{A^x_t} \frac{x_{st}}{x_t} \right) \frac{(x_s/x)_{t+1}}{(x_s/x)_t} \tag{5}$$

Denoting $a^x_{st} = A_{st} \frac{x_{st}}{x_t} / \overline{A^x_t}$, we can obtain a decomposition similar to the one in (2), ie:

$$\frac{A^x_{t+1}}{A^x_t} = \underbrace{\left(1 + \overline{\frac{\Delta (x_s/x)_{t+1}}{(x_s/x)_t}} \right) \left(1 + \overline{\frac{\Delta A_{st+1}}{A_{st}} a^x_{st}} \right)}_{\text{com-A}^x} + \underbrace{cov \left(\frac{\Delta (x_s/x)_{t+1}}{(x_s/x)_t}; \left(1 + \frac{\Delta A_{st+1}}{A_{st}} \right) a^x_{st} \right)}_{\text{alloc-A}^x} \tag{6}$$

The first term – denoted com-A^x – is the product of average growth in factor x sectoral shares and average size-weighted total factor productivity growth. The second term – denoted alloc-A^x – is the covariance across sectors between growth in factor x sectoral shares and the sectoral size-weighted TFP growth. As such, this second term measures the contribution of the reallocation of factor x across sectors to aggregate TFP growth.

2.1.4 From decompositions to regressions

With this methodology at hand, one way to proceed is to compute the above decomposition and then use a set of cross-country cross-time panel regressions to assess the relative importance of the determinants of each component such as credit growth (Borio et al. (2016)). However, this two-stage approach may not be the most efficient way to exploit the cross-sector, cross-time, cross country variation. An alternative approach can make use of all these dimensions in a single stage. This exploits the fact that the allocation component – the covariance term on the right-hand side of the decompositions (2), (3) and (6) – is proportional to the estimated coefficient of a regression in which the accumulation rate of factor x is the dependent variable and the size-weighted growth in factor x productivity is the explanatory variable. That is, consider the following sector-level panel regression:

$$\mathbf{f}^x_{sct} = \beta_0 + \beta_1 . \mathbf{y}^x_{sct} + \varepsilon_{sct} \tag{7}$$

where $\mathbf{f}^x_{sct}$ denotes the growth rate in the amount or share in factor x ($x = \{h; k; l\}$) in sector s in country c between time $t-1$ and time t and $\mathbf{y}^x_{sct}$ size-weighted growth in factor x or (total factor) productivity in sector s, country c between time $t-1$ and time t, i.e. $\mathbf{y}^x_{sct} = \left(1 + \frac{\Delta(Y_s/x_s)_{ct}}{(Y_s/x_s)_{ct-1}}\right) y_{sct-1}$ or $\mathbf{y}^x_{sct} = \left(1 + \frac{\Delta A_{st}}{A_{st-1}}\right) a^x_{st-1}$. Then, under OLS, the estimate of the coefficient β_1 writes as

$$\widehat{\beta_1} = \frac{cov\left(\mathbf{f}^x_{sct}; \mathbf{y}^x_{sct}\right)}{var\left[\mathbf{y}^x_{sct}\right]} = \frac{\text{alloc-x}}{var\left[\mathbf{y}^x_{sct}\right]} \tag{8}$$

and is hence proportional to the allocation component defined in decompositions (2), (3) and (6). In other words, $\widehat{\beta_1}$ measures the extent to which reallocation of factor x across sectors contributes to growth in either aggregate output, aggregate factor x productivity or aggregate TFP. Moreover, regression (7) can be extended to allow for interaction terms. Denoting $\mathbf{m}_{ct}$ a vector of country-level variables, we can estimate for $x = \{h; k; l\}$ the regressions

$$\mathbf{f}^x_{sct} = \beta_0 + \left[\beta_1 + \beta_2 \mathbf{m}_{ct}\right] . \mathbf{y}^x_{sct} + \varepsilon_{sct} \tag{9}$$

The estimated coefficient β_2 then measures how changes in the vector m_{ct} affect the relationship between factor accumulation and size-weighted productivity growth and thereby how such changes contribute to aggregate factor (or total factor) productivity growth.

3 Data and econometric specification

3.1 Baseline regression

In our analysis, we run several regressions based on the following baseline specification:

$$\mathbf{f}^x_{sct} = \alpha_{sc} + \alpha_{ct} + \alpha_{st} + \beta_0 \mathbf{z}_{sct} + \left[\beta_1 + \beta_2 . \mathbf{m}_{ct}\right] \mathbf{y}^x_{sct} + \varepsilon_{sct} \tag{10}$$

where factor accumulation at the sector level $\mathbf{f}^x_{sct}$ is defined differently depending on the specific factor taken into consideration. For labour, $\mathbf{f}^x_{sct}$ is defined as either the year-on-year (yoy) growth rate in the number of

persons employed or the yoy growth rate in the number of hours worked in sector s in country c between two consecutive years. For capital, $\mathbf{f}^x_{sct}$ is defined as the yoy growth rate in the capital stock, ie the investment to capital ratio minus the capital depreciation rate in sector s in country c between year t and $t+1$.[5] On the right hand side, the main explanatory variable $\mathbf{y}^x_{sct}$ is the sectoral measure of size-weighted capital, labour or total factor productivity growth. The other variables are country/sector α_{sc}, country/time α_{cs} and sector/time fixed effects α_{st} and various sector-level control variables $\mathbf{z}_{sct}$, including the initial sectoral share of factor x holdings, as larger sectors are likely to accumulate factors at a slower pace; and the current and one year lagged growth in sectoral real sales, as factors are likely to be accumulated at a faster pace when demand is stronger.

Key to our analysis is the interaction of the main variable $\mathbf{y}^x_{sct}$ with a vector of macro-economic variables $\mathbf{m}_{ct}$ which include:

- 1 and 2-year lagged short and long term interest rate surprises, i.e. the difference between the 1-year ahead forecast and the realized (short and long) interest rates (see below for more details).
- current and 1-year lagged aggregate sales growth, as a measure of aggregate real business cycle.
- current and 1-year lagged aggregate private credit to GDP gap, as a measure of aggregate financial cycle.

In our baseline specification (10), we expect the vector of coefficients β_0 to be positive: for given growth in productivity, an acceleration in current or past real sales implies that demand can be met only by accumulating factors more rapidly. Conversely, we expect the vector of coefficients β_1 to be negative: for given growth in demand, an acceleration in productivity growth would imply that demand can be met with factors being accumulated at a slower pace. The sign of the coefficients β_2 associated with the interaction terms is, instead, ambiguous. For instance, strong real sales can either tighten ($\beta_2 > 0$) or weaken ($\beta_2 < 0$) the relationship between factor accumulation and size-weighted productivity growth. The β_2 coefficient could be negative if higher productivity sectors require fewer ressources to meet stronger aggregate demand.

[5] Given that we will introduce a full set of country/sector as well as time fixed effects, the variable capital growth will essentially boil down to the investment to capital ratio.

However, it could be positive if strong demand acts to dampen the negative effect of productivity growth on factor accumulation.

As to interest rates and credit, there two main possibilities. On the one hand, it could be that lower (than expected) interest rates as well as a high credit gap allow credit constrained firms to expand in line with their productivity. In this case, we would expect the β_2 coefficient to be positive, meaning that low interest rates and easy credit would act to strengthen the relationship between factor accumulation and productivity growth. On the other hand, it is also possible that low interest rates and plentiful credit allow firms to accumulate production factors beyond what their productivity growth would predict. In this case, we would expect a negative β_2 coefficient. Finally, note that any direct effect of macroeconomic variables on factor accumulation is absorbed by the country/time fixed effects.

The use of specification (10) raises a couple of potential econometric issues. The first is that our specification assumes that sales drive and factor accumulation. However if causality runs in the opposite direction, eg in situations of excess demand, factor accumulation affects the ability to sell more, then real sales are not weakly exogenous. But the time period covered in our sample is arguably one during which output at the sectoral level had been demand determined, especially since the GFC. This would suggest that causality runs from changes in real sales to factor accumulation. The second issue concerns the use of the ratio of value added to the number of factor units as a measure of productivity.[6] In this case, factor accumulation appears both in the numerator of the dependent variable and in the denominator of the independent productivity growth variable. By construction, this generates a negative correlation, which could spuriously affect our results. For this reason, we complement regressions using value added to factor units as the productivity measure with regressions using TFP as the productivity measure.

3.2 Data

Our empirical analysis is based on industry-level data from the EU-KLEMS dataset for the period 2000-2015. This dataset covers 15 countries mainly from the Euro Area (Austria, Belgium, Denmark, Finland, France,

[6] The two other productivity measures are based on TFP growth. TFP can be computed using either employment or hours worked as labour input. These are the two TFP measures we use in the analysis.

Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden, United Kingdom, United States). This data source allows us to put together aggregate and sectoral data on value added, sales, employment, hours worked, capital stock and TFP growth.[7] Still, we face some limitations. First, because data on real sales are not available for five countries (Greece, Ireland, Portugal, Spain, United Kingdom), the regression sample shrinks to 10 of the 15 countries listed above. Second, unlike for value added, employment, hours worked and capital, the dataset does not provide information on total factor productivity *levels*, at neither the sectoral nor the aggregate level. Hence, to compute size-weighted TFP growth – the variable required in our baseline specification (10) – we have to approximate TFP weights a^x_{st}, $x = \{h; l; k\}$ with output weights y_{st}. That is, size-weighted TFP growth at the sectoral level is computed as $\left(1 + \frac{\Delta A_{st}}{A_{st-1}}\right) y_{st-1}$ instead of $\left(1 + \frac{\Delta A_{st}}{A_{st-1}}\right) a^x_{st-1}$.

Table 1 below summarises the sectoral breakdown used in the paper. We follow the ISIC 3 rev. 4 industrial classification and consider a sectoral decomposition with 13 sectors: (1) Agriculture, (2) Mining and quarrying, (3) Manufacturing, (4) Electricity and Water Supply, (5) Construction, (6) Wholsesale and retail trade, (7) Transportation, (8) Accomodation, (9) Information and communication, (10) Financial and Insurance activities, (11) Real estate activities, (12) Professional and scientific activities, and (13) Social and Personal Services. In addition, in testing for the robustness of our results, we use a narrower perimeter to define the economy, which excludes non-market activities.

[7] The EU-KLEMS dataset actually provides two measures of TFP, one computed using employment as labour input and one using hours worked.

	Total Economy		Market Economy
code	Industry label	code	Industry label
A	AGRICULTURE, FORESTRY AND FISHING	A	AGRICULTURE, FORESTRY AND FISHING
B	MINING AND QUARRYING	B	MINING AND QUARRYING
C	TOTAL MANUFACTURING	C	TOTAL MANUFACTURING
D-E	ELECTRICITY, GAS AND WATER SUPPLY	D-E	ELECTRICITY, GAS AND WATER SUPPLY
F	CONSTRUCTION	F	CONSTRUCTION
G	WHOLESALE AND RETAIL TRADE; REPAIR OF MOTOR VEHICLES AND MOTORCYCLES	G	WHOLESALE AND RETAIL TRADE; REPAIR OF MOTOR VEHICLES AND MOTORCYCLES
H	TRANSPORTATION AND STORAGE	H	TRANSPORTATION AND STORAGE
I	ACCOMMODATION AND FOOD SERVICE ACTIVITIES	I	ACCOMMODATION AND FOOD SERVICE ACTIVITIES
J	INFORMATION AND COMMUNICATION	J	INFORMATION AND COMMUNICATION
K	FINANCIAL AND INSURANCE ACTIVITIES	K	FINANCIAL AND INSURANCE ACTIVITIES
L	REAL ESTATE ACTIVITIES		
M-N	PROFESSIONAL, SCIENTIFIC, TECHNICAL, ADMINISTRATIVE AND SUPPORT SERVICE ACTIVITIES	M-N	PROFESSIONAL, SCIENTIFIC, TECHNICAL, ADMINISTRATIVE AND SUPPORT SERVICE ACTIVITIES
O-U	COMMUNITY SOCIAL AND PERSONAL SERVICES		
		R-S	ARTS, ENTERTAINMENT, RECREATION AND OTHER SERVICE ACTIVITIES

Table 1: Sectoral decompositions

To identify the effect of monetary policy in regression (10), we need a measure of monetary policy shocks. We consider measures of shocks to short-term policy rates (3 months) and long-term interest rates on government bonds (10 year). The interest rate shocks are computed as the 1-year ahead forecast error for each of these two interest rates, using forecasts from the OECD economic outlook publication. More specifically, the forecast errors are computed as the difference between the forecast and the realized interest rate. A positive forecast error hence implies that actual interest rates are lower than expected by the OECD forecast and therefore represents a measure of accomodation.

There are a number of reasons to consider shocks to both short- and long-term interest rates. Over the 2000-2015 sample period considered in our analysis, monetary policy had initially been conducted through changes in short-term interest rates. However, in in the post-crisis period, policy rates have been constrained by the zero lower bound prompting central banks to reduce long-term interest rates through large-scale bond purchases (eg Gagnon et al (2011), Joyce et al (2011)). That said, fluctuations in long-term government bonds yields may reflect not only policy decisions but also other market developments. Thus, while forecast errors in 3-months rates can be considered as policy shocks, forecast errors in 10-year bond yields may reflect broader shocks to financial conditions. Table 2 shows the periods for which the corresponding data is available in the KLEMS dataset. Finally, to take into account transmission lags and to ensure that

our variables measuring interest rate surprises are pre-determined, we only consider the effect of one- and two-year lagged values of interest rate surprises in the vector $\mathbf{m}_{ct}$.

countries	employment	hours worked	capital stock	value added	gross output	TFP hours worked	TFP employment	3-month policy rate	10-year gov. bond yield
Austria	1995-2014	1995-2014	1995-2014	1995-2014	1995-2014	1996-2014	1996-2014	2001-2015	2001-2015
Belgium	1995-2014	1999-2014		1995-2014	1995-2014	1999-2014	1999-2014	2001-2015	2001-2015
Germany	1995-2014	1995-2014	1995-2014	1995-2014	1995-2014	1996-2014	1996-2014	2001-2015	2001-2015
Denmark	1995-2014	1995-2014	1995-2014	1995-2014	1995-2014	1996-2014	1996-2014	2001-2015	2001-2015
Spain	1995-2014	1995-2014	1995-2014	1995-2014		1996-2014	1996-2014	2001-2015	2001-2015
Finland	1995-2014	1995-2014	1995-2014	1995-2014	1995-2014	1995-2014	1995-2014	2001-2015	2001-2015
France	1995-2014	1995-2014	1995-2014	1995-2014	1995-2014	1995-2014	1995-2014	2001-2015	2001-2015
UK	1995-2014	1995-2014	1997-2014	1995-2014		1998-2014	1998-2014	2001-2015	2001-2015
Greece	1995-2014	1995-2014	1995-2014	1995-2014	1995-2014			2001-2015	2002-2015
Ireland	1998-2014	1998-2014		1995-2014				2001-2015	2001-2015
Italy	1995-2014	1995-2014	1995-2013	1995-2014	1995-2014	1996-2013	1996-2013	2001-2015	2001-2015
Netherlands	1995-2014	1995-2014	2000-2014	1995-2014	1995-2014	2001-2014	2001-2014	2001-2015	2001-2015
Portugal	1995-2014	1995-2014		1995-2014	1995-2013			2001-2015	2001-2015
Sweden	1995-2014	1995-2014	1995-2013	1995-2014	1995-2013	1995-2013	1995-2013	2001-2015	2001-2015
US	2000-2014	1998-2014	1995-2014	1995-2014	1995-2014	1999-2014	1999-2014	2001-2015	2001-2015

Table 2: Data availability

4 A first pass at the data

4.1 Summary statistics of output and productivity growth

We now turn to descriptive statistics for the four main variables of interest – value added growth, labour productivity growth, capital productivity growth and TFP growth – along with the summary statistics of the common and allocative components of each variable. Table 3 highlights a striking difference between measures of individual factor productivity growth and measures of TFP growth. Changes in value added growth as well as labour and capital productivity growth are mostly accounted for by the common component instead of the allocation component. This is true both for average growth and growth volatility. For example, the standard deviation of the allocation component ranges from 25 to 35% of the overall volatility of the corresponding variable, while the standard deviations of the common component is of the same order of magnitude as the volatility of the corresponding variable. By contrast, for measures of TFP growth, the allocation component is sizeable. For example, when hours-based TFP is computed as an average of sectoral hours based TFP weighted by sectoral hours, the allocation component accounts for around 40% of aggregate

TFP growth on average. For employment-based TFP growth, the allocation component represents on average 65 to 85% of aggregate TFP growth, dwarfing the common component. Furthermoe, the ratio of volatilities is relatively similar to that for labour productivity: the allocation component volatility is about one third of aggregate TFP growth volatility, while the common component is roughly as volatile as aggregate TFP growth.

Growth variable	obs.	average	std. dev.	first quartile	median	third quartile	skewness
Real Value Added	**292**	**1.80%**	**2.99%**	**0.63%**	**1.94%**	**3.39%**	**1.918**
Allocation component	*292*	*0.06%*	*0.70%*	*-0.27%*	*0.09%*	*0.45%*	*-0.262*
Common component	*292*	*1.74%*	*3.12%*	*0.52%*	*1.75%*	*3.15%*	*0.001*
Labour productivity growth (employment)	**292**	**1.03%**	**2.24%**	**0.14%**	**0.96%**	**1.93%**	**4.356**
Allocation component	*292*	*0.06%*	*0.70%*	*-0.27%*	*0.09%*	*0.45%*	*-0.080*
Common component	*292*	*0.97%*	*2.31%*	*-0.02%*	*0.87%*	*1.81%*	*4.180*
Capital productivity growth (nominal)	**232**	**-0.55%**	**1.99%**	**-1.59%**	**-0.20%**	**0.64%**	**-0.518**
Allocation component	*232*	*0.02%*	*0.60%*	*-0.27%*	*0.09%*	*0.35%*	*-2.250*
Common component	*232*	*-0.56%*	*2.01%*	*-1.64%*	*-0.34%*	*0.61%*	*-0.402*
Employment based TFP growth	**214**	**0.08%**	**1.68%**	**-0.64%**	**0.22%**	**0.90%**	**-1.165**
TFP (weighted average using employment shares)	214	0.13%	1.68%	*-0.64%*	0.35%	0.90%	-1.281
Allocation component	*214*	*0.11%*	*0.56%*	*-0.18%*	*0.12%*	*0.45%*	*-0.401*
Common component	*214*	*0.03%*	*1.70%*	-0.76%	*0.06%*	*0.99%*	*-0.878*
TFP (weighted average using hours shares)	214	0.20%	1.71%	-0.53%	0.29%	1.09%	-1.133
Allocation component	*214*	*0.13%*	*0.54%*	*-0.22%*	*0.11%*	*0.47%*	*0.186*
Common component	*214*	*0.07%*	*1.70%*	*-0.79%*	*0.17%*	*0.95%*	*-0.727*
Real sales	238	1.76%	2.95%	0.55%	2.19%	3.84%	-1.403
Employment	292	0.76%	1.79%	0.03%	0.92%	1.69%	-1.046
Hours worked	290	0.50%	2.03%	-0.35%	0.75%	1.65%	-1.023
Capital Stock (nominal)	253	4.35%	3.75%	2.49%	4.22%	5.96%	0.353
Capital Stock (real)	251	2.73%	2.23%	1.50%	2.49%	4.04%	0.426

Table 3: Descriptive statistics

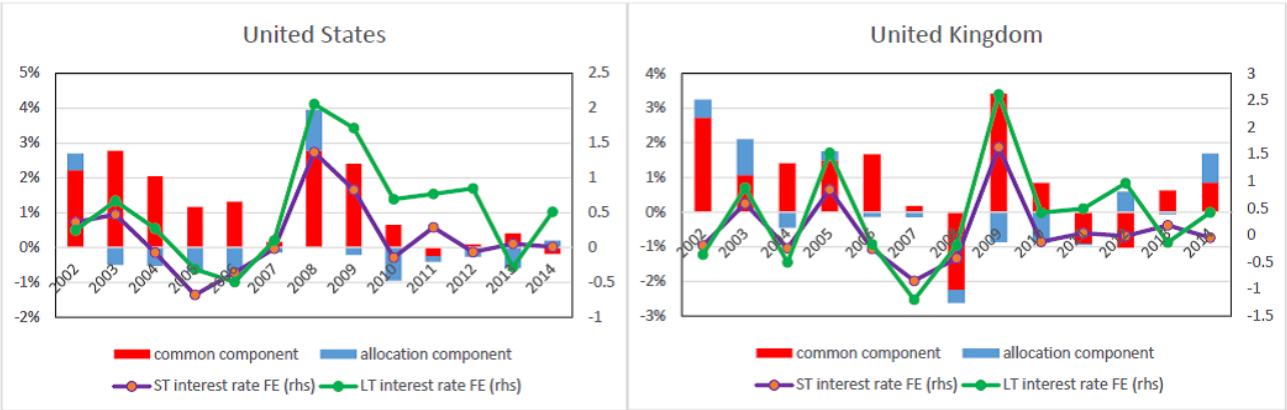
4.2 Summary statistics of interest rates

Over the sample period 2000-2015, agents have been relatively more accurate in forecasting short-term than long-term interest rates. They have also shown a tendency to under-predict short-term rate but over-predict long-term interest rates and hence the slope of the yield curve. That is, while the median short-term interest rate forecast error is very close to zero (-0.04%), the median long-term interest rate forecast error is positive (0.5%), meaning that long-term interest rates have been lower than forecasted one year ahead for more than 50% of our sample observations. This also holds for the forecast error of the yield curve slope, whose median value is around 0.3%.

Interest rate variable	obs.	average	std. dev.	first quartile	median	third quartile	skewness
Short-term interest rate							
Level	*207*	*2.15%*	*1.59%*	*0.60%*	*2.10%*	*3.31%*	*0.334*
Forecast error	*207*	*0.14%*	*0.67%*	*-0.25%*	*-0.04%*	*0.43%*	*1.108*
Long-term interest rate							
Level	*207*	*3.71%*	*1.39%*	*2.94%*	*4.05%*	*4.45%*	*-0.080*
Forecast error	*206*	*0.40%*	*0.47%*	*-0.02%*	*0.47%*	*0.80%*	*-1.901*
Yield curve slope							
Level	*207*	*1.56%*	*1.37%*	*0.82%*	*1.55%*	*2.08%*	*2.243*
Forecast error	*206*	*0.26%*	*0.74%*	*-0.05%*	*0.34%*	*0.66%*	*-1.155*

Table 4: Interest rate summary statistics

The case of the United States (Graph 5) exemplifies the stark contrast between the behaviour of short- and long-term interest rates before and after the onset of the GFC. Prior to the crisis, the short-term policy rate had been close to or above the one-year ahead forecast level, as indicated by negative values of our interest rate surprise variable up to 2007 (Graph 5). But, after 2010, with policy rates stuck at the zero lower bound, interest rate surprises had been concentrated in a very narrow region centered around zero. By contrast, long term interest rate surprises became much larger as the demand for treasuries soared during the financial crisis and as the FED started a number of asset purchase program. Interestingly, forecast errors shrank in 2013, when the announcement of a possible tapering of asset purchases caught markets by surprise and led to an unexpected increase in government bond yields.



Graph 5: Productivity growth and interest rate surprises.

5 Empirical Results

5.1 Labour productivity growth and factor reallocation

We start our empirical examination with a set of regressions where the dependent variable is the sectoral growth rate of employment. Table 6 provides the empirical results from estimating a set of regressions where the dependent variable is relative employment growth at the sector-level and the productivity measure is value added to employment. Results in column (1) of Table 6 show that first, employment growth tends to be lower in sectors which have larger initial shares of total employment. Second, sectors with stronger current and/or one-year lagged real sales growth have higher growth rates of labour accumulation. Turning to the relationship with labour productivity, Column (1) in table 6 shows that there is a negative but insignificant correlation between sector employment growth and size-weighted sector productivity growth. Hence at first glance, labour reallocation across sectors seems to take place independently of cross-sector differences in size-weighted labour productivity. Column (2) however provides a very different view, as the interaction between size-weighted productivity growth and the one year lagged forecast error in the policy rate has a positive and significant coefficient, meaning that when the policy rate falls below the forecasted level one year before, employment growth is stronger in sectors with higher size-weighted productivity growth. This would suggest that an easing shock to monetary policy tends to raise labour productivity growth, by facilitating the reallocation of the labour force into sectors with larger size-weighted productivity gains. Column (3) tests for the presence of such a similar effect, but turning to long term interest rates. Empirical results show that forecast errors in long term interest rates do not significantly affect the relationship between sectoral employment growth and sectoral size-weighted labour productivity growth, neither with a one nor with a two year lag.

However, once surprises to both short and long term interest rate are included, both enter significantly (column (4)). What comes out in column (4) is the main result of the paper: positive surprises on the short-term policy rate, i.e. lower than forecasted policy interest rates, tend to increase aggregate productivity by steepen the relationship between sector labour productivity growth and employment growth. At the same

time lower than forecasted long-term rates, tend to weaken the relationship between sectoral size-weighted labour productivity growth and sectoral employment growth, as is shown by the negative and significant coefficient. Moreover, running an F-test shows that the null that the sum of coefficients is zero cannot be rejected at standard confidence levels, suggesting it is actually the surprise component of the slope of the yield curve that drives the extent to which employment reallocation takes place in favor or to the detriment of sectors with higher size-weighted productivity growth.[8] Specifically, a lower (higher) than expected slope in the yield curve is associated with less (more) reallocation into sectors with high size-weighted productivity growth. And in addition, columns (5) to (7) show that this result -relating to the slope of the yield curve- is robust to controlling for the state of the business cycle proxied by aggregate real sales growth, as well as controlling for the state of the financial cycle, proxied by the private credit to GDP gap.[9] Last column (8) shows that introducing explicitly the slope of the yield curve -defined as the difference between the long and the short run interest rate surprise- provides very similar results.

Dependent variable: Relative employment growth								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log of initial employment share	-0.0790***	-0.0820***	-0.0783***	-0.0811***	-0.0808***	-0.0805***	-0.0799***	-0.0791***
	(0.0183)	(0.0187)	(0.0183)	(0.0186)	(0.0186)	(0.0184)	(0.0184)	(0.0183)
Real sales growth (current)	0.132***	0.131***	0.133***	0.133***	0.133***	0.133***	0.133***	0.133***
	(0.0398)	(0.0391)	(0.0398)	(0.0387)	(0.0387)	(0.0382)	(0.0381)	(0.0380)
Real sales growth (1-year lagged)	0.0733***	0.0734***	0.0723***	0.0728***	0.0732***	0.0737***	0.0741***	0.0757***
	(0.0209)	(0.0209)	(0.0207)	(0.0205)	(0.0208)	(0.0207)	(0.0212)	(0.021)
Size weighted labour productivity growth	-0.352	-0.388	-0.348	-0.362	-0.364	-1.687	-1.913	-1.912
	(0.238)	(0.257)	(0.236)	(0.253)	(0.255)	(1.244)	(1.209)	(1.202)
Interaction with 1-year lagged short-term policy rate forecast error		8.026***		10.80***	10.94***	11.07***	11.66***	
		(2.943)		(3.291)	(3.370)	(3.467)	(3.546)	
Interaction with 2-year lagged short-term policy rate forecast error		2.227		2.712	2.731	2.276	2.121	
		(2.434)		(3.218)	(3.212)	(3.086)	(3.040)	
Interaction with 1-year lagged long-term rate forecast error			-2.815	-8.276**	-8.330**	-8.303**	-8.369**	
			(2.808)	(3.726)	(3.719)	(3.755)	(3.749)	
Interaction with 2-year lagged long-term rate forecast error			2.549	2.409	2.270	1.886	1.885	
			(2.858)	(3.456)	(3.456)	(3.425)	(3.450)	
Interaction with 1-year lagged yield curve slope								-9.625***
								(3.043)
Interaction with 2-year lagged yield curve slope								-2.153
								(2.553)
Interaction with current private credit to GDP gap					-0.0968		-0.0792	-0.0789
					(0.156)		(0.156)	(0.151)
Interaction with 1-year lagged private credit to GDP gap					0.0887		0.140	0.128
					(0.195)		(0.186)	(0.184)
Interaction with current aggregate real sales growth						0.900	0.930	1.156
						(0.811)	(0.821)	(0.822)
Interaction with 1-year lagged aggregate real sales growth						0.388	0.582	0.383
						(0.726)	(0.675)	(0.744)
Observations	1,651	1,651	1,651	1,651	1,651	1,651	1,651	1,651
R-squared	0.558	0.562	0.558	0.565	0.565	0.566	0.566	0.565

[8] The p. value for the null hypothesis that the sum of estimated coefficients for size-weighted productivity growth interacted with 1-year lagged long-term interest rate surprise and size-weighted productivity growth interacted with 1-year lagged short-term interest rate surprise is equal to zero is about 29%. Similarly the p. value for the null hypothesis that the sum of estimated coefficients for size-weighted productivity growth interacted with 2-year lagged long-term interest rate surprise and size-weighted productivity growth interacted with 2-year lagged short-term interest rate surprise is equal to zero is about 17%.

[9] The private credit to GDP gap is computed as the log-difference between the actual private credit to GDP and the HP filtered private credit to GDP.

Table 6: The Employment-Labour Productivity relationship.

We now turn to possible interpretations of our main result. An (unexpected) change in the slope of the yield curve may be either due to an (unexpected) changes at the short or at the long end of the yield curve. We can first think of the former as a standard (conventional) monetary policy shock. In this case, an easing shock would correspond to a higher than expected slope of the yield curve as long term rates are held constant. A conventional easing monetary policy shock would therefore tend to be associated with a stronger positive relationship between sectoral (size-weighted) productivity growth and sectoral employment growth, thereby contributing positively to aggregate productivity growth. Conversely, when the slope of the yield curve changes because of an unexpected change at the long end, then a lower than expected slope corresponds to a lower than expected long-term interest rate, which can, for instance, be the result of accommodative monetary policy carried out through Quantitative Easing (QE). In this case, our results suggest that accommodative unconventional monetary policy would weaken the relationship between sectoral (size-weighted) productivity growth and sectoral employment growth, thus, contributing negatively to aggregate productivity growth.

5.2 Total factor productivity growth and labour reallocation

We now turn to the relationship between employment growth and size-weighted TFP growth. Table 7 provide the estimation results using TFP data computed using hours worked as the labor input. As noted before, using TFP growth as a measure of productivity growth on the right hand side is useful insofar as this productivity measure is computed without using data on factor accumulation which is our dependent variable. Similarly to the results described for Table 6, Table 7 shows that there is no significant relationship between size-weighted TFP growth and relative employment growth (column(1)). However when we allow the surprise component in the short and long term interest rates to affect this sensitivity, column (4) shows that a lower than expected short-term interest rate tends to strengthen sectoral employment growth and size-weighted TFP growth. By contrast, a lower than expected long-term interest rate tends to weaken the relationship between sector TFP growth and employment growth, thus reducing the contribution of reallocation to aggregate TFP. As in Table 6, these results keep holding when we control for the current and

the one year lagged aggregate real sales growth. These also hold true when we control the the current and one lagged aggregate private credit to GDP gap.[10]

Dependent variable: Relative employment growth								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log of initial employment share	-0.0933***	-0.0965***	-0.0924***	-0.0955***	-0.0951***	-0.0954***	-0.0946***	-0.0939***
	(0.0184)	(0.0187)	(0.0185)	(0.0186)	(0.0185)	(0.0185)	(0.0184)	(.0183)
Real sales growth (current)	0.125***	0.124***	0.127***	0.127***	0.127***	0.126***	0.126***	0.126***
	(0.0392)	(0.0385)	(0.0392)	(0.0382)	(0.0381)	(0.0377)	(0.0375)	(.0374)
Real sales growth (1-year lagged)	0.0660***	0.0657***	0.0653***	0.0653***	0.0656***	0.0658***	0.0662***	0.0679***
	(0.0214)	(0.0214)	(0.0211)	(0.0209)	(0.0212)	(0.0212)	(0.0217)	(.0217)
Size weighted total factor productivity growth	0.158	0.137	0.163	0.161	0.162	-0.850	-1.150	-1.187
	(0.114)	(0.111)	(0.117)	(0.111)	(0.111)	(1.104)	(1.141)	(1.221)
Interaction with 1-year lagged short-term policy rate forecast error		7.478**		10.35***	10.50***	10.92***	11.59***	
		(2.938)		(3.321)	(3.371)	(3.511)	(3.587)	
Interaction with 2-year lagged short-term policy rate forecast error		2.233		3.032	3.023	2.655	2.452	
		(2.478)		(3.207)	(3.205)	(3.065)	(3.032)	
Interaction with 1-year lagged long-term rate forecast error			-3.581	-8.829**	-8.867**	-8.891**	-8.949**	
			(2.816)	(3.762)	(3.749)	(3.779)	(3.766)	
Interaction with 2-year lagged long-term rate forecast error			2.271	1.854	1.820	1.570	1.635	
			(2.899)	(3.365)	(3.393)	(3.353)	(3.395)	
Interaction with 1-year lagged yield curve slope								-9.825***
								(3.046)
Interaction with 2-year lagged yield curve slope								-2.312
								(2.520)
Interaction with current private credit to GDP gap					-0.0554		-0.0511	-0.053
					(0.159)		(0.162)	(0.158)
Interaction with 1-year lagged private credit to GDP gap					0.0832		0.139	0.131
					(0.187)		(0.182)	(0.184)
Interaction with current aggregate real sales growth						0.536	0.596	0.811
						(0.710)	(0.743)	(0.760)
Interaction with 1-year lagged aggregate real sales growth						0.449	0.685	0.527
						(0.667)	(0.641)	(0.713)
Observations	1,651	1,651	1,651	1,651	1,651	1,651	1,651	1,651
R-squared	0.555	0.559	0.556	0.562	0.562	0.563	0.563	0.562

Table 7: The Employment-TFP relationship.

This first set of regressions suggests that the sector-level relationship between productivity growth and sectoral labour accumulation is influenced by short and long term interest rate surprises in opposite ways but with very comparable magnitudes. We now want to test whether this results holds for hours worked and capital. Estimations using the relative growth rate in hours worked as a dependent variable are presented in the appendix. In a nustshell, results are very similar from a qualitative standpoint although it is fair to say that the surprise component in the long-term rate seems to be less significant compared with the regressions using the growth rate of employment as a dependent variable. But overall, this set of regressions confirms that a steeper yield curve is associated with a stronger relationship at the sectoral level between growth in hours worked and size-weighted hourly (total factor) productivity growth.

[10] As a robustness test in appendix Table A.1, we confirm that these results hold when TFP is computed using employment headcount instead of hours worked. Results are both qualitatively and quantitatively very similar.

5.3 Productivity growth and capital reallocation

Let us now turn to the case of capital. To do so we estimate a set of regressions where the dependent variable is the relative growth rate in the capital stock at the sector-level while the explanatory variable is either size-weighted capital productivity growth or size-weighted TFP growth. Table 8 provides the estimations results using size-weighted capital productivity growth on the right hand side. Three of them are worth being noted. First, capital growth, i.e. the investment to capital ratio, does not seem to respond to changes in sectoral demand. The estimated coefficients for current and one-year lagged real sales growth are positive but none of them are statistically significant. Similarly, the empirical results suggest that capital growth in a sector does not respond to capital productivity growth (size-weighted) on its own. Yet, there is some (weak) evidence that lower than expected short and long term interest rates have respectively a positive and a negative effect on the relationship between sector capital productivity growth and capital growth. For instance running F-tests on the regression in column (7) of Table 8 shows that one cannot reject the hypothesis that the unexpected component of the slope of the yield curve is actually what determines the strength of the relationship between productivity growth and capital accumulation across sectors. In addition F-tests also suggest that the sum of coefficients for interaction terms with short-term interest rate surprises is positive and significant while the sum of coefficient for interaction terms with long-term interest rate surprises is negative and significant.

Dependent variable: Relative capital growth								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log of initial share in aggregate capital	-0.0571***	-0.0578***	-0.0571***	-0.0577***	-0.0582***	-0.0577***	-0.0579***	-0.0579***
	(0.0171)	(0.0171)	(0.0172)	(0.0172)	(0.0177)	(0.0173)	(0.0177)	(0.0176)
Real sales growth (current)	0.0307	0.0300	0.0305	0.0316	0.0303	0.0322	0.0312	0.0314
	(0.0545)	(0.0540)	(0.0544)	(0.0531)	(0.0532)	(0.0527)	(0.0531)	(0.0531)
Real sales growth (1-year lagged)	0.0195	0.0197	0.0202	0.0206	0.0224	0.0219	0.0232	0.0226
	(0.0386)	(0.0386)	(0.0377)	(0.0380)	(0.0367)	(0.0382)	(0.0370)	(0.0378)
Size weighted capital productivity growth	-0.246	-0.276	-0.236	-0.232	-0.253	-1.124	-0.665	-0.599
	(0.328)	(0.356)	(0.340)	(0.363)	(0.363)	(1.152)	(1.232)	(1.132)
Interaction with 1-year lagged short-term policy rate forecast error		6.517		8.649*	8.903*	7.535	7.512	
		(3.991)		(4.468)	(4.689)	(5.072)	(5.578)	
Interaction with 2-year lagged short-term policy rate forecast error		1.083		3.696*	3.543	3.481	3.520	
		(2.051)		(2.101)	(2.180)	(2.113)	(2.161)	
Interaction with 1-year lagged long-term rate forecast error			-0.151	-7.855*	-7.647*	-7.738*	-7.435*	
			(3.939)	(4.349)	(4.075)	(4.475)	(4.284)	
Interaction with 2-year lagged long-term rate forecast error			-1.887	-3.739	-4.531	-4.368	-4.908	
			(3.827)	(4.615)	(4.592)	(4.750)	(4.709)	
Interaction with 1-year lagged yield curve slope forecast error								-7.564
								(4.820)
Interaction with 2-year lagged yield curve slope forecast error								-3.820*
								(2.036)
Interaction with 1-year current private credit to GDP gap					-0.426*		-0.390	-0.385
					(0.255)		(0.257)	(0.245)
Interaction with 1-year lagged current private credit to GDP gap					0.237		0.210	0.206
					(0.266)		(0.291)	(0.279)
Interaction with current aggregate real sales growth						1.179*	0.872	0.832
						(0.656)	(0.666)	(0.760)
Interaction with 1-year aggregate real sales growth						-0.338	-0.491	-0.521
						(0.718)	(0.820)	(0.713)
Observations	1,464	1,464	1,464	1,464	1,464	1,464	1,464	1,464
R-squared	0.569	0.571	0.569	0.573	0.575	0.574	0.576	0.576

Table 8: The capital-productivity relationship.

The conclusion is therefore as follows: the main result that unexpected changes to the slope of the yield curve drive the sensitivity of factor accumulation to size-weighted (total) factor productivity growth holds both in the case of labour and capital. Yet, the evidence is more significant for labour reallocation than it is for capital reallocation.

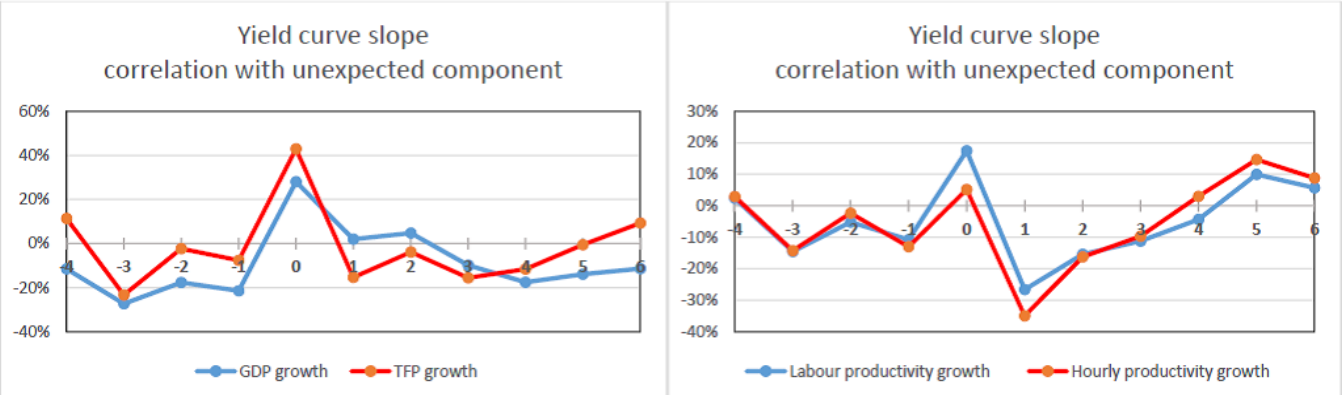
5.4 Extending the empirical analysis

5.4.1 The signaling properties of the slope of the yield curve

Our main result is that an unexpectedly steeper yield curve is followed by factor reallocation into sectors with higher size-weighted productivity growth, thereby contributing to higher aggregate (total) factor productivity growth. Such result could at face value look pretty trivial if a steeper yield curve actually signals higher growth while a flatter one is announcing a recession. Indeed given that productivity tends to be procyclical, it could well be the slope yield curve just provides information on future economic developments, including for output and productivity rather than capture monetary policy shocks. We provide two pieces of evidence against such conclusions. First, as shown in the descriptive statistics, fluctuations in output and productivity

growth are driven to a large extent by the common component. Hence we would expect that fluctuations in the slope of the yield curve reflect fluctuations in the common component, ie. average productivity growth across sector, and to a lesser extent factor reallocation across sectors. Even if a steeper yield curve signals greater factor reallocation into higher (size-weighted) productivity growth sectors, it's still an interesting piece of evidence that market expectations about future output embedded in the slope of the yield curve are (partly) driven by factor reallocation occuring in favor of sectors with higher size-weighted productivity growth.

More fundamentaly, the correlation at the aggregate level between the unexpected part of the slope of the yield curve on the one hand and output and TFP growth on the other hand (Graph 9, left hand panel) shows that while positive and significant contemporanously, is very close to zero or negative when we consider the correlation between our monetary policy shocks and future values of output and TFP growth. All of the one to five-year forward output and TFP growth rates either do not correlate significantly with the unexpected component of the slope of the yield curve or only at the margin. This suggests that the signalling properties of the slope of the yield curve in terms of forward business cycle movement are pretty weak in the sample we look at, despite, a lower than expected slope of the yield curve being contemporaneously associated with higher output and TFP growth.



Graph 9: Dynamic correlation between the unexpected component of the slope of the yield curve and aggregate growth.

This result does not extend to labour productivity. For both headcount and hourly labour productivity growth, forward values correlate negatively with the (unexpected component of the) slope of the yield curve, suggesting the results we captured using the sector-level regressions actually do have an aggregate-level counterpart, or at least are consistent with patterns observed at the aggregate level.

5.4.2 Interest rate forecasts and the surprise component of interest rates.

We have shown that the sensitivity of factor accumulation to sectoral productivity growth increases with size of forecast errors on the slope of the yield curve such that a surprise steepening of the yield curve results in factor stronger factor accumulation in sectors with higher productivity growth.

However it may be that realised -or expected- interest rates, rather than shocks which influence the relationship between sector TFP growth and factor reallocation. To test for this possibility, in Table 10 we decompose forecast errors into forecast and realised interest rates values and allow each of these two components to independently affect the sensitivity of factor accumulation to size-weighted productivity growth.

Column (1) presents the results when employment growth is the measure of factor allocation and TFP growth the measure of sector productivity. When both forecast and realised interest rates are included, the estimated coefficients for realised and forecasted interest rates are opposite and similar in absolute value on both short- and long-term interest rates. A similar result is found when factor allocation is measured in hours worked (Column (2)). The opposite and similar sized coefficients on forecast and realised interest rates in both regressions suggests that neither realised nor forecasted interest rate values have an effect beyond and above that of interest rate surprises. The empirical results pertaining to sectoral growth in the capital stock are qualitatively similar (Column (3)) although with one difference. Once forecast errors are separated into forecast and realised interest rates the former lose statistical significance.[11] Nevertheless, the hypothesis that estimated coefficients for realised and forecasted interest rate values sum up to zero cannot be rejected at standard confidence levels. The main take-away from this exercise is therefore that the sensitivity of factor

[11] Qualitatively and quantitively similar results are obtained when sector productivity is measured as either labour or capital productivity.

accumulation to size-weighted productivity growth depends on interest rates surprises and neither realised nor forecasted interest rates have a statistically significant effect on this sensitivity beyond and above that of forecast errors.

	(1)	(2)	(3)
Dependent variable: Relative growth rate in	**Employment**	**Hours worked**	**Capital stock**
log of initial factor share	-0.0975***	-0.113***	-0.0611***
	(0.0189)	(0.0229)	(0.0179)
Real sales growth (current)	0.128***	0.128***	0.0274
	(0.0380)	(0.0273)	(0.0493)
Real sales growth (1-year lagged)	0.0678***	0.0357	0.0167
	(0.0204)	(0.0243)	(0.0370)
Size-weighted TFP growth	0.114	0.170	-0.126
	(0.146)	(0.190)	(0.332)
Interaction with 1-year lagged short-term rate	-13.01***	-13.87***	-6.511**
	(3.852)	(4.535)	(3.213)
Interaction with 1-year lagged short-term rate forecast	14.82**	13.11**	3.957
	(5.731)	(6.317)	(4.851)
Interaction with 2-year lagged short-term rate	-6.898	-9.697*	-0.216
	(4.879)	(5.564)	(6.377)
Interaction with 2-year lagged short-term rate forecast	0.770	6.565*	1.879
	(3.076)	(3.540)	(2.482)
Interaction with 1-year lagged long-term rate	10.97**	11.73**	7.731*
	(4.640)	(5.057)	(4.418)
Interaction with 1-year lagged long-term rate forecast	-14.55**	-13.90*	-7.269
	(5.817)	(7.947)	(7.831)
Interaction with 2-year lagged long-term rate	4.254	10.64	4.944
	(5.967)	(8.348)	(10.34)
Interaction with 2-year lagged long-term rate forecast	3.494	-7.450*	-0.752
	(3.657)	(4.459)	(6.515)
Observations	1,651	1,633	1,464
R-squared	0.564	0.564	0.572

Table 10: Separating interest rate surprises into forecasts and realization.

5.4.3 Separating the pre and post GFC periods.

As discussed above, monetary policy was conducted using very different tools in the first and the second half of the sample. In addition, the behavior of credit markets was also very different in the first and second half of the sample covered in this study. Prior to the GFC, private sector credit growth rates were exceptionally strong. The GFC caused significant dysfunction to credit markets with credit freezes and credit rationing. Against this backdrop of very different monetary policy instruments and credit conditions, there is good reason to believe that the effect of interest rate surprises on the strength of factor accumulation to more productive sectors may have behaved differently at different points of time in our sample.

To test for this possibility, in Table 11, we include the triple interaction between size-weighted productivity growth, interest rate surprises and a time dummy variable which takes a value one from 2009 onwards. The results on the allocation of employment, hours and capital stock which taken together suggest that the effect

of surprises in short-term policy rate becomes weaker after 2008. At the same time the effect of long term interest rate surprises arises from the post-2008 period.

In column (1), the effect of standard monetary policy accommodation on the sensitivity of employment growth to sectoral productivity through the short term policy rate holds only in the period preceding the GFC. After the GFC, the F-tests summing the coefficients in rows (a) + (b) and (c) + (d) show that the hypothesis that short term policy rate surprises do not affect the sensitivity of employmentgrowth to sectoral productivity cannot be rejected. By contrast, F-tests examining the effect of long-term interest rates shown by the row which sums the coefficients of (e) + (f) suggest they affected the employment-productivity relationship after the GFC.

When factor allocation is measured by growth in hours worked (Column (2)) the effect of short-term interest rate surprises also becomes insignificant after 2008 (F-test summing coefficients in rows (a) + (b)), while being significant before (F-test summing coefficients in rows (a) + (c)). At the same time the effect of long term interest rate surprises is very much related to post-2008 periods (F-tests which sum the coefficients from rows (e) and (f) as well as that which sums the coefficients in rows (g) and (h)).

Column (3) examines how the sensitivity of capital growth to sectoral productivity is affected by interest rate surprises before and after the GFC. Overall, the results also suggest the influence of short-rate surprises wained after 2008, while the effect of long-rate surprises became significant (F-test summing coefficients (g) + (h)).

	Dependent variable (relative growth)	Employment	Hours worked	Capital stock
		(1)	(2)	(3)
	log of initial factor share	-0.0972***	-0.113***	-0.0614***
		(0.0184)	(0.0230)	(0.0181)
	Real sales growth (current)	0.126***	0.126***	0.0257
		(0.0381)	(0.0275)	(0.0488)
	Real sales growth (1-year lagged)	0.0655***	0.0330	0.0152
		(0.0210)	(0.0240)	(0.0359)
	Size-weighted TFP growth	0.181	0.117	0.0536
		(0.117)	(0.145)	(0.281)
a	Interaction with 1-year lagged short-term policy rate forecast error	16.95***	10.22**	14.20*
		(4.960)	(4.852)	(8.522)
b	post-2008 interaction	-11.02**	-2.203	-10.52
		(5.501)	(5.918)	(7.967)
c	Interaction with 2-year lagged short-term policy rate forecast error	1.091	8.932	-3.147
		(5.899)	(7.420)	(8.796)
d	post-2008 interaction	0.0878	-3.561	8.307
		(7.297)	(9.043)	(9.983)
e	Interaction with 1-year lagged long-term rate forecast error	-21.13***	-7.331	-12.32
		(7.400)	(7.751)	(11.15)
f	post-2008 interaction	14.66**	-2.487	4.048
		(6.554)	(8.071)	(12.34)
g	Interaction with 2-year lagged long-term rate forecast error	5.547	-5.573	2.665
		(8.733)	(9.269)	(12.60)
h	post-2008 interaction	-5.639	-1.088	-7.964
		(9.176)	(9.809)	(12.01)
	Observations	1,651	1,633	1,464
	R-squared	0.564	0.564	0.572
	F-test	*p. values*		
	(a)+(b)=0	0.175	0.131	0.082
	(a)+(c)=0	0.010	0.018	0.633
	(c)+(d)=0	0.747	0.215	0.196
	(e)+(f)=0	0.075	0.057	0.356
	(e)+(g)=0	0.211	0.358	0.145
	(g)+(h)=0	0.980	0.055	0.091

Table 11: The evolving pattern of the relationship between factor accumulation and size-weighted TFP growth.

6 Conclusion

In this paper we study the relationship between TFP and factor reallocation by providing a decomposition of aggregate growth in value added, factor productivity and TFP. This method shows that the contribution to aggregate labour (capital) productivity growth from reallocation of factors can be estimated by running a panel regression of the growth rate of firm/sectoral employment (capital) on the same firm/sector's labour (capital) productivity growth rate weighed by firm/sector's size. We use this insight to examine the impact of monetary policy on factor reallocation, by studying the effect of shocks to both short and long-term interest rates. Our key finding is that sectoral factor reallocation is closely linked to the slope of the yield curve, rather than either simply short-term or long-term interest rates alone. Shocks to the yield curve which flatten the slope, tend to have a negative effect on the contribution of reallocation to aggregate productivity growth. This relationship between the yield curve slope and reallocation holds both in the pre-GFC data as well as after the GFC. This suggests that there may be some state dependency in the relationship between

monetary policy and reallocation as the relationship between the surprises to the yield curve slope and monetary policy operations have changed with short-term interest rates at or near the effective lower bound.

One interpretation of this state dependency is that in upturns with high entry rates and strong aggregate demand, lower interest rates can assist credit constrained productive firms grow, taking market share from less productive firms. By contrast in a downturn, low aggregate and low entry rates limit the benefits of rapid growth, instead low interest rates impair productivity growth by slowing the exit of less productive firms. One conclusion from this result is that quantitative easing policies which aimed at lowering long term interest rates -as short term interest rates had reached their effective lower bound- may have been detrimental to productivity growth through a reallocation channel in the post-crisis period.

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7 Appendix

Dependent variable: Relative employment growth							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
log of initial employment share	-0.0912***	-0.0942***	-0.0903***	-0.0933***	-0.0929***	-0.0931***	-0.0923***
	(0.0183)	(0.0187)	(0.0184)	(0.0185)	(0.0185)	(0.0184)	(0.0183)
Real sales growth (current)	0.125***	0.125***	0.127***	0.127***	0.127***	0.126***	0.126***
	(0.0391)	(0.0385)	(0.0392)	(0.0381)	(0.0381)	(0.0376)	(0.0375)
Real sales growth (1-year lagged)	0.0672***	0.0669***	0.0664***	0.0665***	0.0668***	0.0671***	0.0675***
	(0.0213)	(0.0213)	(0.0210)	(0.0208)	(0.0211)	(0.0211)	(0.0216)
Size weighted total factor productivity growth	0.0757	0.0517	0.0807	0.0757	0.0767	-1.011	-1.310
	(0.116)	(0.119)	(0.117)	(0.117)	(0.118)	(1.125)	(1.157)
Interaction with 1-year lagged short-term policy rate forecast error		7.465**		10.34***	10.50***	10.88***	11.56***
		(2.936)		(3.306)	(3.360)	(3.494)	(3.569)
Interaction with 2-year lagged short-term policy rate forecast error		2.251		3.001	2.994	2.612	2.406
		(2.489)		(3.224)	(3.222)	(3.081)	(3.047)
Interaction with 1-year lagged long-term rate forecast error			-3.570	-8.810**	-8.852**	-8.871**	-8.929**
			(2.834)	(3.771)	(3.756)	(3.794)	(3.780)
Interaction with 2-year lagged long-term rate forecast error			2.350	1.956	1.916	1.627	1.697
			(2.910)	(3.378)	(3.404)	(3.370)	(3.411)
Interaction with current private credit to GDP gap					-0.0588		-0.0516
					(0.158)		(0.162)
Interaction with 1-year lagged private credit to GDP gap					0.0833		0.139
					(0.188)		(0.182)
Interaction with current aggregate real sales growth						0.609	0.669
						(0.721)	(0.753)
Interaction with 1-year aggregate real sales growth						0.447	0.682
						(0.669)	(0.640)
Observations	1,651	1,651	1,651	1,651	1,651	1,651	1,651
R-squared	0.555	0.559	0.556	0.562	0.562	0.562	0.563

Table A.1: The employment-TFP relationship

Dependent variable: Relative capital growth							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
log of initial share in aggregate capital	-0.0605***	-0.0613***	-0.0604***	-0.0611***	-0.0617***	-0.0610***	-0.0613***
	(0.0177)	(0.0178)	(0.0179)	(0.0180)	(0.0185)	(0.0181)	(0.0185)
Real sales growth (current)	0.0262	0.0253	0.0263	0.0272	0.0255	0.0271	0.0259
	(0.0517)	(0.0511)	(0.0514)	(0.0501)	(0.0502)	(0.0500)	(0.0505)
Real sales growth (1-year lagged)	0.0150	0.0149	0.0160	0.0161	0.0175	0.0168	0.0179
	(0.0373)	(0.0372)	(0.0365)	(0.0366)	(0.0354)	(0.0368)	(0.0356)
Size weighted total factor productivity growth	0.0217	0.00537	0.0355	0.0493	0.0401	-0.362	0.0728
	(0.259)	(0.276)	(0.265)	(0.279)	(0.277)	(1.136)	(1.264)
Interaction with 1-year lagged short-term policy rate forecast error		5.891		8.071*	8.321*	6.976	6.974
		(3.717)		(4.179)	(4.344)	(4.802)	(5.276)
Interaction with 2-year lagged short-term policy rate forecast error		0.913		3.640*	3.529	3.567*	3.632*
		(1.910)		(2.158)	(2.220)	(2.141)	(2.188)
Interaction with 1-year lagged long-term rate forecast error			-0.962	-8.181*	-7.996**	-7.981*	-7.728*
			(3.692)	(4.260)	(4.030)	(4.418)	(4.262)
Interaction with 2-year lagged long-term rate forecast error			-2.178	-4.039	-4.784	-4.472	-5.022
			(3.661)	(4.512)	(4.483)	(4.676)	(4.616)
Interaction with current private credit to GDP gap					-0.382		-0.357
					(0.241)		(0.245)
Interaction with 1-year lagged current private credit to GDP gap					0.222		0.188
					(0.245)		(0.277)
Interaction with current aggregate real sales growth						0.758	0.469
						(0.643)	(0.660)
Interaction with 1-year aggregate real sales growth						-0.371	-0.512
						(0.666)	(0.792)
Observations	1,464	1,464	1,464	1,464	1,464	1,464	1,464
R-squared	0.567	0.569	0.568	0.571	0.573	0.571	0.573

Table A.2: The capital-TFP relationship.

Dependent variable: Relative growth in hours worked							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
log of initial share in aggregate hours worked	-0.0934***	-0.0954***	-0.0935***	-0.0966***	-0.0969***	-0.0966***	-0.0965***
	(0.0226)	(0.0225)	(0.0227)	(0.0226)	(0.0226)	(0.0225)	(0.0225)
Real sales growth (current)	0.135***	0.134***	0.135***	0.135***	0.135***	0.133***	0.133***
	(0.0282)	(0.0277)	(0.0284)	(0.0272)	(0.0273)	(0.0273)	(0.0272)
Real sales growth (1-year lagged)	0.0408	0.0402	0.0416*	0.0410*	0.0404	0.0411	0.0407
	(0.0249)	(0.0248)	(0.0249)	(0.0247)	(0.0250)	(0.0249)	(0.0252)
Size weighted hourly labour productivity growth	-0.463	-0.494	-0.464	-0.433	-0.431	-2.094*	-2.361*
	(0.289)	(0.313)	(0.293)	(0.312)	(0.307)	(1.251)	(1.303)
Interaction with 1-year lagged short-term policy rate forecast error		9.388***		11.53***	11.31***	13.77***	13.97***
		(3.287)		(3.599)	(3.608)	(3.976)	(4.013)
Interaction with 2-year lagged short-term policy rate forecast error		3.820		7.278**	7.323**	6.412**	6.320**
		(2.349)		(3.213)	(3.231)	(3.105)	(3.083)
Interaction with 1-year lagged long-term rate forecast error			1.788	-8.476*	-8.449*	-8.779*	-8.818*
			(3.851)	(4.562)	(4.574)	(4.539)	(4.548)
Interaction with 2-year lagged long-term rate forecast error			-1.916	-5.622	-5.470	-5.945*	-5.596
			(2.609)	(3.471)	(3.459)	(3.478)	(3.426)
Interaction with current private credit to GDP gap					0.141		0.142
					(0.192)		(0.191)
Interaction with 1-year lagged private credit to GDP gap					-0.138		-0.0394
					(0.211)		(0.201)
Interaction with current aggregate real sales growth						0.414	0.565
						(0.840)	(0.866)
Interaction with 1-year lagged aggregate real sales growth						1.211	1.331*
						(0.732)	(0.731)
Observations	1,633	1,633	1,633	1,633	1,633	1,633	1,633
R-squared	0.561	0.566	0.561	0.568	0.569	0.570	0.570

Table A.3: The hours worked-hourly labour productivity relationship

Dependent variable: Relative growth in hours worked							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
log of initial share in aggregate hours worked	-0.109***	-0.111***	-0.109***	-0.112***	-0.112***	-0.113***	-0.112***
	(0.0230)	(0.0228)	(0.0231)	(0.0228)	(0.0228)	(0.0228)	(0.0228)
Real sales growth (current)	0.126***	0.125***	0.126***	0.127***	0.127***	0.125***	0.125***
	(0.0281)	(0.0276)	(0.0283)	(0.0273)	(0.0274)	(0.0273)	(0.0273)
Real sales growth (1-year lagged)	0.0334	0.0324	0.0342	0.0333	0.0326	0.0330	0.0327
	(0.0243)	(0.0241)	(0.0243)	(0.0240)	(0.0244)	(0.0243)	(0.0245)
Size weighted total factor productivity growth	0.0679	0.0443	0.0745	0.108	0.109	-1.282	-1.736
	(0.135)	(0.142)	(0.138)	(0.143)	(0.141)	(1.088)	(1.224)
Interaction with 1-year lagged short-term policy rate forecast error		8.808***		11.16***	10.97***	13.76***	14.17***
		(3.197)		(3.548)	(3.496)	(4.050)	(4.083)
Interaction with 2-year lagged short-term policy rate forecast error		3.909		7.667**	7.710**	6.867**	6.684**
		(2.444)		(3.258)	(3.279)	(3.104)	(3.101)
Interaction with 1-year lagged long-term rate forecast error			0.571	-9.437**	-9.358**	-9.772**	-9.778**
			(3.744)	(4.518)	(4.501)	(4.524)	(4.496)
Interaction with 2-year lagged long-term rate forecast error			-2.134	-6.122*	-5.702*	-6.175*	-5.633*
			(2.568)	(3.259)	(3.280)	(3.287)	(3.262)
Interaction with current private credit to GDP gap					0.208		0.196
					(0.183)		(0.184)
Interaction with 1-year lagged private credit to GDP gap					-0.140		-0.0301
					(0.194)		(0.192)
Interaction with current aggregate real sales growth						0.0832	0.308
						(0.723)	(0.764)
Interaction with 1-year lagged aggregate real sales growth						1.282*	1.504**
						(0.675)	(0.715)
Observations	1,633	1,633	1,633	1,633	1,633	1,633	1,633
R-squared	0.556	0.561	0.556	0.563	0.564	0.565	0.566

Table A.4: The hours worked-TPF relationship