Productivity growth, capital reallocation and the financial crisis: evidence from Europe and the US

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Productivity Growth, Capital Reallocation and the Financial Crisis: Evidence from Europe and the US*

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Abstract

Has productivity growth been held back by impaired capital reallocation since the financial crisis? Have low interest rates disrupted the reallocation process? This paper calculates the effect on productivity growth of capital reallocation between industries. It uses an accounting framework, due to Jorgenson and his co-authors, that computes the contribution of capital services to productivity growth relative to a counter-factual of a well-functioning financial system. Using data from 11 countries (the major EU economies plus the US), in 1997-2013, we find: (a) the contribution of reallocation to productivity growth has generally fallen in most economies since the 2000s, notably in Mediterranean countries and fell sharply in many countries in the financial crisis years (b) reallocation is impaired in countries with more uncertainty and where banks hold less regulatory capital and (c) more reallocation is correlated with lower real interest rates, contrary to the hypothesis that low real interest rates have hurt reallocation.

Keywords: productivity growth, capital reallocation JEL reference: O47, E22, E01

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1 Introduction

It is widely alleged that, since the financial crisis, the financial system has been impaired so that it functions less well in allocating capital thus restraining productivity growth. Whilst this suspicion is widespread, it has proved difficult to gather evidence to examine it.

This is perhaps not surprising since it is a hard question for at least four reasons. First, we require a plausible counter-factual against a well-functioning system. That is we need to calculate (1) productivity (or growth) if capital were being allocated to “right” sectors and compare that to (2) productivity (or growth) under the current, allegedly, misallocated situation.

Second, we need information before and after the financial crisis (and perhaps over countries as well). Third, we need a sense of scale. Suppose for example that new high technology investment is misallocated. Since much of the extant (business) capital stock is buildings, any such reallocation might be too small scale to make much material difference.

Finally, if we do manage to find evidence of capital misallocation, we want to know what is causing it. Maybe low interest rates make for more misjudged investment. Or, perhaps the problem is inadequate bank competition or regulation.

We see two broad streams of research that speaks to the question of whether capital movement has been impaired post-financial crisis. We propose to complement these with a third.

The first broad stream of work follows from the more general research on misallocation and productivity exemplified by Hsieh and Klenow (2009) and implemented on cross-country firm data before and after the financial crisis by, for example Gopinath, Kalemli-Özcan, Karabarbounis, and Villegas-Sanchez (2017), Dias, Marques, and Richmond (2016); Gamberoni, Giordano, and Lopez-Garcia (2016); Gamberoni et al. (2016) (see Restuccia and Rogerson (2013) for an extensive survey; see Bartelsman, Haltiwanger, and Scarpetta (2013) for an earlier study).

This calculates how misallocation in general affects TFP levels. It calculates TFP levels relative to a benchmark undistorted equilibrium predicted by theory. In a simple version of the model, this benchmark is where there is no variance in TFP revenue levels, because that is the theoretical equilibrium when there are no capital allocation distortions. That undistorted equilibrium also maximises output, so misallocation directly measures the output loss from such distortions. This work looks at TFP levels but not TFP growth and, it relies on theory results and various parameter assumptions (like the elasticity of substitution) to generate a benchmark, therefore the benchmark might be questioned.

The second broad stream of work is centred around financial “frictions” and looks directly at how financial frictions might lower TFP (typically TFP growth) by impairing the movement of capital from less to more productive activities. So for example Cecchetti and Kharroubi (2015) look at TFP growth and R&D, Cetto, Fernald, and Mojon (2016) focus on TFP growth and interest rates, McGowan, Andrews, and Millot (2017) investigate TFP growth and fraction of “zombie” firms and the Caggese and Perez (2017) model predicts that low interest rates impair reallocation in an intangible-intensive economy.¹

In this paper we implement a third method, due to Jorgenson and co-authors (see e.g. Jorgenson, Gollop, and Fraumeni (1987) , Jorgenson, Ho, Samuels, and Stiroh (2007)) that we

¹Some (non-academic) authors have simply asserted that low interest rates worsen capital reallocation, see for example Stephen King (2017).

see as complementary to the above literature. The basic Jorgenson et al. growth accounting approach measures the contribution of capital growth to productivity. The Jorgenson reallocation approach contrasts this contribution with a counter-factual contribution if capital were allocated in an undistorted fashion. The benchmark “undistorted” allocation has an economic logic defined as the case where the rate of return on capital is equalised between industries in the economy. Thus this is a growth counterfactual that is similar in spirit to the level counter-factual in Hsieh and Klenow (2009). In Hsieh and Klenow (2009) TFP *levels* are impaired by misallocation if distortions create variation in revenue TFP. In growth accounting, TFP *growth* is impaired if capital migrates to relatively low rate of return sectors.

How does the Jorgenson-type approach work? Recall that the Jorgenson-Griliches (Jorgenson and Griliches (1967)) contribution of capital services to productivity growth is, for one capital good, the share of capital rental payments times capital stock growth; write this in industry i as $Con\Delta\ln K_i = ((P_K K / P_Y Y) \Delta\ln K)_i$. Since $P_K = P_I(\rho_i + d)$, where ρ_i is a rate of return, d depreciation and P_I investment prices, we can write this in terms of rates of return (Hall and Jorgenson (1967)) as $Con\Delta\ln K_i = ((P_I K_i / P_Y Y_i)(\rho_i + d) \Delta\ln K_i)$. Thus the sum of contributions over all industries is $\Sigma Con\Delta\ln K_i = \Sigma((P_I K_i / P_Y Y_i)(\rho_i + d) \Delta\ln K_i)$.

If we are to measure whether productivity is impeded because capital is not being allocated “well” we need a benchmark of productivity under “well allocated” capital. Define that benchmark as productivity growth when textitex post rates of return across industries are equalised. We can then calculate capital services under this assumption, and sum them over all industries, call this $\Sigma(Con\Delta\ln K^*) = \Sigma((P_I K_i / P_Y Y_i)(\rho + d) \Delta\ln K_i)$ where notice that ρ is not subscripted by i . Jorgenson’s capital reallocation term compares this with the contribution above using the industry-specific rate of return: $REALL = \Sigma(Con\Delta\ln K) - \Sigma(Con\Delta\ln K^*)$. How does this help us?

We might not expect the economy to be at the benchmark point all the time. Rather, theory suggests that if allocation is working well, capital will be drawn away from low return industries towards industries where rates of return are highest. By contrast, a malfunctioning economy would be where capital is either moving towards low return industries, or is not being reallocated away from low return industries.

The Jorgenson framework indicates productivity-promoting reallocation when $REALL > 0$. Why? Suppose capital is growing in high rate of return industries and slowing in low return industries. The industries attracting capital will then show high $(Con\Delta\ln K)$ and industries losing capital low $(Con\Delta\ln K)$, relative to the benchmark case. The reason is that in the benchmark case, all industries have the same rate of return. Thus the expanding industries deliver relatively high capital services relative to the benchmark, since their capital growth is being calculated at a relatively high rate of return.

When capital is being allocated badly, $REALL < 0$. If for some reason capital is flowing to low rate of return industries, then $(Con\Delta\ln K)$ will be low in that industry, relative to the benchmark case where we use a relatively higher rate of return for that industry.

We therefore calculate these $REALL$ terms for countries over time. We find for example, that $REALL$ becomes negative in many countries in the immediate Great Recession years. It continues negative in, for example, Spain but recovers in, for example, the US. We then relate $REALL$ to measures of, for example, banking regulation. Whilst this measure has the

desirable properties of being linked to productivity growth and computable before and after the crisis, how does it correspond to the other approaches above? First, as mentioned, the Hsieh-Klenow approach is powerful in that the counterfactual is an undistorted economy that maximises the *level* of TFP. The measure used here has as a counterfactual TFP *growth* with an equalised rate of return across industries. That counterfactual is theory driven, in the sense that equalised returns would be predicted in a competitive market, but it is not necessarily maximum productivity growth (since arithmetically, the contribution to overall productivity growth would be very large if capital was accumulating in above average rate of return industries). So this measure is not directly information above the loss relative to some maximum, a strength of the Hsieh-Klenow approach. But if it has got worse, then this does suggest that capital allocation mechanism relating to productivity growth has declined and so it is useful to compare the extent of capital reallocation over time within a country as a diagnostic.

Second, this measure is a between-industry measure: the firm literature cited above looks within industries. Following Samuels (2017) we shall use the term "reallocation" in this paper rather than "misallocation" or "allocation" used in Bartelsman et al. (2013).

Other papers have performed this calculation, most obviously in the work of Jorgenson and co-authors cited above, although their work is mostly for the US. To the best of our knowledge, there is one-cross country study, Samuels (2017), which covers many of the same countries as here. However, it ends before the financial crisis in 2006 and it does not test the effect of financial variables on reallocation². In addition, his work covers all industries, while we look at the non-farm business sector given the significant difficulties in assigning a rate of return, ρ , to the public sector.

Thus our paper is new in the following regards. First, we calculate capital reallocation over countries and time, before and after the financial crisis. Second, we perform this calculation with and without intangible assets and look at whether reallocation differs between intangible and tangible assets: a number of papers have argued that growing intangible-intensity has changed the relation between capital allocation and interest rates (Caggese and Perez (2017)). Third, we study the correlation between REALL and various indicators so that we may look at e.g. whether REALL is correlated positively or negatively with low interest rates, or banking regulation and/or competition.

To preview our results, our findings are the following. First, we document how REALL varies over time. It has generally fallen in most economies since the 2000s, has fallen notably in Mediterranean countries and fell in most countries in the financial crisis years. Second, we examine some correlates of this fall. These associations reveal that it has fallen in countries with more economic uncertainty and where there is less regulatory capital; the effects of banking competition interact with regulatory capital. We also find that the fall in REALL has been offset by lower real interest rates, i.e. REALL is negatively correlated with real interest rates, contrary to the hypothesis that low real interest rates have hurt reallocation.

The rest of this paper proceeds as follows. The next section sets out some theory. Section three reviews the Jorgenson et al model, section four illustrates some descriptive results while section five shows the empirical estimates. Section six concludes.

²Samuels (2017) looks at the impact of fiscal balance, age-dependency ratios, productivity, governance, openness and GDP relative to trend. The relation between our measures and his is in section 4.4 and the Appendix.

2 Some models

Restuccia and Rogerson (2013) survey papers on productivity and misallocation under two headings, direct and indirect. The direct method is to study the link between some likely source of capital misallocation (regulation, taxes, imperfect markets e.g. for credit) and TFP or TFP growth. Thus for example Cecchetti and Kharroubi (2015) regress various measures of sector TFP growth on indicators of the size of the financial sector, and find that larger financial sectors are associated with lower TFP growth in non-financial sectors. Thus the counterfactual is one where finance is smaller, back for example, to historically lower sizes. Misallocation is inferred. Leroy (2016) implicitly looks for capital misallocation by looking at the links between banking competition and manufacturing productivity growth for 11 manufacturing industries in 10 European countries, 1999-2009. They regress country-industry-time $\Delta \ln TFP$ on Rajan-Zingales' measure of the industry dependence on financing interacted with a banking competition measure due to Boone (2008) implemented by Clerides, Delis, and Kokas (2015). Cettè et al. (2016) regress industry TFP growth on real interest rates and argue that financial impairment would affect industries differentially, whilst McGowan et al. (2017) look for a relation between TFP growth and the number of zombie firms (defined as firms unable to cover interest payments over three successive years).

A second approach is the indirect method. This starts from the view that total TFP might be lowered via a somehow suboptimal mix of sectoral/company TFP; that is, misallocation comes from a “mix” effect rather than effects on each sector. Thus the counterfactual is the non-distorted economy, where the mix of sectoral TFPs maximises overall TFP.

Perhaps the best-cited paper is Hsieh and Klenow (2009) who present a model where economy-wide TFP is a weighted average of firm-level TFP. With their chosen functional forms, total TFP levels are less than a theoretical maximum when there is dispersion in firm-level revenue TFP levels. Thus they identify misallocation as dispersion in firm-level revenue TFP.³ A close relation to this method is used by Barnett et al (2014). They take UK data and ask what productivity sacrifice would occur if the economy reacted to sectoral shocks by only adjusting labour and not capital. Such a productivity level sacrifice turns out to rise with the variance of prices across sectors.

A number of recent papers have implemented and/or built on the Hsieh and Klenow method on cross-country data over time. Gopinath et al. (2017) for example, look at company-level manufacturing data from successive waves of ORBIS-AMADEUS, where in their model marginal revenue products differ across firms due to distortions plus adjustment costs and financing constraints. They find persistently growing gaps between the undistorted and distorted TFP level for manufacturing in Spain, Italy and Portugal but not in France, Germany and Norway (interestingly, we find increasingly poor TFP growth due to lack of re-allocation in Spain and somewhat in Italy, but no trend in Germany and France). Gamberoni et al. (2016) use company data from CompNet and find worsening capital allocation in Belgium, France, Italy and Spain,

³Bartelsman and Wolf (2017) for example discuss some of the criticisms of Hsieh and Klenow (2009). For example, the effect on aggregate TFP due to dispersion depends in part on the assumed imperfect substitutability between goods (in an economy where all consumers wear shoes and socks, high TFP in shoes but low TFP in socks means resources have to be reallocated from shoes to socks thus lowering overall TFP). For a discussion of how such dispersion might also be consistent with differing adjustment costs, see Asker, Collard-Wexler, and Loecker (2014).

but not Germany.

Why might misallocation occur? Hsieh and Klenow (2009) assume misallocation is due to sector/firm specific distortions that drive wedges between marginal products and undistorted factor prices, with these wedges being unspecified. A more recent literature tries to model explicitly why capital might remain in low productivity sectors. Azariadis and Kaas (2016) present a model where, following sectoral shocks, capital does not flow to the more productive sectors due to financial frictions. The frictions are that capital from less productive sectors might be unable to move to more productive sectors if such capital is required for borrowing in the unproductive sectors.

Other papers build on the frictions idea. In Cecchetti and Kharroubi (2015) entrepreneurs find high productivity projects are harder to fund with collateral. Caggese and Perez (2017) present a model of an economy with tangible and intangible capital. By assumption, intangible capital is more productive than tangible and so productivity growth is higher with a shift to intangible capital, but such a shift is impeded by intangible-specific frictions: firms cannot borrow against intangible capital and so have to fund intangible capital investment out of retained earnings. The steady state of the economy then depends on the interaction of (endogenous) interest rates and the (exogenous) intangible capital intensity, so for example, as the intangible sector gets larger firms with cash, “saving up” to invest in intangibles, are hurt with lower interest rates, since their savings accumulate more slowly, and so invests less in intangibles. The prediction of their model, which they test by simulation, is that growth falls when interest rates fall in an intangible-intensive economy.

3 Reallocation in a sources of growth model

3.1 Sources-of-growth approach

This paper computes capital reallocation term set out in papers such as Jorgenson et al. (2007); Jorgenson et al. (1987); Jorgenson and Schreyer (2013) which is different to the approaches above. In the HK model, the highest TFP level is where “revenue TFP” is equalised across firms. So any observed deviation from that gives, by assumption, the potential gains in TFP levels from reallocation.

In the growth-accounting approach, the benchmark is equal rates of return to capital across sectors. Thus the counterfactual is to ask: what would the contribution of capital services to productivity growth if there was a uniform rate of return across sectors? As we shall see, the index so calculated is higher when capital flows to the high rate of return sectors and low if capital flows to the low return sectors. Reallocation and so productivity growth therefore falls if capital is “trapped” in the low rate of return sectors.

3.2 Capital contribution measures as indicators of reallocation

There are a capital types. The capital stock K_a of each type is built from the perpetual inventory model:

$$(1) \quad K_{a,t} = \frac{P_{Ia}^* I_a}{P_{Ia}} - \delta^{Ka} K_{a,t-1}$$

Where nominal investment in asset $P_{Ia}^* I_a$ is deflated by an asset deflator P_{Ia} . The asset deflator may or may not be a good measure of the “true” asset price P_{Ia}^* depending on e.g. quality-adjustment of the deflator etc.

The rental cost of each asset type is the user-cost relation between P_I and P_K

$$(2) \quad P_{Ka} = \tau P_{Ia}(\rho + \delta^{Ka} + (\Delta P_{Ia}/P_{Ia})) = \tau_a P_{Ia}(\rho + d_a)$$

Where τ is a tax adjustment factor, δ depreciation, ρ a rate of return and $\Delta P/P$ a capital gain term.

3.3 Measurement of ρ

To measure the rental cost in (2), we need a measure of ρ . But we do not observe ρ directly, and so use the *ex post* method to infer it. We may estimate an industry-specific (ρ_i) or economy-wide ρ . In the former case the sum of the payments to capital in the industry sum to observed industry profits. That is, for an industry-specific ρ_i , where i denotes industry:

$$(3) \quad P_{Qi}Q_i - P_{Li}L_i = \sum_{a=1}^A P_{Ka,i}K_{ai} = \sum_{a=1}^A \tau_{a,i}P_{Ia}(\rho_i + d_a)K_{a,i}$$

Where $P_L L$ are payments to labour and we assume that P_I does not vary across industry (i.e. the same building purchased in two different industries costs the same). By contrast, for economy-wide ρ , the sum of payments to capital in the whole economy sum to observed economy-wide profits:

$$(4) \quad \sum_{i=1}^I P_{Qi}Q_i - \sum_{i=1}^I P_{Li}L_i = \sum_{i=1}^I \sum_{a=1}^A P_{Ka,i}K_{ai} = \sum_{i=1}^I \sum_{a=1}^A \tau_{a,i}P_{Ia}(\rho + d_a)K_{a,i}$$

Where there are I industries.

3.4 Capital contributions and measuring reallocation

To see some intuition, consider two sectors, D and E. We just write down the contributions of capital services to productivity in each sector when ρ is sector-specific:

$$\begin{aligned}
(5) \quad s_D^K \Delta \ln K_D^{\rho=\rho_i} &= \sum_{a=1}^A \left(\frac{\tau_{a,D} P_{Ia}(\rho_D + d_a) K_{a,D}}{P_{Q,D} Q_D} \right) \Delta \ln K_{aD} \\
s_E^K \Delta \ln K_E^{\rho=\rho_i} &= \sum_{a=1}^A \left(\frac{\tau_{a,E} P_{Ia}(\rho_E + d_a) K_{a,E}}{P_{Q,E} Q_E} \right) \Delta \ln K_{aE}
\end{aligned}$$

Following Jorgenson, contrast this with a model in which $\rho_i = \rho$. Let us write this as

$$\begin{aligned}
(6) \quad s_D^K \Delta \ln K_D^{\rho=\rho} &= \sum_{a=1}^A \left(\frac{\tau_{a,D} P_{Ia}(\rho + d_a) K_{a,D}}{P_{Q,D} Q_D} \right) \Delta \ln K_{aD} \\
s_E^K \Delta \ln K_E^{\rho=\rho} &= \sum_{a=1}^A \left(\frac{\tau_{a,E} P_{Ia}(\rho + d_a) K_{a,E}}{P_{Q,E} Q_E} \right) \Delta \ln K_{aE}
\end{aligned}$$

Inspection of (5) and (6) reveals the following. Suppose sector D has a relatively high rate of return so that $\rho_D > \rho > \rho_E$. Suppose the financial system is working “well” in the sense that capital is flowing to the high return sector. Thus $\Delta \ln K_D > \Delta \ln K_E$.⁴ From (5) the contribution of capital services are high in D and low in E and the sum of contributions will be higher in the ρ_I case than the ρ case. By contrast, if capital is accumulating in the low return sectors, the sum of contributions will be lower in the ρ_I case than the ρ case.

Thus define capital reallocation (REALL) as:

$$\begin{aligned}
(7) \quad REALL &\equiv \sum_{i=1}^I (S_i^K \Delta \ln K)^{\rho=\rho_i} - \sum_{i=1}^I (S_i^K \Delta \ln K)^{\rho=\rho} \\
&= \sum_{i=1}^I \sum_{a=1}^A \left(\frac{\tau_{a,i} P_{Ia}(\rho_i + d_a) K_{a,i}}{P_{Q,i} Q_i} \right) \Delta \ln K_{ai} - \sum_{i=1}^I \sum_{a=1}^A \left(\frac{\tau_{a,i} P_{Ia}(\rho + d_a) K_{a,i}}{P_{Q,i} Q_i} \right) \Delta \ln K_{ai} \\
&= \sum_{i=1}^I \sum_{a=1}^A \left(\frac{\tau_{a,i} P_{Ia} K_{a,i}}{P_{Q,i} Q_i} \right) \Delta \ln K_{ai} (\rho_i - \rho)
\end{aligned}$$

From (7), $REALL > 0$ if the economy is “working well” i.e. capital is flowing to the high ρ sectors, so there is a positive covariance between ΔK_i and ρ_i , other things equal. By contrast, suppose the financial sector is working “badly”. Then there is a negative covariance between ρ_i and $\Delta \ln K_i$. This causes measured, industry specific, contributions to be low relative to when ρ is measured economy-wide. Thus $REALL < 0$.

A number of points are worth making. First, REALL depends upon the covariance between ρ and $\Delta \ln K$, but also on the weights. This is as it should be, since there might be severe reallocation of an asset a but if it is of small scale then it should make a small contribution to REALL. So this then is the sense in which, as referred to in the introduction, the impact of reallocation on a particular asset is correctly scaled.

Second, one might criticise the ex post method used in this paper since it assumes e.g. perfect foresight (Oulton (2007)) or equal risk in industries. This would produce a bias if there

⁴Or $\Delta K_D > \Delta K_E$ since there K appears in the numerator of the bracket in (5).

has been systematic change in such factors (in fact in our regressions we use time and country dummies so the change would have to be net of time and country effects). Fourth, economies differ according to how well they double-deflate their value-added measures and so the real value added by industry might be mismeasured.⁵

4 Reallocation data and results

4.1 Data

The database employed in this paper has multiple dimensions: country, industry, institutional sector and time. It includes data on both tangible and intangible capital inputs as well as standard growth accounting variables such as output and labour input. The main method for variables other than intangible capital follows the EU KLEMS database (www.eu-klems.net) (see O'Mahony and Timmer (2009) for details): that is, we calculate capital services by country, industry and asset from investment data harmonized across countries. The tangible investment data are updated to 2013 using national accounts sources. For the market sector, intangible capital is taken from the INTAN-invest database (www.intaninvest.net) as outlined in Corrado, Haskel, Jona-Lasinio, and Iommi (2016). This divides intangible assets into three broad groups - computerized information, innovative property and economic competencies. Computerized information basically coincides with computer software and databases. Innovative property refers to the innovative activity built on a scientific base of knowledge as well as to innovation and new product/process R&D more broadly defined. Economic competencies include spending on strategic planning, worker training, redesigning or reconfiguring existing products in existing markets, investment to retain or gain market share and investment in brand names. The measurement of intangible assets has been extended as part of the SPINTAN (www.spintan.net) project to include the non-market industries (public administration, education and health) and to include a division into private and public sectors.

Thus our data is for 1995-2013 and includes a breakdown into 20 industries and for 12 countries. The latter include the US, large Northern European economies (Germany (DE), France (FR) and the UK), three Scandinavian countries (Denmark (DK), Finland (FI) and Sweden (SE)), Mediterranean economies (Spain (ES) and Italy (IT) and three smaller European economies (Austria (AT), the Czech Republic (CZ) and the Netherlands (NL)).

Both tangible and intangible are calculated from real investment using the perpetual inventory method and geometric depreciation. Real value added and the input shares are adjusted to take account of the capitalization of these assets (see Corrado et al. (2016) for details).

In the light of the theory above, our coverage is as follows. First, we dropped CZ, since

⁵Finally, what is the link between REALL and productivity growth? We may think of REALL as conveying two pieces of information. First, as mentioned above, it measures what labour productivity growth would be were the economy to move towards one with equalized rates of return. Second, as set out in e.g Jorgenson et al. (2007); Jorgenson and Schreyer (2013), it measures the difference between two diverse ways to calculate TFP growth. If all factors are assumed to be paid the same, then value added and inputs can be simply added up across industries and aggregate TFP growth can be calculated as this value added growth less share-weighted aggregate capital and labour services. If factors are paid differently, one may calculate aggregate TFP growth via a different aggregate method: compute industry-specific gross output-based TFP as industry gross output growth less share-weighted capital, labour and intermediate services and then Domar-weight aggregate these measures. The former TFP growth turns out to equal the latter TFP growth plus REALL (of capital and labour).

we had unreliable tangible and intangible measures, perhaps due to measurement problems in a transition economy. Second, as a matter of national accounts convention, non-market institutional sectors do not earn a net rate of return. Likewise, in some industries, sales are insufficient to cover salaries and so subsidies are paid (the Arts for example). Such subsidies are typically not well measured if at all, biasing downwards the measure of rates of return and possibly making it negative. Thus we chose only industries in what we shall call “non-farm business sectors”, which drops sectors dominated by the public sector (health, education) and also by subsidies (agriculture) and other badly measured sectors (real-estate, Arts, entertainment and recreation, Activities of households, and Activities of extraterritorial organizations and bodies). Our industries are set out in the Data Appendix. We shall check for negative rates of return, see below.

Third, we started our analysis in 1998 to guard against capital stock measurement problems from the initial year (1995).

4.2 Measures of ρ

We start our analysis looking at some descriptive statistics about ρ_i to get the sense of the characteristics of the sample economies. Figure 1 shows the maxima, mean and minima of ρ_i by country. Despite only using the non-farm business sector, some industries have a negative ρ_i , in particular industry S (Other service activities). Those with the highest ρ_i are typically finance.⁶ Figure 2 shows the standard deviation of ρ_i : it shows no particularly uniform trend after the financial crisis.

4.3 Measures of REALL

Turning to REALL, Figure 3 shows REALL for when all intangible assets are capitalized (see Appendix for only national accounts intangibles capitalized: Figure 7. First, in the run up to the financial crisis, experience across countries varied. In Spain, US and UK the trend seems downwards, with the contribution turning negative in the UK even in advance of the crisis. Second, in the crisis years themselves (2008 and 2009), both charts suggest that *REALL* became negative in many, although not all countries. The fall in the UK and Spain seems particularly sharp. In Denmark and Germany REALL improved. Third, after the crisis some countries recovered e.g. the US, Austria. But in many REALL kept falling, notably Spain, Finland and Italy. Denmark has seem REALL improve.

To get some idea of numbers, Table 1 sets out some average per centage growth over the period. Column 1 shows that, with the exception of Austria, the pre-great recession period, 1998-07 saw *REALL* positive in all countries, with, for example, Spanish contributions of 0.245 percentage per annum. Column 2 shows REALL in the financial crisis years was negative in five economies: the UK is noteworthy as being large. Looking at the average row, REALL fell by 0.082pppa (for reference, TFP growth has fallen by 2.08pppa). Finally, since 2011, REALL

⁶A number of papers, for example Oulton and Rincon-Aznar. (2012) have documented large variance in rates of return in the EU-KLEMS dataset and suggested they might be implausible. As far as this paper is concerned (a) we tax-adjust which other papers do not do due to lack of data (b) we use more aggregated sectors than in the original EU-KLEMS data (which has 72 sectors) (c) we exclude industries dominated by the public sector (d) our results hinge on the *gap* between the rate of return by industry and by whole economy rather than the level of the return.

Figure 1: Maxima, mean and minima of industry-specific rate of return

Source authors' calculation

has risen, but stayed low relative to the pre-crisis years, at an average contribution of 0.04%pa. The negative contribution of Spain and Italy is notable, and, compared with 1998-07 REALL has fallen in all countries bar Austria, Germany and Denmark.⁷

Figure 4 shows REALL broken down by tangible and intangible. The two are quite correlated with the exceptions of AT, DE and ES where much of the variance in REALL is due to tangible reallocation and the UK, where the recession REALL fall seems very much due to tangible.

⁷Most of the variation in REALL is within country, that is, there is twice as much within variation as between variation.

Figure 2: Standard deviation of industry-specific rate of return

Source authors' calculation

Table 1: Capital reallocation (percent per annum, non-farm business)

Country	1998-07	2008-10	2011-13	Average
AT	-0.034	-0.08	-0.004	-0.037
DE	0.029	-0.005	0.042	0.025
DK	0.071	0.208	0.304	0.14
ES	0.245	-0.107	-0.096	0.115
FI	0.176	0.054	0.007	0.122
FR	0.075	0.055	0.019	0.061
IT	0.078	0.031	-0.004	0.054
NL	0.127	0.1	0.112	0.119
SE	0.049	0.032	0.016	0.039
UK	0.117	-0.121	0.011	0.053
US	0.118	-0.009	0.039	0.08
Average	0.096	0.014	0.041	0.07

Figure 3: Capital reallocation (all intangibles capitalized)

Note: vertical lines are 2008 and 2010. Source: authors' calculation

Figure 4: Reallocation of tangible and intangible capital

Source: authors' calculation

4.4 Comparison with other findings

Samuels (2017) computes both capital and labour reallocation but uses EU-KLEMS data, 1995-2008 for the whole economy with no tax adjustment, national accounts intangibles (which did not include R&D at that time) on an older industry classification. We used our data to recalculate capital reallocation for the whole economy, with national accounts intangibles (which include R&D), no tax adjustment but the NACE2 industry composition (a more current composition of around 20 industries). The correlation between our country-time measures and those in Samuels for the periods for which he gives averages were 0.46 (1995-06), 0.43 (1995-2000) and 0.16 (2000-06) i.e. a lower correlation in the 2000s. More information is in the Appendix: further work would be required to see why the correlations deteriorate over the period. As noted above, calculations for the whole economy across countries need assumptions on the rates of return in public-sector dominated industries such as health and education.

This is the most direct comparison. More indirectly, McGowan et al. (2017) calculate the fraction of capital stock in a number of countries of firms classified as “zombie firms”, namely those whose value added is less than their debt repayments for three successive years. The relation between REALL and this measure is set out in Appendix 2⁸. If countries with more zombie firms are indicate of poor allocation, then the correlation of zombies and REALL should be negative. For IT and ES there seems a negative correlation, not so for the other countries. Note that the UK has a somewhat positive correlation: according to the zombie measure, the UK has had a fall in the zombie firm capital share since the crisis, i.e. a particularly “good” by this measure.

5 Correlates of reallocation

5.1 Estimating model

We turn now to exploring some correlates of REALL. We have no new theory model to contribute, nor a “natural experiment” (except perhaps the financial crisis itself) to try to establish causality. Rather, we examine some candidate correlates with reallocation based on speculation in the literature. This then but a start of an wider investigation.

We have a country-year panel, with about twice as much within as between variation. Thus the general form of a regression might be:

$$(8) \quad REALL_{c,t} = \beta Z_{c,t} + \lambda_c + \lambda_t + \epsilon_{c,t}$$

Where Z are controls, subscripts c and t refer to country and time, and λ_t and λ_c are time and country dummies. Our main controls are (more details in the data appendix) as follows.

The real interest rate (RINTRATE) We would of course expect more investment with low interest rates, but the question here is whether there is more reallocation with low interest rates. A range of theories are reviewed in Forbes (2017) and Gopinath et al. (2017), most of which center on the idea that lower interest rates promote the existence of less productive firms and

⁸We thank Dan Andrews of OECD for kindly sharing these data.

hence lower productivity. A variant on this would be to see if the effect on REALL, if any, of interest rates has changed after the crisis, measured by an interaction with a post-crisis dummy. We use the treasury bonds rate minus GDP inflation as our measure of real interest rates.

Economic sentiment/confidence indicator (ESI). Measures of sentiment are also widely thought to correlate with investment via expectations and the like and might also affect reallocation if, for example, irrational exuberance leads to unwise investment. The indicator of economic sentiment is a weighted measure of surveyed confidence from the *Joint Harmonised EU Programme of Business and Consumer Surveys* for the EU while for the US we use the OECD Business climate indicator.

Intangible-intensity (INTAN). A number of models assume that intangibles are harder to raise collateral against and thus might be source of financial frictions. If this impairs reallocation then this is of independent interest, although the level of intangible investment is itself endogenous. The Caggese and Perez (2017) model predicts that low interest rates impair reallocation in an intangible-intensive economy and thus to test this we interact RINTRATE with INTAN, where INTAN is measured as intangible investment as a share of total investment.

Banking. It might be argued that various features of banking might be associated with less REALL if, for example, banks lend too speculatively, or only to easily collateralisable projects like mortgages. There are many possible hypotheses and variables so as a first pass we used the following. First, the ratio of tier 1 regulated capital to bank assets (*REGCAP_ASSETS*). Second, used the Boone bank competition indicator (*COMPET*), since this is more consistently available than the Herfindahl or Lerner indices.

Crisis. To see the possible effects of the crisis, we simply entered time dummies for all years and, see below, will calculate the time dummies for 2008-10.

Other variables. To test robustness, we look at other measures below.

Before looking at the results, a word on interpretation. In these regressions we are looking at how much REALL correlates with, say, interest rates, bank competition etc. Recall that REALL itself is already the covariance of $\Delta \ln K_i$ with $\rho_i - \rho$. The regressions therefore ask whether the strength of the covariation between $\Delta \ln K$ and rates of return varies with interest rates, banking variables etc.

How might the strength of that covariation vary? For tangible assets, one might imagine that some can be repurposed between industries in the light of market signals: an administrative office block or car for example, but not so a purpose-built building or truck. At the margin then, the covariation, or reallocation, likely consists mostly of new or short-lived or fungible tangible capital equipment responding to price signals and we might expect to see tangible capital, that cannot be repurposed, persisting in apparently low return industries.

Regarding intangible capital, if intangible capital is a pure public good, then it can be reallocated between industries more or less instantly: general training for example. Such capital would then respond instantly to price signals, and indeed we might not pick up any effect of

price signals on reallocation. Some intangible capital however is likely deeply (firm or) company-specific; branding being a leading example, or firm-specific training, or data. Thus reallocation of this sunk intangible capital would be zero, and so intangible reallocation would be driven by new investment, which one would expect to respond to price signals.

It seems then that the pace of reallocation might vary naturally between countries depending on country-specific capital vintages and the extent of country-industry specificity (e.g. cold countries with snow-clearing airport equipment, hot countries without). In addition, much evidence suggests that intangible capital is very hard to borrow against. Thus a hypothesis would be that reallocation of intangibles will be largely uncorrelated with banking variables, to the extent that such banking variables pick up conventional debt financing that is not used for financing intangibles and perhaps more correlated with optimism to the extent that financing might not help reallocation.

5.2 Patterns in the raw data.

Figure 5 shows REALL plotted against the real long-term interest rate (on the left y axis). In almost all countries, bar Spain and Italy the interest rate has been falling: as we shall see below, there is a (weakly) positive correlation between it and REALL.

Figure 5: Reallocation and real long-term interest rates

Source: authors' calculation and data from the World Bank.

Figure 6 shows two banking measures, a competition index due to Boone (2008) and a measure of regulatory capital to assets. Especially starting in the period just after the financial

crisis competition fell and has fallen since, with some exceptions, the US and the UK. Regulatory capital rose over the crisis and has risen since, strongly so in some cases.

Figure 6: Bank regulatory capital and competition

Source: authors' calculation and data from the World Bank.

Finally, Table 2, upper panel, sets out period averages of the data. As the table shows, REALL has fallen and then risen, as has ESI. Real interest rates have fallen throughout, and regulatory capital has risen. Competition has risen but then fallen, as has the interaction between regulatory capital and competition i.e. the fall in competition has not been offset by a rise in regulatory capital.

5.3 Econometric considerations

We have country-time variation. With a small T (the banking data is 1999-2013) 15 years of data and small N (11 countries) we eschew GLS type methods whose small sample properties are not well known and use instead random and fixed effects, clustering by country. We experimented with various lags and found the most statistically significant results as below: the exact lags of the variables made little difference.

5.4 Statistical associations

Table 3 is representative. Columns 1 and 2 show weak positive relation between REALL and (lagged twice) real interest rates with, respectively, no controls and fixed effects. Column 3 adds

Table 2: Raw data and regression accounting (upper panel: unweighted averages per annum, non-farm business; lower panel: regression accounting see text)

Period	REALL*100	real int rate	ESI	Regcap/asset	compet	compet*regcap	time dummies	Sum
1999-07	0.096	0.026	1.041	0.121	0.047	0.005	-0.075	
2008-10	0.014	0.021	0.945	0.134	0.063	0.008	-0.165	
2011-13	0.041	0.014	0.973	0.151	0.047	0.006	-0.144	
<hr/>								
Regression coeffs		-1.64	0.34	1.63	-1.36	9.05		
<hr/>								
Actual change 98/07 to 08/10	-8.20%	-0.50%	-9.60%	1.30%	1.60%	0.30%	-8.98%	
Predicted change		0.82%	-3.30%	2.12%	-2.17%	2.72%	-8.98%	-8.80%
<hr/>								
Actual change 08/10 to 11/13	2.70%	-0.70%	2.80%	1.70%	-1.60%	-0.20%	2.05%	
Predicted change		1.14%	0.96%	2.77%	2.17%	-1.81%	2.05%	7.28%

Notes to table: REALL is multiplied by 100. Changes are percentage point changes.

time dummies, giving a significant negative association. So controlling for country and time effects, low real interest rates are associated with higher REALL.

Column 4 interacts *RINTRATE* with a post-crisis dummy (taking value 1 after 2007), but shows no statistically significantly different marginal impact of real interest rates post-crisis. Column 5 shows that low economic sentiment (ESI) is correlated with lower REALL (note this controls for country and time effects).

Column 6 adds INTAN (intangible asset investment as a proportion of total investment) and its interaction with real interest rates. The point estimates suggest lower REALL with more INTAN, and that lower interest rates mean lower REALL with more INTAN. These effects are in line with the theory predictions of Caggese and Perez (2017), but the effect is not statistically significant.

Column 7 adds the bank regulatory capital/asset ratio and the banking competition indicator. The signs suggest more regulatory capital is correlated with more REALL, but more competition with less REALL. To explore this, column 8 therefore interacts regulatory capital and competition and finds a positive interaction. What does this mean? First, the more REGCAP is associated with more REALL the more the competition in the banking market. Second, the effect of competition depends upon RECAP: less competition is correlated with more REALL but only when there is little REGCAP (when REGCAP is below 15%, the 2013 average is 16%).

Finally, columns 9 and 10 separate out tangible and intangible REALL. There are (statistically significantly) weaker marginal effects on intangible relative to tangible REALL from the banking variables, consistent with the idea that intangibles are difficult to obtain conventional

banking finance for. The point estimates are lower for RINTRATE, but statistically insignificantly different.

Table 3: Regression results (dependent variable: $REALL_{c,t}$)

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	$REALL_{c,t}$					$REALL_{c,t}^{tan}$				
$RINTRATE_{c,t-2}$	0.07 (0.12)	0.34 (0.33)	-2.95* (-2.17)	-2.34 (-1.56)	-2.11* (-2.19)	-4.89 (-1.69)	-1.94** (-2.48)	-1.64* (-2.21)	-0.88 (-1.25)	-0.76** (-2.63)
$RINTRATE_{c,t-2} * PostCrisis$				-1.32 (-0.63)						
$ESI_{c,t-2}$					0.50** (2.26)	0.50* (2.22)	0.36** (2.47)	0.34** (2.37)	0.36** (2.63)	-0.01 (-0.34)
$INTAN_{c,t-2}$						-0.19 (-0.40)				
$INTAN * RINTRATE_{c,t-2}$					6.14 (1.06)					
$Compet_{c,t-1}$							-0.25*** (-4.51)	-1.36*** (-3.62)	-1.17*** (-4.09)	-0.18 (-1.60)
$RegCapital_{c,t-1}$							1.50 (1.41)	1.63* (2.08)	1.25* (2.21)	0.38 (1.27)
$Compet * RegCapital_{c,t-1}$								9.05** (2.94)	7.41*** (3.19)	1.64 (1.74)
<i>Fixed effects</i>										
<i>Time effects</i>	X	X	Y	Y	Y	Y	Y	Y	Y	Y
<i>Cluster by country</i>	X	Y	Y	Y	Y	Y	Y	Y	Y	Y
<i>Observations</i>	165	165	165	165	165	165	165	165	165	165
<i>R – squared</i>	0.00	0.00	0.29	0.30	0.35	0.36	0.44	0.48	0.51	0.23
<i>Number of countries</i>	11	11	11	11	11	11	11	11	11	11

NOTES— Dependent variable in columns 1 to 8 is total capital reallocation ($REALL_{c,t}$), while in columns 9 and 10 is reallocation of tangible ($REALL_{c,t}^{tan}$) and intangible ($REALL_{c,t}^{intan}$) capital, respectively .

5.5 Robustness

We ran some additional robustness checks by adding the following (lagged) variables to column 8 of Table 3. In all of the following cases the additional variables were insignificant and left the above results unaffected: (a) product market competition and employment market strictness from the OECD (b) deviation of GDP growth from trend (c) old- and young- age dependency ratios (these were used in (Samuels 2017)) (d) survey indicators of financial constraints (e) government-debt to GDP ratio (f) the Bloom uncertainty index⁹. Finally, if we drop finance itself, the statistical significance of the variables is hardly affected, but the coefficients fall somewhat on REGCAP (0.78) and REGCAP*Compet (6.17).

5.6 Economic significance

To get some idea of the magnitudes involved, return to Table 2, lower panel. Consider the first group of numbers in the lower panel, setting out the change from before the crisis (1999-07) to the crisis years (2008-10). REALL fell sharply, by 8.20ppa (first data column). Real interest rates fell, and multiplying that fall by its coefficient predicts a rise in REALL by 0.82ppa. The ESI index fell too and multiplying that fall by its coefficient predicts a fall of 3.30ppa. As for bank policy variables; regulatory capital, competition and their interaction all rose, predicting rises in REALL of a total of 2.63ppa. Finally, the time dummies predict a fall in REALL of 8.98ppa. So this model mostly “accounts” for the fall in REALL via the time dummies, but suggests reinforcing effects from low economic sentiment, but offsetting effects from banking characteristics.

The final rows in the lower panel of Table 2 looks at the recovery of REALL between 2008/10 and 2011/13. That rise was helped by falling real interest rates, a slight rise in ESI and in regulatory capital, and a fall in competition, somewhat offset by rising competition/regulatory capital interactions. Once again, however, the time dummies have a strong effect.

All in all, most of the behavior is accounted for by time dummies, i.e. unknown shocks. But, if the remaining effects are causal, then the table does suggest that adverse shocks to reallocation can be offset by lower real interest rates, higher ESI, more regulatory capital and more competition.

6 Conclusions

We have tried to look at whether the financial crisis has impaired the reallocation of capital, relative to a benchmark case, that might inhibit productivity growth. We do this by calculating the Jorgenson reallocation term, which gives a measure of the contribution to aggregate productivity growth due to the allocation of capital growth across sectors relative to a benchmark economy where rates of return are equalized. We have done this for 11 major economies before and after the financial crisis.

We have two main findings. First, the raw data indicates that reallocation got worse in many countries between 2008 and 2010, has recovered since then, but not back to pre-financial crisis levels. Second, we have explored the correlates of REALL. Rising REALL is associated

⁹We also replaced ESI by the Bloom uncertainty indicator but the uncertainty measure was insignificant.

with rising economic optimism and bank regulatory capital, with the effects of bank competition depending on regulatory capital held. Finally, low real interest rates are associated with higher REALL, contrary to the assertion that the lowering of real interest rates by Central Banks has itself worsened capital reallocation.

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A Appendix 1.

The Figure 7 below shows REALL with only national accounts intangible capitalized.

Figure 7: Capital reallocation (only national accounts intangibles capitalized)

The Figure 8 below shows the correlation between the two measures which is very high.

Figure 8: Reallocation: comparison with all and only national accounts intangibles capitalized

B Appendix 2

The graph below shows a comparison with Samuels (2017), where the Samuels data is for the whole economy and taken from a table in his paper that shows the time intervals as below.

Figure 9: Comparison with Samuels (2017)

C Appendix 3: comparison with Zombie firms calculation

In a recent paper, McGowan et al. (2017) calculate the fraction of capital stock in a number of countries of firms classified as “zombie firms”, namely those whose value added is less than their debt repayments for three successive years. We thank Dan Andrews of OECD for sharing these data. For IT and ES there seems a (negative) correlation, which one might expect: not so for the other countries. Note that the UK has a somewhat positive correlation: according to the zombie measure, UK has falls in the share of zombie firms which would raise TFP by this measure.

Figure 10: Capital reallocation (all intangibles capitalized) and share of capital in Zombie firms according to OECD calculations in (McGowan, Andrews, and Millot 2017)

D Data appendix

The main variables (tangible gross fixed capital formation, value added, labour input) are from EUKLEMS and National Accounts. Other variables are from the sources indicated below:

The Economic Sentiment Indicator (ESI) is a composite indicator made up of five sectoral confidence indicators with different weights: Industrial confidence indicator, Services confidence indicator, Consumer confidence indicator, Construction confidence indicator Retail trade confidence indicator. Confidence indicators are arithmetic means of seasonally adjusted balances of answers to a selection of questions closely related to the reference variable they are supposed to track (e.g. industrial production for the industrial confidence indicator). Surveys are defined within the Joint Harmonised EU Programme of Business and Consumer Surveys. The economic sentiment indicator (ESI) is calculated as an index with mean value of 100 and standard deviation of 10 over a fixed standardised sample period. For the US we use the OECD Business climate indicator. Source: EUROSTAT.

Long term interest rate: (Maastricht criterion bond yields (mcby)) definition used for the convergence criterion for EMU for long-term interest rates (central government bond yields on the secondary market, gross of tax, with around 10 years' residual maturity). Source: EUROSTAT.

Bank competition. The World Bank ¹⁰ discusses a number of competition indicators. The Boone index is available from the World Bank and from Clerides et al (the Herfindahl and Lerner indices are incomplete in years and countries). Leroy favours the Clerides indicator (he argues there are less outliers and it uses a superior methodology). The Clerides indicator is in fact more noisy than that of the Bank (it might be an updated version and so we used the Bank indicator, smoothing it with a three year moving average). For a discussion of these various indicators see Mirzaei and Moore (2014). The Boone indicator regresses, for a sample of banks, (log) profits on (log) marginal costs, $(\ln \pi = \beta \ln MC)$ and obtains a negative relation. The more negative in absolute value, the more there is competition. Why? As Clerides explains, suppose a bank becomes less efficient i.e. its MC rises. A small (in absolute value) β , say -0.01 , means a small penalty to being inefficient. A large (in absolute value) β , say -0.1 , means a larger penalty to being inefficient. As a matter of data, this index is quite noisy and so we smoothed it with a simple $(t + 1, t, t - 1)$ moving average, hence the data goes from 2000-2014. Finally, we multiplied the index by -1, and called it a competition indicator: that is, if it rises, then competition rises. Source: World Bank.

Bank regulatory capital to assets ratio. It is defined as “ratio of total regulatory capital to its assets held, weighted according to risk of those assets”. Source: World Bank.

Intangible intensity. Ratio of total intangible spending to GDP. Source: www.intaninvest.net

Age dependency ratio, old, is the ratio of older dependents — people older than 64 — to the working-age population — those ages 15-64. Data are shown as the proportion of dependents per 100 working-age population. Source: World Bank. **Age dependency ratio, young,** is the ratio of younger dependents — people younger than 15 — to the working-age population — those ages 15-64. Data are shown as the proportion of dependents per 100 working-age population. Source: World Bank.

Central government debt, total (% of GDP). Debt is the entire stock of direct government fixed-term contractual obligations to others outstanding on a particular date. It includes domestic and foreign liabilities such as currency and money deposits, securities other than shares, and loans. It is the gross amount of government liabilities reduced by the amount of equity and financial derivatives held by the government. Because debt is a stock rather than a flow, it is measured as of a given date, usually the last day of the fiscal year. Source: World Bank.

Industries The industries in the data are set out in Table 4.

¹⁰(www.worldbank.org/en/publication/gfdr/background/banking-competition)

Table 4: Industries in dataset

Industry (NACE, Revision 2)		Non-farm business	
A	<i>Agriculture, forestry and fishing</i>		<i>X</i>
B	Mining and quarrying	<i>Y</i>	
C	Manufacturing	<i>Y</i>	
D	<i>Electricity, gas, steam and air conditioning supply</i>		<i>X</i>
E	<i>Water supply; sewerage, waste management and remediation activities</i>		<i>X</i>
F	Construction	<i>Y</i>	
G	Wholesale and retail trade; repair of motor vehicles and motorcycles	<i>Y</i>	
H	Transportation and storage	<i>Y</i>	
I	Accommodation and food service activities	<i>Y</i>	
J	Information and communication	<i>Y</i>	
K	Financial and insurance activities	<i>Y</i>	
L	<i>Real estate activities</i>		<i>X</i>
M	Professional, scientific and technical activities	<i>Y</i>	
N	Administrative and support service activities	<i>Y</i>	
O	<i>Public administration and defence; compulsory social security</i>		<i>X</i>
P	<i>Education</i>		<i>X</i>
Q	<i>Human health and social work activities</i>		<i>X</i>
R	<i>Arts, entertainment and recreation</i>		<i>X</i>
S	Other service activities	<i>Y</i>	
T	<i>Activities of households</i>		<i>X</i>
U	<i>Activities of extraterritorial organisations and bodies</i>		<i>X</i>

Notes to table: Table shows all NACE revision 2 industries. “X” in body of table, and italics, denotes industry not included in non-farm business, rows marked with “Y” indicates included as non-farm business.

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