The UK productivity puzzle, 2008-2012: evidence using plant level estimates of total factor productivity

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Abstract

This paper presents new information from plant-level data on the UK's productivity performance since 2008 and considers whether a fall in the capital-labour ratio explains the UK's productivity puzzle. The results show that, while both manufacturing and services experienced large declines in labour productivity post-2008, the UK's poor TFP productivity performance is primarily a service sector and small-plant phenomenon. Most of the fall in TFP in services is accounted for by a large negative TFP shock in 2008-2012. By decomposing the change in average labour productivity, it is shown that declines in the intermediate inputs-labour (rather than the capital-labour) ratio and decreases in TFP were responsible for the fall in labour productivity.

JEL codes: D21; D24; O47

1. Introduction

At the end of 2014 (nearly 7 years after the 2008 banking crisis), output-per-worker for the whole UK economy was slightly below the 2007 level, and 13 per cent lower than if the pre-2007 trend had continued (Office of National Statistics, 2015). This performance is particularly disappointing when compared to that of other countries: in the US and France, labour productivity has fully recovered since the banking crisis, which has allowed them to extend their pre-existing 'productivity gap' with the UK (see Chart 1 in Hughes and Salaheen, 2012; OECD, 2015). It is also unusual in the context of UK history since output-per-worker quickly recovered following previous recessions (e.g., those starting in 1973, 1979, and 1990 – see Figure 4 in Pessoa and Van Reenen, 2014). If this loss in labour productivity is due to persistent (and likely permanent) factors, rather than cyclical explanations such as firms wishing to hold 'spare capacity' in the short-run, this has important consequences for long-run growth.[1] It also has implications for the effective operation of policy since knowledge of the productive capacity of the economy[2] and hence the size of the 'output gap' (the gap between potential and actual output) allows better forecasts of future growth. These in turn inform decisions relating to the size of the government deficit (e.g., if growth is lower, then any structural deficit cannot be quickly reduced through rising tax revenues) and the use of fiscal and monetary policy to boost/constrain output since negative (or even small positive) output gaps are linked to a risk of higher inflation, while large positive output gaps coincide with higher unemployment and

[1] Productivity growth is recognised as the major determinant of long-run economic growth (Krugman, 1997; Baumol, 1984; Mourre, 2009). Any (long-run) decline will have self-perpetuating adverse consequences. For example, lost competitiveness will lead to lost markets – especially export markets – and lost opportunities to realise technological advancement.

[2] There are various definitions of potential output, such as what the economy could achieve at full utilisation of labour and capital. Over time, the definition has evolved to incorporate a more explicit link with inflation, with potential output being '… the level of goods and services that an economy can supply without putting pressure on the rate of inflation' (Conway and Hunt, 1997, p.2).

the risk of underinvestment in the future productive capacity (potential output) of the economy.

Consequently, there has been a debate (and some limited analysis) on the causes of the UK's productivity puzzle (e.g., Blundell *et al.*, 2014; Broadbent, 2012; Barnett *et al.* 2014a; Disney *et al.*, 2013; Goodridge *et al.*, 2013; McCafferty, 2014; Pessoa and Van Reenen, 2014; and Sargent, 2013). Most of this has centred on labour productivity (measured as gross value added per worker), and so a central aim of this paper is to look at whether total factor productivity (TFP) followed a similar pattern to that of labour productivity, given that TFP is regarded as a superior measure of productivity due to its being invariant to changes in factor inputs. The second purpose of the paper is to link TFP directly to labour productivity (measured as gross output per worker) to consider how much of the labour productivity 'puzzle' is due to TFP and how much to changes in factor proportions. In so doing, we are able to test whether, as has been argued by Pessoa and Van Reenen (2014), the UK's poor productivity performance is due to a fall in the capital-labour ratio caused by a credit squeeze/rising cost of capital and a fall in real wages. Although not the primary focus of the paper, evidence is also provided that relates to whether productivity has been adversely affected by under-utilisation of resources and/or a misallocation of factor inputs across plants. The latter would occur if relatively high productivity plants closed, possibly because of low interest rates and bank forbearance (i.e. the creation of 'zombie' firms – cf. Cabellero *et al.*, 2008; Arrowsmith *et al.*, 2013),[3] or low productivity plants opened. However, we do not test other explanations of the productivity 'puzzle'. For example, our data precludes an analysis of whether there has been a decline in the quality of labour (Blundell *et al.*, 2014) which may

[3] The rising cost of working, fixed and R&D capital, because of the financial crisis, plays a potentially important and significant role as set out in, for example, Millard and Nicolae (2013), Caballero *et al.* (2008), and Estevão and Severo (2010).

have played a role since official estimates of human capital show a decline since 2008 (Fender and Calver, 2014).

While there have been some attempts to examine the above 'explanations' (especially Disney *et al.*, 2013; Patterson, 2012; Hughes and Saleheen, 2012), the results are mixed, with no consensus emerging on what explains the UK's productivity puzzle. Furthermore, earlier work has mostly used industry-level data but it is likely a proper evaluation of the causes of the productivity puzzle requires a much more detailed micro-economic approach, which is the approach we (and a small number of others – e.g., Riley *et al.*, 2014; Barnett *et al.*, 2014b; Field and Franklin, 2013) take in this paper.

The next section (section 2) explains how TFP is estimated for each plant, which then allows us to examine the extent to which TFP has declined post-2007. In section 3 we investigate if there are any differences in the levels of TFP/labour productivity (denoted LP hereafter) post-2007 across industry and plant size bands, to consider the 'compositional effect'. In section 4, an identity is used that decomposes changes in LP into the effects of changes in factor inputs and TFP for 2007-12. Plants that operated in 2007 and 2012, as well as new and exiting plants are considered. Finally, there is a summary and conclusion.

2. Estimates of TFP

The earlier analysis of Harris and Moffat (2015) that estimates TFP for market-sector plants operating in Great Britain in 1997-2008 has been updated to 1997-2012. They describe in detail the rationale for inclusion of the variables in the model, the data and the econometric methodology used. Here an overview is provided, and the reader is referred to the earlier article for more information.

TFP is estimated by plant (i.e., 'local units') for each year covering 1997-2012 for most market-based sectors.[4] The first step was estimation of separate Cobb-Douglas log-linear gross output production functions for the industry sub-groups set out in Table U.1 using a system-GMM approach (Blundell and Bond, 1998; 2000):[5]

$$y_{it} = \alpha_i + \alpha_E e_{it} + \alpha_M m_{it} + \alpha_K k_{it} + \alpha_X X_{it} + \alpha_T t + \varepsilon_{it} \quad (1)$$

where *y*, *e*, *m* and *k* refer to the natural logarithms of real gross output, employment, intermediate inputs[6] and capital stock in plant *i* in time *t* (*i* = 1,…, *N*; *t*=1,…*T*) respectively and X is a vector of observed (proxy) variables determining TFP (as set out in Table 1). In order to calculate TFP, equation (1) is estimated (see Harris, 2005a) providing values of the elasticities of output with respect to inputs (α_E, α_M, and α_K), and then (logged) TFP is calculated as the level of (logged) output that is not attributable to factor inputs (employment, intermediate inputs and capital) – i.e., TFP is due to efficiency levels and technical progress:[7]

$$ln\widehat{TFP}_{it} = y_{it} - \hat{\alpha}_E e_{it} - \hat{\alpha}_M m_{it} - \hat{\alpha}_K k_{it} = \hat{\alpha}_i + \hat{\alpha}_X X_{it} + \hat{\alpha}_T t + \hat{\varepsilon}_{it} \quad (2)$$

We are not estimating a gross value added (GVA) function since the latter imposes weak separability (capital and labour are separable from intermediate inputs in production) and thus homogeneity with respect to α_M. As discussed by Gandhi *et al.* (2012), this means that the only plausible underpinning of the GVA approach is that firms exhibit Leontief

[4] Manufacturing includes all those plants and firms that belonged to SIC15111-37200 (using the 1992 Standard Industrial Classification). For services, all those in SIC50101-93010 are included, with the following industries being excluded: financial intermediation (SIC65-67); public services (SIC75-85); and private households and extra-territorial activities (SIC95-99). Agriculture and fishing, utilities and construction are also excluded because of lack of data.

[5] Table U.1 is available in the online appendix. Note, given the very large numbers of observations involved, low KI services was sub-divided into 4 sub-groups: sales and repairs of motor vehicles (SIC50); wholesale (SIC51); retail (SIC52); and the remainder. Equation (1) was estimated separately for each of these sub-groups. Note the groups chosen are based on common levels of technology being used (e.g., high-tech manufacturing through to low knowledge intensive services).

[6] Intermediate inputs cover materials, fuels, semi- and finished-goods and (especially business) services used in the production of new goods and services.

[7] TFP here comprises those factors contained in *X* that shift plants towards the 'best-practice' current technological frontier; together with a time trend, *t*, that proxies technological progress. It also comprises an error term ($\hat{\varepsilon}_{it}$), which will pick up measurement error, unobserved inputs (e.g., intangibles not captured by the R&D variable), and changes in the level of utilisation of factor inputs.

technology (where there is no substitution among factor inputs).[8] Hence, we do not make comparisons between a gross output and a GVA measure of TFP in this paper.

The use of a two-stage procedure to obtain TFP, based on estimating equation (1) with the vector *X* omitted, generates an omitted variables problem while estimators (such as Olley and Pakes, 1996; Levinsohn and Petrin, 2003) are based on assumptions we believe are more restrictive than those implied by system-GMM (e.g., there are no fixed-effects in the model[9] – see also the issues raised by Ackerberg *et al.*, 2015).

Table 1 around here

The data used to estimate equation (1), as described in Table 1, comprise mostly plant level data from the Annual Respondents Database (*ARD*), which has been extensively discussed by previous users (see especially, Harris and Moffat, 2015; Harris, 2005a; but also Oulton, 1997; Harris, 2002; and Griffith, 1999).[10] Data on R&D spending is available from the Business Enterprise R&D (*BERD*) database and ONS enterprise level and reporting unit codes (together with information on the postcode and industry classifications) that are available in both the *ARD* and *BERD* are used to match records. Information on outward foreign direct investment (OFDI) subsidiaries and branches is available from the Annual Foreign Direct Investment (*AFDI*) survey carried out by the ONS, covering some 8,500-12,000 observations per year (although only about 980-2,500 firms, termed enterprises in the surveys, since many firms have multiple subsidiaries/branches in different countries); these

[8] See also Sudit and Finger (1981, p. 15) who discuss gross output versus value-added measures of the production function, referring particularly to the work of Diewert (1978) and Bruno (1978), who both were early proponents of a gross output approach. Diewert (op. cit., p.42) went as far as saying: 'one is … led to wonder about how much of the "unexplained residual" in growth studies … is due to the unjustified use of a real value-added framework'.

[9] The inclusion of fixed effects is necessary as empirical evidence using micro-level panel data consistently shows that plants/firms are heterogeneous (productivity distributions are significantly 'spread' out with large 'tails' of plants/firms with low TFP) and that the distribution is persistent (see, for instance, Bartelsman and Dhrymes, 1998 and Martin, 2008). Such persistence suggests that firms have 'fixed' characteristics (associated with access to different path dependent (in)tangible resources, managerial and other capabilities) that change little through time, and thus need to be modelled.

[10] A more detailed discussion of the data used is provided in the online appendix.

data were amalgamated into a single observation per firm per year and merged into the *ARD* using the ONS codes available in both datasets.[11] Estimates of plant level capital stocks are obtained using the perpetual inventory approach and plant level estimates of real investment; the methods used are set out in Harris and Drinkwater (2000) and Harris (2005b). Due to the sampling frame of the *ARD* being biased towards larger plants, the figures presented below are weighted to be representative of the population of plants (the need for weighting the data is discussed in Harris, 2002, and Harris, 2005a).[12]

Table 2 around here

The estimates for the output elasticities used to predict TFP are provided in Table 2; the estimates obtained are economically sensible, and pass tests of the validity of the instruments used[13] and, in most cases, tests for autocorrelation. That is, the null that the over-identifying restrictions are valid is not rejected for all 11 models using the Hansen test. With regard to autocorrelation (*cf*. the AR(1) and AR(2) test statistics), there should be evidence of significant negative first order serial correlation and no evidence of second order serial correlation in the differenced residuals , which is mostly the case here.[14]

While the parameter estimates associated with X_{it} in equation (1) are not the major focus of this paper, a brief justification for their inclusion and commentary on the results

[11] Note, over 95% of *BERD*/*AFDI* records are matched into the *ARD*.

[12] The actual time-varying weights used are based on total employment in the population divided by the total employment of plants surveyed by the ONS in each year, calculated separately for each size band-industry-region cell (based on 10 equal-sized size bands, 3-digit SICs and 11 regions of Great Britain). When the sample data is weighted using this approach, the total employment of the sample equals the total employment of the population. An alternative would be to count the the number of plants in the population for each cell and divide by the number of plants in the sample for that cell; the correlation between the weighting variable thus obtained and the one we actually use is 0.998. The difference is that this alternative approach does not ensure the total employment of the sample equals the total employment of the population.

[13] Output (*y*, including lagged output in the dynamic model) and factor inputs (*e*, *m* and *k*), are treated as endogenous. Brownfield foreign-ownership, R&D, and OFDI in Table 1 are also treated as endogenous. In all cases endogenous variables are instrumented by their lagged values (in first differences for the levels equation and levels for the first differenced equation). The validity of the instruments (i.e. the fact that they are correlated with endogenous regressors but are not correlated with the production function error term – and hence productivity) can be assessed using the Hansen test of over-identification.

[14] Note, while some of our models do less well in terms of serial correlation, this should not result in endogeneity of the lags of output, since we instrument these values (and the Hansen test does not reject the validity of our instruments).

obtained is warranted. They can be grouped into variables related to foreign-ownership; technical change (as proxied by the time trend); spatial factors; plant age; and all other variables. Foreign-owned plants are expected to have higher TFP, given they are likely to have access to specialised knowledge about production and better management or marketing capabilities (Hymer, 1976; Dunning, 1988). The results presented in Tables U.2 – U.4 (in the online appendix) confirm that this is generally the case, especially for US-owned plants. Spatial variables include measures of industrial agglomeration, diversification, and location in Assisted Areas, regions and cities. Agglomeration and diversification are proxies for potential (pecuniary and non-pecuniary) spillover effects (e.g., intra-industry common labour pools; access to a wider pool of business services; knowledge spillovers across industries). Assisted areas are expected to have more deep-seated economic problems (hence why they are eligible for EU structural funding); major cities are expected to bring spillover benefits associated with large and dense urban environments (see Harris and Moffat, 2012); and more peripheral regions could have negative 'place' effects because of industrial decline and/or more rural settings. Our results tend to support higher (lower) TFP associated with agglomeration (diversification), which is in line with our previous work (Harris and Moffat, 2012, 2013, and 2015). The results for assisted areas are mixed (but mostly not significant); city effects are also quite varied; and there are a number of relatively large negative values associated with the more peripheral regions of Great Britain. An 'age' variable is included to measure whether through learning-by-doing productivity increases as the plant ages (e.g., Jovanovic and Nyarko, 1996) or younger plants produce with greater efficiency and better technology than older plants. Moreover, since it is unlikely that capital stock estimates are fully adjusted for obsolescence, there may also be a vintage capital effect and new plants may have a relative advantage in adopting new technology if existing plants face sunk costs (Campbell, 1998). These latter arguments make it unsurprising that the results obtained are uniformly significant and negative in value. As to other variables in X_{it}, R&D is significant and positive in about half of the sectors covered and plants belonging to outward FDI firms generally had higher TFP, unless the plant was foreign-owned.

Table 2 also includes the parameter estimates for the 2008-12 dummy variable included as part of X_{it} in equation (1) to test if there is any evidence of a downward shift in TFP post-2007. For most manufacturing sectors (except low-tech manufacturing) there is evidence that TFP was (cet. par.) 7-13 per cent lower;[15] however the largest negative effects are in other low knowledge intensive (KI) services (excluding SIC50-52), KI services, and wholesale (-30, -16 and -15 per cent respectively). Other low KI services experienced an 8 per cent decrease, while repairs and sales of motor vehicles had a small, but significant boost in TFP post-2007. There were no statistically significant impacts in high-tech KI services or retail. Overall, there is evidence of a significant negative shock post-2007, when we control for other factors that impact on TFP (as set out in the last term in equation 2). In order to test whether the shock was sustained throughout 2008-12, the 2008-12 dummy was replaced with year dummies. For those industries where the coefficient on the 2008-12 dummy was negative and statistically significant, a test that the individual year dummies were equal is not rejected at the 5% level (see Table 2). Given the length of this 'shock' (5 years), it seems unlikely that this downward shift in TFP is due to a cyclical under-utilisation of labour and/or capital.[16] Rather the 'shock' points to a more sustained loss in productive capacity that needs to be accounted for by other explanations of the productivity 'puzzle'.

Figure 1 around here

[15] The estimates for the dummy variable in Table 2 are converted as follows: $e^{\hat{\beta}} - 1$.

[16] Barnett *et al.* (2014a) also reaches this conclusion, citing little evidence of spare capacity from business surveys and employment outcomes.

3. Productivity levels post-2007

Based on equation (2), and using the elasticities reported in Table 2, *ln* TFP was calculated for each plant for 1997-2012; Figure 1 summarises the (weighted) mean values across plants for Great Britain,[17] and also includes a similar series for labour productivity (both series are normalised to 1997=1). This provides clear evidence that productivity levels, however measured, declined significantly post-2008, and failed to recover.

Figures 2 and 3 around here

Figures 2 and 3 present estimates for TFP and LP divided into manufacturing and services. With respect to TFP, there is no evidence of any 'productivity puzzle' in manufacturing, which shows that the post-2008 decline seen in Figure 1 is accounted for by services. For LP, there is evidence that both sectors have seen a substantial and sustained decline (of around 20 per cent since the 2007 peak, with a slightly larger decline in services[18]). This suggests (and is corroborated later) that in manufacturing changes in factor proportions, rather than declines in TFP, explain the decline in LP.[19]

Figure 4 around here

When plants are grouped by the size of their (real) output, Figure 4 shows that the post-2008 decline in TFP is confined to smaller plants (especially the very smallest) and was absent for plants producing over £714 thousand sales per year (in 2000 prices). In fact, the

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[17] In order to check whether our results are dependent upon our methodology, Figure U.1 in the online appendix shows the *ln* TFP series obtained when a net capital stock (with straight-line depreciation) replaces our preferred measure; when the Levinsohn-Petrin approach is used to estimate equation (1); when the time trend and the 2008-12 dummy are replaced with year dummies for 1998-2012 and when a growth-accounting approach is used with α_E calculated as total labour costs divided by gross output, α_M calculated as the cost of total intermediate inputs divided by gross output, and $\alpha_K = (1 - \alpha_E - \alpha_M)$. Overall, this analysis suggests the estimates of TFP are fairly robust to the use of different approaches.

[18] This differs from the official ONS figure since the series presented here is not weighted by output shares– Figure 3 is a (weighted) mean of *ln* output per worker for plants in each year.

[19] Given the results reported in Table 2 for the 2008-2012 dummy variable, commented upon in the last section, the fact that manufacturing did not experience any significant downturn in TFP post-2007 shows that while there was a negative TFP shock, other factors positively influencing TFP (included in the vector X in equation 1) increased in importance. We return to this below, and present evidence on what was causing the changes in TFP.

largest plants on average increased their *ln* TFP levels (the normalised index increases from 1.0 in 2007 to 1.1 by 2012). This provides initial evidence that, as well as manufacturing not experiencing a decline post-2007 in TFP, large plants (which are much more prevalent in manufacturing) did not contribute to the 'productivity puzzle', at least in TFP. Field and Franklin (2013), who also use (firm-level) micro-data, likewise find that '… the productivity conundrum is more pronounced in services… than in manufacturing… and among smaller firms'.[20]

Figure 5 around here

Mean values (as depicted in Figures 1–4) only capture a point-estimate of differences across plants. Therefore, the (weighted) distribution of plant TFP (ordered from lowest-to-highest) for manufacturing and services is presented in Figure 5. For manufacturing, the TFP distribution for plants operating in 2012 'dominates' (i.e., lies to the right of) the distribution for 2007 for plants with the highest productivity levels (there is some evidence that 2007 'dominates' at the lowest productivity levels but this is not statistically significant). The Kolmogorov-Smirnov (K-S) statistic tests whether the largest gap between the two distributions is significantly different from zero, with the gap being measured under the assumption that (i) the 2012 distribution dominates and (ii) that the 2007 distribution dominates. In Figure 5, only statistically significant gaps are reported. Thus, in manufacturing, 2012 dominates with a statistically significant gap of 6 per cent. The result for services is that TFP in 2007 dominates with a significant maximum gap of 7 per cent.[21]

Table 3 around here

[20] They obtain estimates of TFP using a 'growth-accounting' approach based on factor input shares in total costs and their data only covers 2001-2010.

[21] With regard to plant size, Figure U.2 in the online appendix shows that there is a significant gap in favour of the 2007 TFP distribution for the smallest plants (producing less than £98 thousand gross output) and medium sized plants (£715-2,869 thousand sales); for other size-bands, 2007 dominates at lower levels of TFP and 2012 at higher, with the largest plants mostly dominated by the 2012 distribution at all levels. In manufacturing foreign-owned plants had higher TFP in 2012, while for services this was only the case for plants at the top end of the distribution (and overall 2007 tended to more dominant for foreign-owned service sector plants).

Having presented evidence on TFP changes post-2007, we next present figures decomposing this change (and especially the differences between manufacturing and services), based on the variables that make up TFP (i.e. the right-hand-side of equation 2). Table 3 shows the change in TFP in plants between 2007 and 2012 when the variables contained in X_{it} (including the time trend and $\hat{\varepsilon}_{it}$) are aggregated into sub-groups. In manufacturing, the very small change of 0.3 percentage in the *ln* TFP index is accounted for by the negative shock associated with the post-2007 period (of -6.4 per cent) which is more than cancelled by a positive gain from technological change during the period (of 10.4 per cent). Most of the difference between these two effects (i.e., +4 per cent) is matched by the 'remainder' term (-3.9 per cent), which includes variables such as single-plant and R&D status, together with the error term (which here could be picking up a number of negative influences). In services, the very large change in 2007-12 of -12.9 per cent is dominated by the productivity shock that occurred in this sector. The relatively small gains attributed to technical change were mostly offset by the ageing of plants, which lowered TFP.

However, when plants are separated into those that were in operation throughout 2007-12 and those that entered or exited, the results indicate that continuing plants in both manufacturing and services experienced significant falls in TFP. The average impacts of technical change and the post-2007 TFP shock are, of course, effectively the same; but for manufacturing, the negative 'remainder' term (dominated by $\hat{\varepsilon}_{it}$) is now larger and the negative impact of ageing is stronger (as older plants in this sub-group do not close). In services, the results for 'continuers' are similar to the 'overall' results covering all plants, except for the impact of ageing and a larger positive 'remainder' term. For net entrants[22], the change in TFP was positive and very large for manufacturing because of the combined

[22] The opening and closure of plants (i.e., 'churning') has been shown to account for a large proportion of output and be a major influence on productivity growth in the UK (Disney *et al.* 2003, Harris and Robinson, 2005; Harris and Moffat, 2013).

positive impacts of technical change and the net replacement of old plants with new, and thus younger, plants. In services, net entrants experienced a much smaller positive gain in TFP, partly because the negative TFP shock was larger in services, technical change was lower, and the positive impact of younger plants through net entry was significantly lower.[23]

In summary, the results presented show that 'composition' is an important part of the explanation of the aggregate TFP 'productivity puzzle', with larger, manufacturing plants less likely to have experienced any significant decline in productivity post-2007. However, our 'composition' explanation does not address the issue of whether low productivity sectors have gained market share at the expense of high productivity sectors.[24] This will be pursued in further work that we plan to do.

Table 4 around here

4. Reconciling differences in the levels of labour productivity and TFP

In this section, changes in LP during 2007-2012 are decomposed into components attributable to changes in factor inputs and TFP. Rearranging the first part of equation 2, and expressing LP growth as:[25]

$$\Delta(y-e)_{it} = (\hat{\alpha}_E - 1)\Delta e_{it} + \hat{\alpha}_M \Delta m_{it} + \hat{\alpha}_K \Delta k_{it} + \Delta ln\widehat{TFP}_{it} \quad (3)$$

shows that labour productivity increases $[\Delta(y-e)_{it}]$ are negatively related to increases in employment [since $(\hat{\alpha}_E - 1)) < 0$], and positively related to increases in intermediate inputs,

[23] This is because (Tables U1 – U3 in the online appendix) the negative parameter estimates associated with *ln* age are much greater in manufacturing relative to (especially distributive) services.

[24] A complete analysis of the effects of 'composition' on aggregate productivity would require knowledge of initial productivity levels, the importance of different sub-groups in terms of market shares and changes over time in both market share and productivity. Our focus here is solely on the latter.

[25] We are unable to make direct comparisons with, for example, Pessoa and van Reenen (2014) who also decompose LP in a similar way, because we measure productivity using gross output and do not impose constant returns-to-scale.

capital stock and TFP. We also present results from a factor-intensities version of equation (3), given that this is the more commonly used approach. That is, we can rewrite (3) as:

$$\Delta(y-e)_{it} = \gamma\Delta e_{it} + \hat{\alpha}_M\Delta(m_{it}-e_{it}) + \hat{\alpha}_K\Delta(k_{it}-e_{it}) + \Delta ln\widehat{TFP}_{it} \qquad (3')$$

where $\gamma = \hat{\alpha}_E + \hat{\alpha}_M + \hat{\alpha}_K - 1$. The results for all plants operating in 2007 and 2012 in the top panel of Table 4 show the mean value across plants for each of the components in Equation (3). For manufacturing, the 19 per cent decline in LP[26] was mostly the result of a fall in the use of (output-elasticity weighted) intermediate inputs (which contributed -40.5 per cent), and a smaller negative contribution from capital, both of which were to some extent offset by reductions in employment. There was a small gain in TFP of 0.3 per cent (cf. Figures 2 and 3). Hence, in manufacturing, declining LP was the result of changes in 'factor proportions', but not the result of a large relative decline in investment and thus a (relative) fall in the capital-labour ratio (see the lower part of Table 4 for confirmation). Instead, the primary cause of the fall in LP was a decline in the intermediate inputs-labour ratio, suggesting that the relative cost of intermediate inputs was the underlying 'cause' of the fall in labour productivity.[27] Indeed, Figure 6 shows that the producer price of inputs in manufacturing rose substantially post-2007 relative to the producer price of outputs (prices at the 'factory' gate), and this was likely due (at least in part) to a substantial fall in the effective exchange rate which would have made (intermediate) imports much more expensive.

Figure 6 around here

In the service sector, the slightly greater decline in 2007-12 in LP (20 per cent for all plants) is explained by a much larger fall in TFP (nearly 13 per cent), together with a (relative to manufacturing) smaller but still important negative contribution (of -14.5 per cent) from a

[26] Given the *ln* gross output per worker declined from 4.26 to 4.07 (or £70.8 thousand to £58.6 thousand in actual values), this equates to a fall of £12.3 thousand per worker (or 19 per cent based on the log difference).

[27] Standard factor-demand models show that the demand for factor inputs is determined by 'output' and 'substitution' effects – the former because (cet. par.) higher levels of output require more of all factor inputs, while relative input prices (i.e., costs) determine the 'mix' of inputs needed to maximise profits.

fall in the use of (output-elasticity weighted) intermediate inputs. Offsetting these effects, the capital stock increased slightly and there was a much smaller decline in employment compared to manufacturing, indicating that changes in factor inputs were less important in services.

So far it has been shown that for plants in operation in 2007 and 2012, the fall in LP is not dominated by declines in investment, and thus a substantive fall in the capital-labour ratio – an explanation favoured by Sargent (2013) and to some extent Pessoa and Van Reenen (2014) among others.[28] Instead, lower intermediate input usage dominates, together with lower TFP in services. When plants that were open in *both* 2007 and 2012 are considered (the 'continuers' sub-group in Table 4), the story changes for manufacturing (there is much less difference in services between 'all plants' and 'continuers'). For manufacturing plants operating throughout the period, falls in intermediate inputs are less of a factor (although they still dominate) and falls in TFP are now much more relevant. Indeed, for continuing plants, manufacturing and services are much more similar in terms of what determined similar declines in labour productivity. This shows that much of the difference between the two sectors is linked to the characteristics of plants that entered post-2007 and closed before 2012 (the last three rows in Table 4(a) and (b)).

The productivity advantage of exiting plants over entering plants was smaller in manufacturing than services (16.2 per cent lower compared to nearly 25 per cent lower). Since plants that open tend to be smaller than plants that close, in terms of their use of all factor inputs, the productivity gap in part reflects these size differences. This was especially

[28] As noted in footnote 25, Pessoa and van Reenen (op. cit.) also attempt to explain the declines in LP using a similar framework to that set out in equation (3) – although they use GVA and have therefore netted out any impact of intermediate inputs. However their (to quote them) '… very crude, back-of-the envelope estimates' (p. 447) in part involve putting together their best estimates of the contribution to labour productivity change of changes in the capital-labour ratio and then 'backing-out' (rather than estimating) an index for TFP. They show that TFP has little to contribute to the 'productivity puzzle'. However, they themselves acknowledge the considerable uncertainty surrounding the accuracy of their attempts to measure the capital stock, as well as their method. The shortcomings of their approach are discussed further by Oulton (2013, pp. 22-25).

true for manufacturing. However, the productivity disadvantage from using relatively little capital and intermediate inputs is offset by the much higher TFP of entering plants (the latter was over 40 per cent higher in manufacturing). This is in line with a priori expectations (and results from other studies – e.g. Disney *et al.*, 2003) that new entrants tend to use the latest technology, and Table 3, which shows the importance of technical change and the age of the plant. In services, opening plants also used relatively little capital and intermediate inputs but, unlike in manufacturing, the effect of this on LP was not offset to the same extent by higher TFP for new plants replacing those that closed.[29] The details are provided in Table 5 (which reports the underlying figures used to obtain the figures in Table 4 for net entrants); this shows that plants that closed in services had similar TFP levels to those in new service sector plants.

Table 5 around here

Riley *et al.* (2014) and Barnett *et al.* (2014b) also considered the contribution of changes in within-firm labour productivity vis-à-vis reallocation due to the entry and exit of firms, to the overall pattern of decline in LP post-2007. Both argue that the main contribution was from within-firm declines, rather than the impact of 'churning' which was positive because the effect of the closure of relatively low productivity plants outweighed that from the opening of low productivity plants, although neither paper provides information on the sources of changes in LP. In comparison the results presented in Table 4 show that both 'continuers' and net entry were important contributors to the decline in average LP, but for different reasons across sectors (cf. the importance of lower intermediate input usage in manufacturing and lower TFP in services). However, it is important to reiterate (see footnote

[29] Table U.5 presents an extended version of Table 4 that includes information for 1997-2002 and 2002-2007. This shows, for example, that the composition of the TFP effects for manufacturing were similar in terms of declining TFP in continuing plants being offset by higher TFP in net entrants, although the relative magnitude of these effects differed in the three periods shown, with an overall decline in manufacturing TFP in 1997-2002 and an increase in 2002-2007. Table U.6 similarly extends Table 5, again including information for 1997-2002 and 2002-2007, as well as data on all plants and 'continuers' as well as net entrants.

24) that our analysis does not take account of the impact of changes in market shares between continuing, entrants and exiting plants, and therefore comparisons with the work of others is only indicative.

5. Summary and conclusions

This study uses plant-level panel data to investigate some of the proposed explanations of the UK productivity puzzle. Based on (weighted) mean values, average productivity levels (both LP and TFP) for the market-based economy declined significantly post-2008, and did not recover, indicating that the loss in productivity is likely to be due to permanent rather than cyclical factors. For labour productivity, there was evidence that both manufacturing and service sectors experienced a substantial and sustained decline post-2007. However, with regard to TFP, there was no evidence of any 'productivity puzzle' in manufacturing; the entire post-2008 decline was accounted for by services. While continuing plants in both sectors experienced substantial falls in TFP, this effect was offset by the contribution of net entrants in manufacturing. This fall in TFP was also confined to smaller plants (especially the very smallest), which are particularly prevalent in the service sector. These results are in line with those of Field and Franklin (2013) and show the importance of considering sectoral variations to gain a full understanding of the productivity puzzle.

The change in LP during 2007-2012 was then decomposed into the contribution of changes in factor inputs and TFP. In manufacturing, declining LP in plants that operated in both 2007 and 2012 was linked mainly to changes in factor proportions, but not to falls in the capital-labour ratio as discussed by Pessoa and Van Reenen (2014). This is consistent with the findings of Oulton (2013) and Riley *et al.* (2014) and suggests that falls in the real wage rate and increases in the cost of capital have not led to widespread substitution of labour for capital. Instead there was a substantial decline in the intermediate inputs-labour ratio that may be associated with an appreciation in the exchange rate. In the service sector, the larger decline in LP was explained by a much greater fall in TFP (nearly 13 per cent). Thus, for services, there was less evidence of changes in factor proportions being the major influence. Moreover, in contradiction of the argument that there has been substitution of labour for capital, the capital stock increased (slightly) and employment fell.

In relation to entry and exit, plants that opened post-2007 had lower LP but higher TFP, especially in manufacturing, than plants that closed before 2012. This was due to these plants being smaller in terms of their use of capital and intermediate inputs. A reduction in the rate of plant opening and closure may therefore explain decreases in the rate of TFP, but not LP, growth. Barnett *et al.* (2014b) and Riley *et al.* (2014) also found, using a decomposition of productivity growth, that opening (closing) plants had a negative (positive) effect on labour productivity growth post-2007 but that the positive impact of closure outweighed the negative impact of opening.

Further work needs to be undertaken to explain whether the decline in TFP post-2007 can be linked to other explanations of the 'productivity puzzle'. For example, other datasets could be utilised to look at whether changes in the composition of the UK labour market have contributed to the UK's poor productivity performance.

Supplementary material

Supplementary material – the Appendix – is available online at the OUP website.

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ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data. This work uses research datasets which may not exactly reproduce National Statistics aggregates. We would also like to thank two anonymous referees for their helpful comments, which have improved the paper; as usual the authors' accept full responsibility for any remaining errors.

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Table 1. Variables needed to estimate TFP in equation (1)

Variable	Definitions	Source	Mean[a]	S.D.
Real gross output[b]	Plant level gross output data deflated by 2-digit ONS producer price (output) indices. Data are in £000 (2000 prices)	ARD	4.644	3.064
Real intermediate inputs	Plant level intermediate inputs (gross output minus GVA) deflated by 2-digit ONS producer price (input) indices (non-manufacturing only has a single PPI). Data are in £000 (2000 prices)	ARD	4.086	2.786
Employment	Number of employees in plant	ARD	1.581	1.300
Capital	Plant & machinery capital stock (£m 1995 prices) plus real value of plant and machinery hires (deflated by producer price index) in plant. Source: Harris and Drinkwater (2000, updated)	ARD	-2.517	4.174
Age	Number of years plant has been in operation based on year of entry	ARD/ IDBR	1.281	1.264
Single-plant	Dummy coded 1 when plant comprises a single-plant enterprise	ARD	0.256	0.739
Multi-region enterprise	Dummy coded 1 if plant belongs to multiplant enterprise operating in more than one UK region	ARD	0.460	0.263
Greenfield US-owned	Dummy coded 1 if plant is US-owned and newly opened during 1997-2012	ARD	0.020	0.110
Brownfield US-owned	Dummy coded 1 if plant is US-owned and not newly opened during 1997-2012	ARD	0.031	0.141
Greenfield EU-owned	Dummy coded 1 if plant is EU-owned and newly opened during 1997-2012	ARD	0.013	0.092
Brownfield EU-owned	Dummy coded 1 if plant is EU-owned and not newly opened during 1997-2012	ARD	0.016	0.103
Greenfield other foreign-owned	Dummy coded 1 if plant is foreign-owned by another country and newly opened during 1997-2012	ARD	0.005	0.054
Brownfield other foreign-owned	Dummy coded 1 if plant is foreign-owned by another country and not newly opened during 1997-2012	ARD	0.012	0.087
OFDI	Dummy coded 1 if plant belongs to a UK or UK-registered foreign-owned firm involved in outward FDI	ADFI	0.174	0.275
Herfindahl	Herfindahl index of industry concentration (3-digit level)	ARD	-2.277	2.140
Industry agglomeration	Percentage of industry output (at 5-digit SIC level) located in travel-to-work (TTWA) in which plant is located – MAR-spillovers	ARD	-0.139	2.073
Diversification	Percentage of 5-digit industries (from over 650) located in TTWA in which plant is located – Jacobian spillovers	ARD	-0.276	0.336
R&D[c]	Dummy coded 1 if plant had positive R&D stock based on undertaking intramural and/or extramural R&D since 1997	BERD	0.013	0.116
Assisted Area	Dummy coded 1 if plant is located in assisted area	ARD	0.234	0.048
Region	Dummy coded 1 if plant is located in particular administrative region	ARD	na	
City	Dummy coded 1 plant is located in major GB city (defined by NUTS3 code)	ARD	na	
Industry	Dummy coded 1 depending on 1992 SIC of plant (used at 2-digit level).	ARD	na	

[a] Values are logged (except for dummy variables) and weighted.
[b] *ln* Labour productivity is calculated as *ln* real gross output per employee.
[c] R&D stocks are computed using perpetual inventory method with 30% depreciation rate for the largest components of R&D spending (intra-mural current spending and extra-mural R&D). See Harris, Li and Trainor (2009) for details of methods used.

Table 2. Estimated long-run parameters for factor inputs from estimating equation (1), by sector, Great Britain 1997-2012

	Manufacturing				Services						
	High-tech	Med high-tech	Med low-tech	Low-tech	High-tech KI	KI-market	Low KI[a]	Other Low KI	SIC50	SIC51	SIC52
ln Intermediate Inputs	0.436***	0.288**	0.380***	0.533***	0.495***	0.565***	0.421***	0.652***	0.769***	0.304**	0.319***
	(3.66)	(2.57)	(3.71)	(2.65)	(5.90)	(5.21)	(8.09)	(25.47)	(24.34)	(2.17)	(3.92)
ln Employment	0.203*	0.554***	0.430***	0.360**	0.442***	0.527***	0.515***	0.863***	0.310***	1.019***	0.620***
	(1.83)	(3.23)	(4.54)	(2.41)	(5.84)	(4.93)	(4.94)	(4.94)	(9.02)	(4.64)	(8.45)
ln Capital	0.229***	0.224*	0.167**	0.247**	0.091**	0.135**	0.229***	0.107**	0.021***	0.095**	0.071***
	(2.72)	(1.85)	(2.21)	(2.20)	(2.28)	(2.14)	(2.18)	(2.37)	(4.71)	(1.96)	(3.84)
Time trend	0.031***	0.026*	0.020***	0.018***	0.016***	0.004	0.046***	-0.012	-0.003***	0.011*	-0.020***
	4.57)	(5.21)	(4.11)	(3.66)	(2.99)	(0.65)	(5.55)	(-1.37)	(-4.48)	(1.69)	(-9.71)
Dummy 2008-12	-0.126***	-0.073*	-0.141***	0.002	0.016	-0.172***	-0.355***	-0.083**	0.016***	-0.168***	0.009
	(-2.54)	(-1.81)	(-2.48)	(0.03)	(0.39)	(-2.51)	(-5.95)	(-2.31)	(2.73)	(-3.70)	(0.54)
AR(1) z-statistic	-5.15***	-4.60***	-4.33***	-4.38***	-8.97***	-2.73***	-26.06***	-10.78***	-5.44***	-3.67***	-14.46***
AR(2) z-statistic	1.74*	1.33	-0.76	1.67*	0.44	1.33	1.73*	1.77*	-1.36	-1.59	-1.11
Hansen test	33.37	30.79	15.95	4.10	5.52	12.92	3.62	1.19	5.72*	9.00	0.40
Returns-to-scale	-0.132**	0.066	-0.023	0.140***	0.028	0.227***	0.165***	0.622***	0.100***	0.417***	0.010
H_0: 2008-12 year dummies are equal (p-value)[b]	0.245	0.110	0.700	0.150	0.000	0.075	0.121	0.130	0.000	0.082	0.000
Observations	10,191	31,836	39,022	62,225	69,580	41,595	616,672	185,581	76,170	110,128	700,143
Local units	3,538	10,208	13,330	18,596	22,618	14,875	167,821	43,416	18,677	23,314	152,647

[a] Excludes SIC50-52, which were estimated separately.

[b] Model re-estimated with year dummies for 2008-12; test reported is of the null that these dummies have the same parameter value.

Note, *t*-values are given in parenthesis. * Indicates significance at 10% level, ** significance at 5% level and *** significance at 1% level. Full results are available in Tables U.2 – U.4 in the online appendix.

Table 3. Decomposition of change in weighted mean TFP 2007-12 for GB by market-based sector

	Total[a]	Foreign ownership[b]	Time trend[c]	Spatial variables[d]	Age of plant[e]	2008-12 shock[f]	Remainder[g]
All plants							
Manufacturing	0.003	0.000	0.104	-0.007	0.008	-0.064	-0.039
Services	-0.129	-0.002	0.043	0.020	-0.031	-0.163	0.003
All sectors	-0.116	-0.001	0.051	0.018	-0.033	-0.161	0.010
Continuers[h]							
Manufacturing	-0.133	-0.002	0.103	-0.008	-0.081	-0.064	-0.082
Services	-0.117	-0.007	0.037	0.019	-0.092	-0.163	0.088
All sectors	-0.129	-0.006	0.045	0.018	-0.093	-0.161	0.069
Entrants minus exitors[i]							
Manufacturing	0.405	0.007	0.107	-0.008	0.280	-0.064	0.082
Services	0.020	0.003	0.068	0.022	0.083	-0.163	0.007
All sectors	0.047	0.003	0.073	0.020	0.090	-0.161	0.022

[a] TFP index in 2012 minus 2007 index (Figure 2)
[b] Predicted TFP 2012 minus predicted TFP 2007 using $\hat{\alpha}_X X_{it}$ (equation 2) related to foreign-ownership (Table 1)
[c] Predicted TFP 2012 minus predicted TFP 2007 related to time trend
[d] Predicted TFP 2012 minus predicted TFP 2007 related to spatial variables (Table 1) – agglomeration, diversification, assisted area, region and city.
[e] Predicted TFP 2012 minus predicted TFP 2007 related to age of plant
[f] Predicted TFP 2012 minus predicted TFP 2007 related to dummy 2008-12 variable
[g] Predicted TFP 2012 minus predicted TFP 2007 related to all remaining variables (Table 1) plus $\hat{\varepsilon}_{it}$(equation 2)
[h] Only plants that were open in both 2007 and 2012
[i] TFP index in 2012 (for plants that opened post-2007) minus TFP index in 2007 (for plants open in 2007 that closed before 2012).

Table 4. Decomposition of change in weighted mean labour productivity 2007-12 for GB by market-based sector

(a)	$\Delta(y-e)_{it}$	$\hat{\alpha}_K \Delta k_{it}$	$\hat{\alpha}_M \Delta m_{it}$	$(\hat{\alpha}_E - 1)\Delta e_{it}$	$\Delta ln\widehat{TFP}_{it}$
All plants					
Manufacturing	-0.190	-0.156	-0.405	0.368	0.003
Services	-0.200	0.011	-0.145	0.063	-0.129
All sectors	-0.190	0.001	-0.150	0.075	-0.116
Continuers[a]					
Manufacturing	-0.199	-0.039	-0.224	0.196	-0.133
Services	-0.184	0.024	-0.202	0.111	-0.117
All sectors	-0.182	0.014	-0.171	0.103	-0.129
Entrants minus exitors[b]					
Manufacturing	-0.162	-0.566	-0.649	0.648	0.405
Services	-0.248	-0.127	-0.156	0.016	0.020
All sectors	-0.231	-0.145	-0.168	0.035	0.047

(b)	$\Delta(y-e)_{it}$	$\hat{\alpha}_K \Delta(k-e)_{it}$	$\hat{\alpha}_M \Delta(m-e)_{it}$	$[(\hat{\alpha}_K + \hat{\alpha}_M + \hat{\alpha}_E) - 1]\Delta e_{it}$	$\Delta ln\widehat{TFP}_{it}$
All plants					
Manufacturing	-0.190	-0.005	-0.046	-0.142	0.003
Services	-0.200	0.034	-0.077	-0.028	-0.129
All sectors	-0.190	0.027	-0.074	-0.027	-0.116
Continuers[a]					
Manufacturing	-0.199	0.034	-0.081	-0.019	-0.133
Services	-0.184	0.065	-0.069	-0.063	-0.117
All sectors	-0.182	0.053	-0.059	-0.047	-0.129
Entrants minus exitors[b]					
Manufacturing	-0.162	-0.317	-0.163	-0.087	0.405
Services	-0.248	-0.127	-0.142	0.001	0.020
All sectors	-0.231	-0.137	-0.137	-0.004	0.047

Source: calculations based on equation (3). Figures in first data column are *ln* labour productivity in 2012 minus *ln* labour productivity in 2007 (Figure 3).

[a] Only plants that were open in both 2007 and 2012

[b] *ln* labour productivity in 2012 (for plants that opened post-2007) minus *ln* labour productivity in 2007 (for plants open in 2007 that closed before 2012).

Table 5. Weighted mean values for opening and closing plants, 2007-12 for GB by market sector

	$(y-e)_{it}$	$\hat{\alpha}_K k_{it}$	$\hat{\alpha}_M m_{it}$	$(\hat{\alpha}_E - 1)e_{it}$	$ln\widehat{TFP}_{it}$
Entrants					
Manufacturing	4.074	-1.068	2.062	-0.933	4.013
Services	3.595	-0.761	1.685	-0.516	3.186
All sectors	3.620	-0.777	1.705	-0.538	3.230
Exitors					
Manufacturing	4.236	-0.501	2.710	-1.581	3.608
Services	3.842	-0.634	1.841	-0.531	3.166
All sectors	3.851	-0.632	1.873	-0.573	3.183

Source: figures underlying 'entrants minus exitors' data in Table 4.

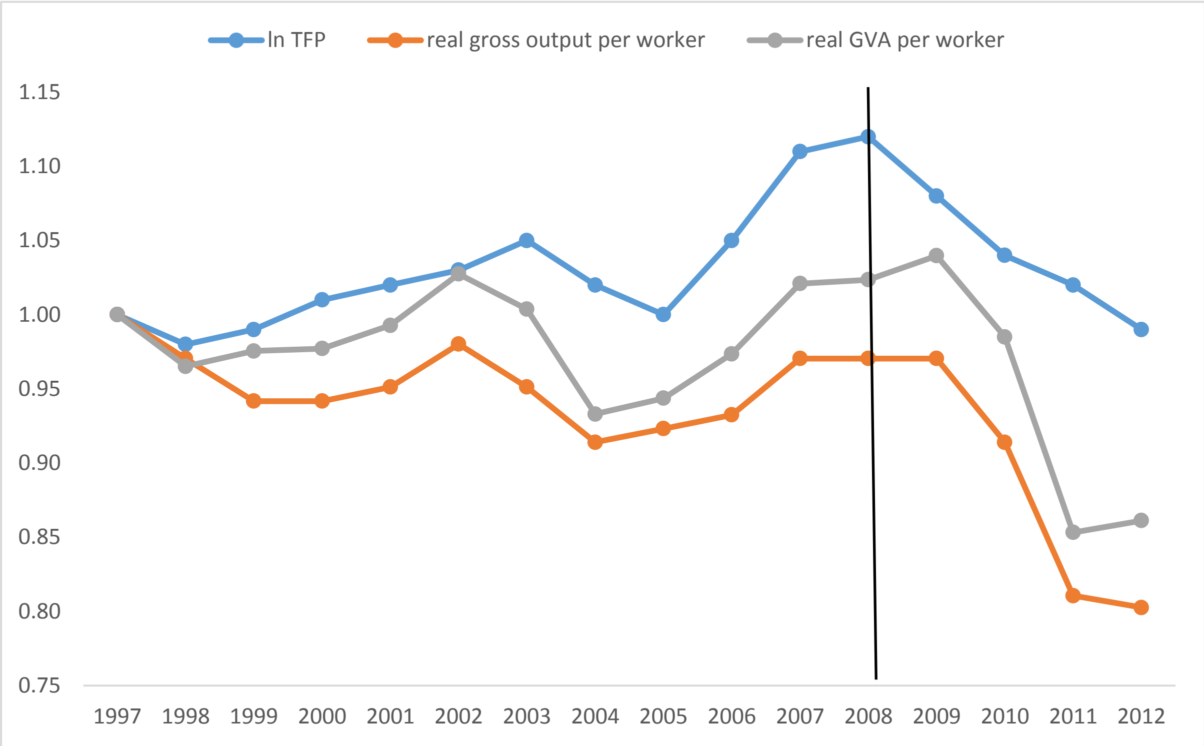

Fig. 1. Weighted Mean TFP and Labour Productivity for All Marketable Output Sectors (1997=1) for GB
Source: weighted estimates based on equation (2) for TFP; see Table 1 for definition of LP

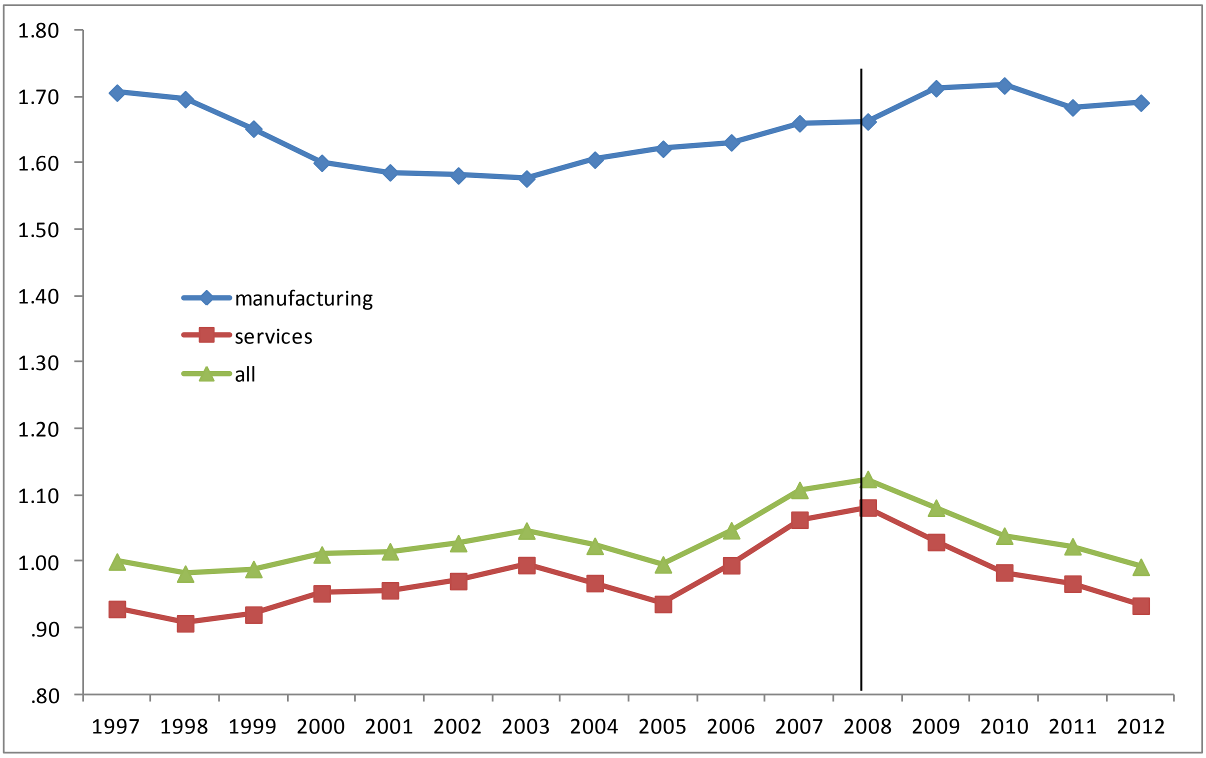

Fig. 2. Weighted Mean TFP for Manufacturing and Services (1997=1 for All Plants) for GB
Source: weighted estimates based on equation (2) for TFP

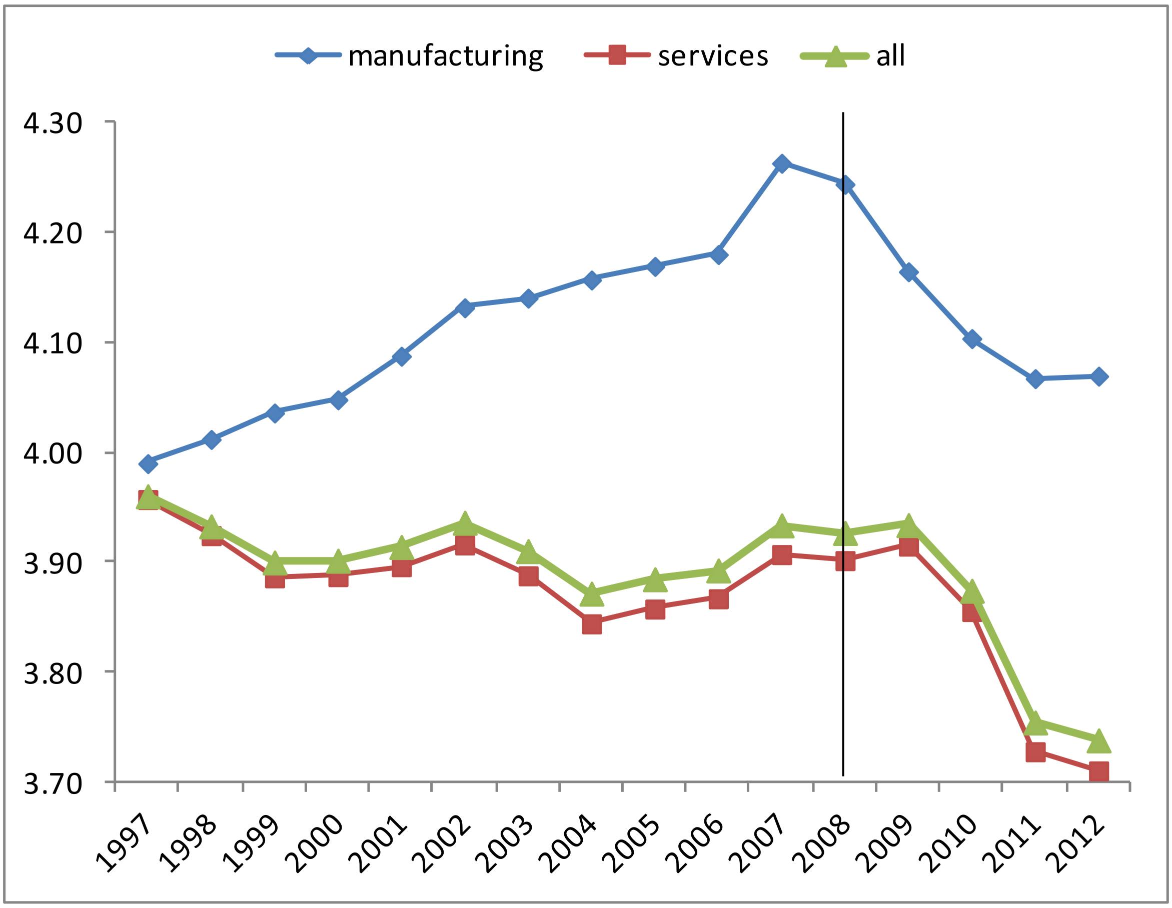

Fig. 3. Weighted Mean Real Gross Output per Worker for Manufacturing and Services (Logged £000 2000 Prices) for GB
Source: weighted estimates; see Table 1 for definition of LP

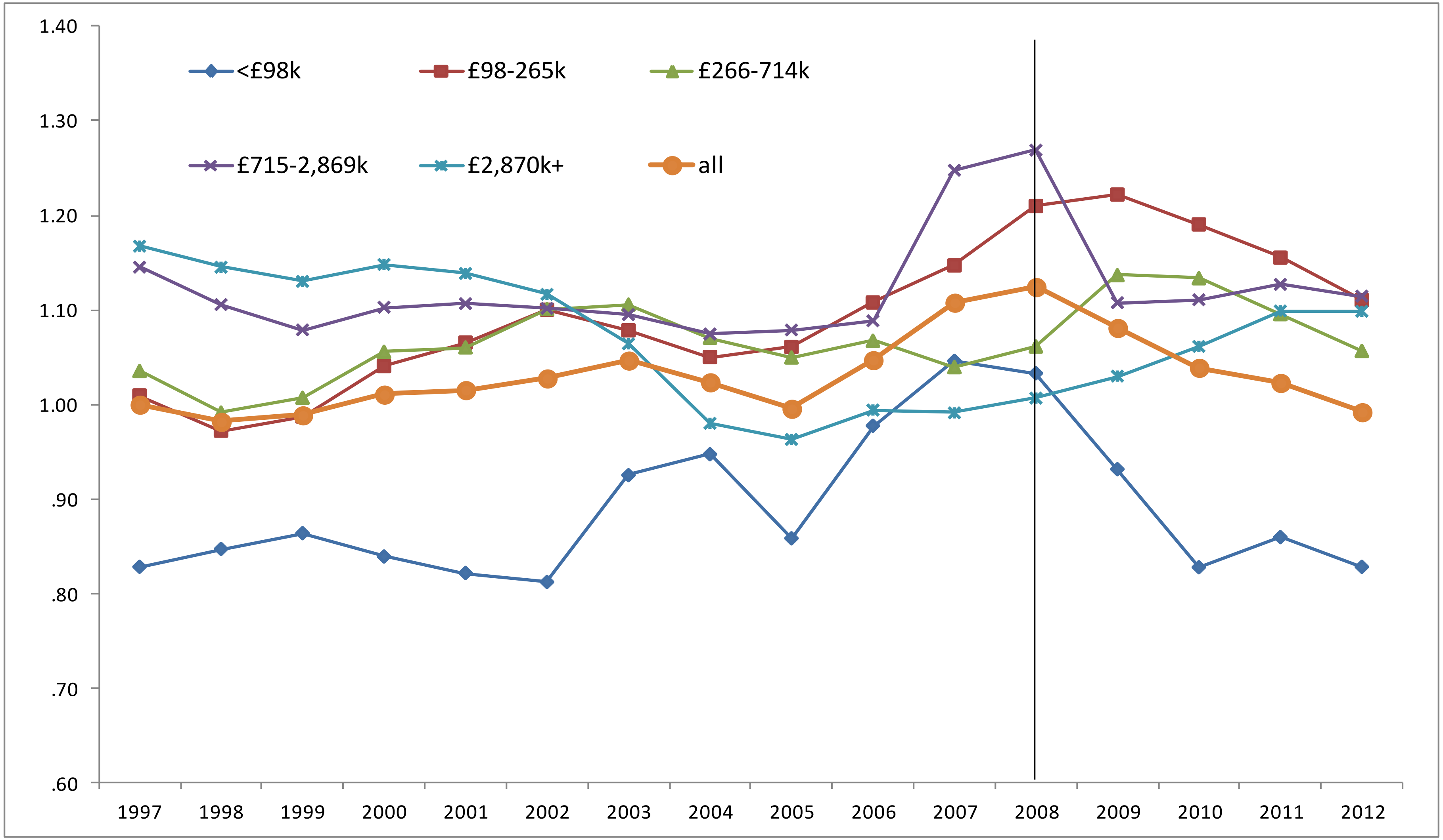

Fig. 4. Weighted Mean TFP for Plants of Different Size Based on Real Gross Output (1997=1 for All Plants) for GB
Source: weighted estimates based on equation (2) for TFP

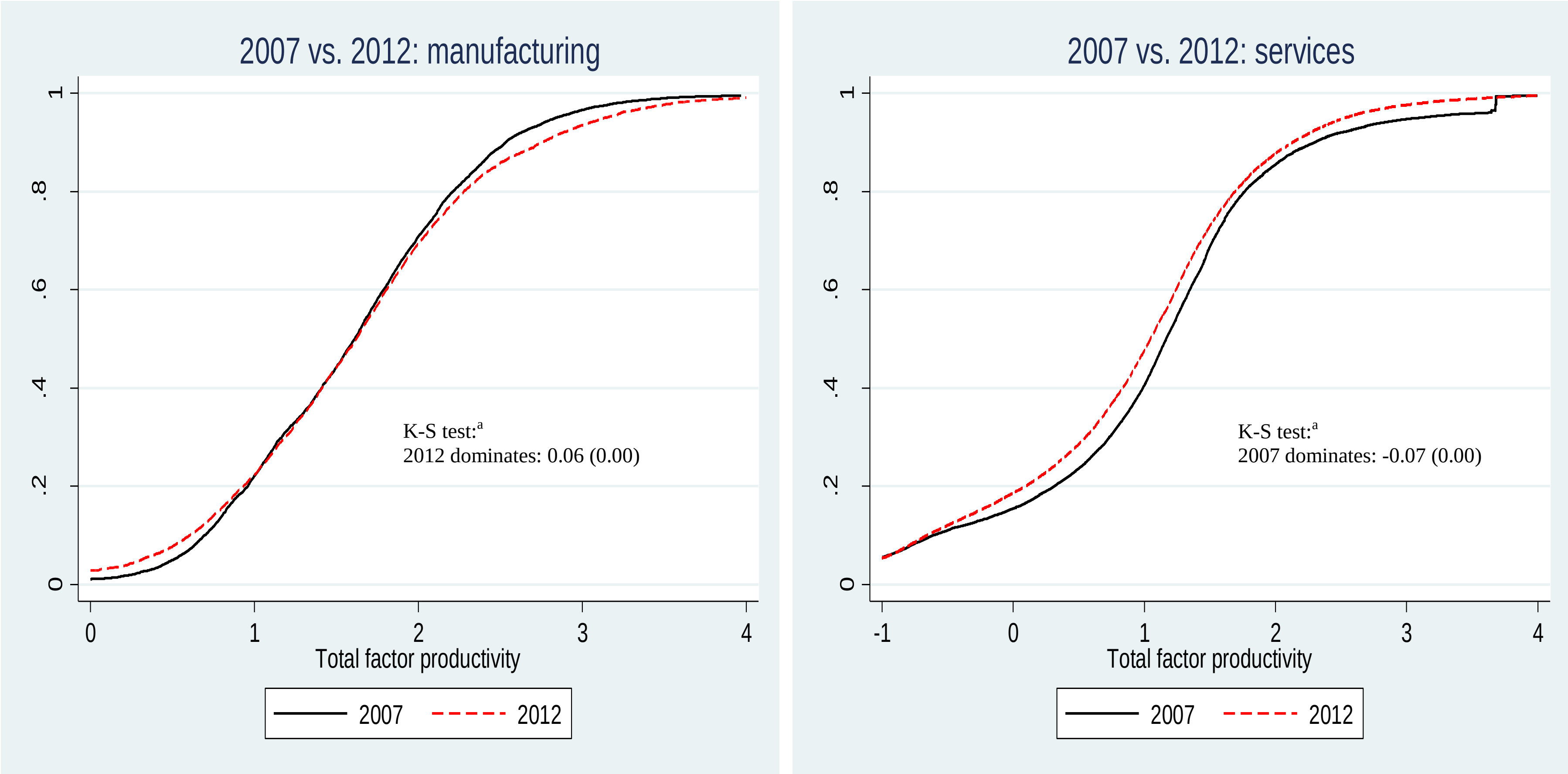

Fig. 5. Cumulative (weighted) Plant-Level TFP for Various Sub-Groups

[a] Kolmogorov-Smirnov test for equality of distribution functions; figures represent the maximum gap in favour of 2012 or 2007 with significance level in parenthesis. See Figure U.1 in the online appendix for more graphical evidence across more disaggregated sectors, size-bands and ownership.

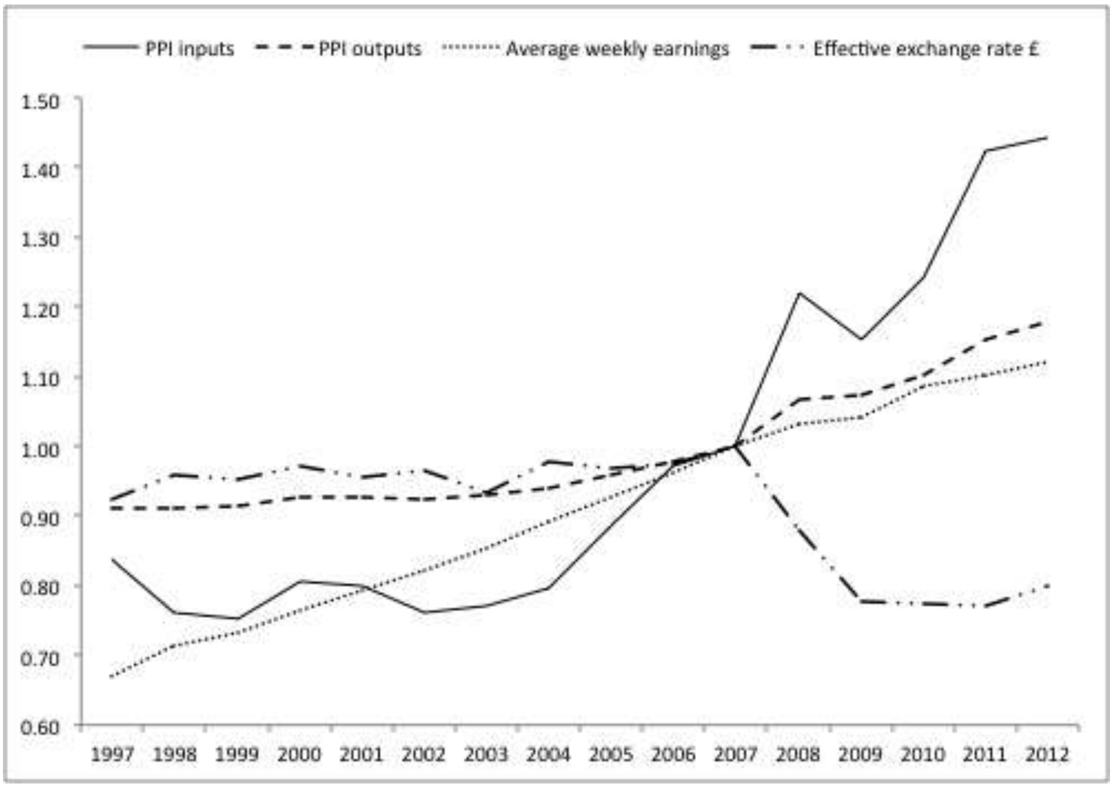

Fig. 6. Prices and wages in manufacturing, 1997-2012 (2007=1)
Source: MM22 (producer price indices); Average weekly earnings database; exchange rate (series XUAABK67) – all data is from online ONS sources.