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Abstract

This paper constructs estimates of total factor productivity (TFP) growth for the United Kingdom for the period 1970-2000, using an industry data set that spans the whole economy. The estimates are obtained by controlling for variable utilisation of capital and labour, and costs of adjusting these factors. The analysis is focused on the 1990s. This was a period when the growth rate of the standard measure of TFP growth for the United Kingdom, the Solow residual, did not match the sharp rise in US productivity, even though the macroeconomic environment in both countries was similar. The paper delivers two main results. First, the aggregate Solow residual underestimates TFP growth throughout the 1990s, since it does not account for falling utilisation rates and high capital adjustment costs. Second, the impact of non-technological factors on the Solow residual is similar in the first and the second half of the 1990s. This means that the broad movement in the Solow residual during the 1990s is similar to that of the estimated TFP growth. Potential reasons behind these results are discussed using disaggregated data.

Summary

The aim of monetary policy is to keep inflation low and stable. A key influence on inflationary pressure is the balance between the demand for and the economy's capacity to supply goods and services. This capacity depends both on the quantities and qualities of the inputs into the production process (capital and labour), and on the efficiency with which they are combined. The latter concept is often referred to as total factor productivity (TFP). A good understanding of past and current TFP growth is thus important for understanding aggregate supply capacity, and so is relevant for the conduct of monetary policy.

During the 1990s, productivity growth did not increase in the United Kingdom while it rose sharply in the United States. This diverging performance looks puzzling, especially when considering that, following the 1990-92 recession, the macroeconomic environment in the two countries was similar. This research tries to estimate underlying productivity growth by accounting for a number of factors that may bias the standard estimate of productivity growth, and thereby give us a distorted picture of underlying technological progress. By doing so, it tries to assess and account for the lack of a pickup in UK productivity growth during the 1990s.

The starting point of the analysis is a standard measure of aggregate TFP growth, or the so-called Solow residual. This is calculated as that part of aggregate output growth that cannot be accounted for by the primary factors of production, under the assumptions of perfect competition, constant returns to scale, no costs to adjusting the factors of production and therefore full utilisation of available factors.

When any of these assumptions is violated, the Solow residual may not correctly measure underlying technological progress. For example, increasing returns to scale in the production of output may cause this measure of TFP growth to rise whenever input growth rises. And if firms face adjustment costs when hiring and firing workers or changing the level of capital, they could respond to short-run fluctuations in demand by adjusting the intensity with which they use labour and capital. This would cause larger fluctuations in output than in capital and labour, and hence procyclical movements in measured TFP growth. In addition, if firms face costs to adjusting capital and labour, marketable output (which matters for the Solow residual) may be low during periods of rapid investment or hiring growth. This is because firms may spend resources internally to install capital or labour, rather than producing marketable output. In this paper, we try to control for these types of non-technological factors, to see whether this affects our conclusions about the United Kingdom's productivity performance during the 1990s.

It is not possible to observe how hard companies are working capital and labour – or their utilisation levels – directly. But by assuming that firms maximise profits, we can derive links between variables such as hours worked and the amount of intermediate inputs used, and changes in the rate of utilisation of capital and labour. The paper also tries to account for the amount of resources that is used by firms to install new capital and hire new labour, instead of producing marketable output.

The results suggest that the aggregate Solow residual underestimates underlying UK total factor productivity growth through the 1990s, since it does not account for falling utilisation rates and high capital adjustment costs. We find, however, that these non-technological factors had a similar impact on the Solow residual during the first and the second half of the 1990s. The broad movement in the aggregate Solow residual through the 1990s is therefore similar to that of our estimate of underlying productivity growth. Thus the puzzle of the apparent lack of a pickup in UK productivity growth during the 1990s remains.

In a comparison with the United States, the paper notes that the US experience of a rise in TFP growth between the first and the second half of the 1990s was, to a large extent, driven by strong growth in ICT-producing industries, the distribution sector and financial services. A broadly similar pattern is found for the United Kingdom. One difference, however, is that whereas the US durables manufacturing sector as a whole contributed to rising rates of TFP growth, UK estimates suggest that most durables industries did not see an increase in TFP growth over the same periods. So the results suggest that the rise in TFP growth appears to have been more broadly based in the United States than in the United Kingdom, and this may partly explain the difference in the aggregate data.

1 Introduction

It is well documented that, during the second half of the 1990s, productivity growth in the United Kingdom did not match the sharp rise seen in the United States, although the macroeconomic environment in the two countries was similar: output growth rose, investment surged and unemployment fell to low levels.[1] One potential explanation for this productivity puzzle is that the standard measure of total factor productivity (TFP) growth – the Solow residual – masks the effect of non-technological factors such as variations in the utilisation of inputs, or costs to adjusting the level of these inputs. Basu, Fernald and Shapiro (2001) found that for the United States, the increase in measured productivity growth during the 1990s appears to arise from an increase in the rate of technological change – even after controlling for variable utilisation of capital and labour, and capital adjustment costs. A similar study remains to be done for the United Kingdom, and this is the purpose of this paper. In particular, we estimate UK TFP growth, controlling for non-technological factors that may affect the standard Solow residual, to see whether this affects our conclusions about the United Kingdom's productivity performance during the 1990s.

The standard measure of TFP growth, the Solow residual, is calculated as that part of output growth that cannot be accounted for by the primary factors of production, under the assumptions of perfect competition, constant returns to scale, no costs to adjusting factors of production and therefore full utilisation of available factors. When any of these assumptions is violated, the Solow residual does not correctly measure underlying technological progress. Chart 1 shows the Solow residual for the UK non-farm private economy. The Solow residual displays high frequency fluctuations and is strongly procyclical, both at the aggregate and the industry level.

Productivity may of course be procyclical as a consequence of procyclical technology. There are, however, several other possible explanations, not related to technology. Increasing returns to scale in production may cause measured productivity to rise whenever inputs rise. If firms face adjustment costs in hiring and firing workers and in changing the level of capital, they could respond to short-run fluctuations in demand by adjusting the intensity of utilisation of labour and capital. This would cause larger fluctuations in output than in observed inputs and, consequently, procyclical movements in measured productivity. Also, procyclical movements in aggregate productivity could reflect cyclical reallocation of resources across sectors.

To control for these factors, we use a framework based on Basu *et al* (2001) that allows for non-constant returns to scale, variable factor utilisation, adjustment costs, and reallocation of resources across sectors. Using the first-order conditions from the theoretical model, we derive links between (unobserved) changes in factor utilisation and (observed) changes in average hours, intermediate inputs, and investment. As in the analysis by Basu *et al*, we assume that workers need

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[1] See Oulton (2001), O'Mahony and de Boer (2002), van Ark *et al* (2002), Jorgenson (2003) and Basu, Fernald, Oulton and Srinivasan (2004) for estimates of UK productivity growth. Basu, Fernald and Shapiro (2001) look at the US performance over the same period, and Basu *et al* (2004) compare growth performance in the two countries.

to be compensated for the disutility that increased effort implies, and there is a shift premium for working at non-regular shifts. In addition, we consider different adjustment costs for ICT (information and communication technology) and non-ICT capital. Also, non-ICT capital is assumed to depreciate at a faster rate with a more intensive use, whereas the depreciation rate for ICT capital is not affected by the intensity of use.

TFP growth is estimated at the industry level, using a data set for 31 services and manufacturing industries, covering the period 1969-2000. The industry results are aggregated, to be able to analyse the contribution of non-technological factors to aggregate productivity growth. The bottom-up approach allows us to analyse if the decrease in productivity growth is widespread across sectors, and whether the factors explaining the performance differ across industries. In addition, the approach lets us examine the role played by the reallocation of resources across sectors in explaining aggregate UK productivity performance.

The results suggest that the aggregate Solow residual underestimates TFP growth throughout the 1990s, since it does not account for falling utilisation rates and high capital adjustment costs. However, since the impact of the non-technological factor on TFP growth is similar in the first and the second half of the 1990s, the broad movement in the Solow residual is similar to that of the estimated TFP growth. This means that, even after controlling for non-technological factors, the United Kingdom's TFP performance continues to fall short of that of the United States. At the sectoral level, we find falling growth rates in three groups of industries: manufacturing, oil and gas, and construction and distribution services. By contrast, growth rates have increased in utilities, transportation services, and a number of services industries, such as communication, finance and business services.

The paper is organised as follows. Section 2 presents a brief review of the literature and Section 3 develops the theoretical framework used for the estimations. Section 4 describes the adjustment cost estimates used for the study, and Section 5 briefly describes the data. Section 6 discusses the estimation results obtained at the sectoral level. Section 7 uses the sectoral estimates to calculate aggregate TFP and decomposes the resulting TFP growth in its contributing factors. Section 8 concludes.

2 Factor utilisation, returns to scale and TFP growth

Consider a production function for the representative firm or industry of the following form:

$$Y = F(Ks, Ls, M, Z) \qquad \textbf{(2.1)}$$

The firm or industry produces gross output, Y, using capital services, Ks, labour services, Ls, and intermediate inputs, M. Z indexes technology, defined as any input that affects productivity but is not compensated for by the firm. The level of capital and the number of employees are quasi-fixed factors of production, so their levels cannot be changed costlessly, but firms may vary the intensity with which they use these inputs. Thus, capital services are the product of the level of capital, K, and its rate of utilisation, *S*, while labour services are the product of the number of workers, *N*, the hours worked per employee, *H*, and the effort of each worker, *E*. The firm's production function *F* is homogeneous of an arbitrary degree γ in total inputs.

By taking the logarithm of **(2.1)** and differentiating the expression with respect to time, we obtain,

$$dy = \frac{F_K K}{F}(dk + ds) + \frac{F_L L}{F}(dn + dh + de) + \frac{F_M M}{F} dm + dz \qquad \textbf{(2.2)}$$

where *dx* denotes the growth rate of variable *X*, F_K the derivative of *F* with respect to capital services *Ks*, F_L and F_M the derivative of *F* with respect to *L* and *M*, respectively, and *dz* TFP growth, defined as that part of output growth that cannot be accounted for by the growth of inputs. The assumptions of cost minimisation and the homogeneity of *F* allow the output elasticities in **(2.2)** to be expressed in terms of observed input prices and quantities,

$$\frac{F_X X}{Y} = \mu \frac{P_X X}{PY} = \mu s_X, \qquad X = Ks, L, M \qquad \textbf{(2.3)}$$

where P_X and s_X are the price and the revenue-share of factor *X*, respectively, and μ the markup of the price over marginal cost. Substituting **(2.3)** in **(2.2)** and rearranging terms gives

$$dy = \mu\left[s_K dk + s_L(dn + dh) + s_M dm\right] + \mu(1 - s_M)\left[\frac{s_K ds + s_L de}{1 - s_M}\right] + dz \qquad \textbf{(2.4)}$$

Taking into account that *F* is homogenous of degree γ and using equation **(2.3)**, it is further possible to show that

$$\gamma = \mu(1 - \pi) \qquad \textbf{(2.5)}$$

where π are pure profits over income. Using this in expression **(2.4)** allows us to express output growth in terms of cost shares,

$$dy = \gamma\left[c_K dk + c_L(dn + dh) + c_M dm\right] + \gamma(c_K + c_L)\left[\frac{c_K ds + c_L de}{c_K + c_L}\right] + dz \qquad \textbf{(2.6)}$$

where c_X is the cost share of factor *X*. The term within the first brackets on the right-hand side of **(2.6)** is a cost-share weighted average of input growth, and the term within the second brackets is a weighted average of the unobserved variation in input utilisation. Denoting these two terms *dx* and *du*, respectively, we get the basic equation for the estimation of productivity growth,

$$dy = \gamma dx + \gamma(c_K + c_L)du + dz \qquad \textbf{(2.7)}$$

If there are constant returns to scale and inputs are perfectly observable, all terms in **(2.7)** are observable and *dz* can be computed as a residual. This case gives the standard Solow residual. If there are increasing returns to scale and inputs are perfectly observable, *dz* can be estimated by regressing *dy* on *dx*. However, if input utilisation is variable and non-observable, this approach obtains a biased estimator of TFP growth, also when there are constant returns to scale. To obtain a good measure of technological change in the presence of variable and non-observable utilisation, the challenge is therefore to relate *du* to observable variables.

The literature has proposed three general methods to deal with *du*. Jorgenson and Griliches (1967), Abbot *et al* (1998) and Shapiro (1987) use a variable that proxies factor utilisation, but where the relationship between the proxy used and utilisation is *ad hoc*. Burnside *et al* (1995) and Basu (1996) impose separability assumption on the production function to be able to derive a proxy for utilisation. Here we follow the more general approach by Basu and Kimball (1997) and Basu *et al* (2001) who derive links between observed variables and unobserved utilisation using the first-order conditions for cost minimisation. The basic insight behind this approach is that a cost-minimising firm will operate at all margins simultaneously, ensuring that the marginal benefit of any input equals its marginal cost (for example, the marginal cost of increasing labour should be the same irrespective of whether hours or effort is raised). This means that the firm's first-order conditions for cost minimisation imply a relationship between observed and unobserved inputs that can be used to proxy unobserved variation in utilisation.

Controlling for variable utilisation has proven to be an important issue. The resulting productivity estimates tend to be less procyclical than the standard Solow residual (eg Burnside *et al* (1995), Basu (1996) and Sbordone (1997)). In most of these empirical studies, allowing for variable factor utilisation also eliminates or reduces the evidence for large increasing returns to scale (Burnside *et al* (1995), Basu and Kimball (1997)).

3 Theoretical framework for the estimation of TFP growth

In order to estimate TFP growth, we adopt a framework similar to Basu *et al* (2001). Firm *i* produces gross output, *Y*, using capital, *K*, employees, *N*, and intermediate inputs, *M*. It is costly to change the level of capital and labour, and the firm may vary the intensity of utilisation of these inputs. We here consider adjustment costs for labour and capital, and adjustment costs for ICT capital are allowed to differ from those of non-ICT capital. Moreover, workers need to be compensated for the disutility of higher effort or for working at non-regular shift hours (shift premium), and non-ICT capital is assumed to depreciate faster with more intensive use.

Let the production function for the representative firm in sector *i* be given by

$$Y = F\left(S_j K_j, NHE, M, Z\right)\left(1-\Psi\left(\frac{R}{N}\right)\right)\prod_j\left(1-\Phi_j\left(\frac{I_j}{K_j}\right)\right), \quad j = ict, non \qquad \textbf{(3.1)}$$

where subindex *j* denotes asset (ICT and non-ICT capital), and where the industry subscripts have been suppressed. Firms may vary the utilisation of capital, *S*, and the utilisation of labour can be varied using hours worked, *H*, or effort, *E*. The costs of adjustment are given by the convex functions $\Psi(R/N)$ and $\Phi(I/K)$, where *R/N* is the ratio of the flow of hiring to the number employed, and where I/K denotes the investment to capital ratio. The production function F is assumed to be a generalised Cobb-Douglas function and we assume that there are no pure economic profits. [2]

The shadow prices of the quasi-fixed factors capital and labour may differ from the observed market prices. This, in turn, implies that the output elasticities are not equal to the respective cost shares. To overcome these problems, we follow Basu *et al* (2001) and take a first-order approximation of **(3.1)** around the steady state to obtain

$$dy = \sum_j \left(\frac{F_{K_j} S_j K_j}{F} \right)^* (dk_j + ds_j) + \left(\frac{F_L L}{F} \right)^* (dn + dh + de) + \left(\frac{F_M M}{F} \right)^* dm - \sum_j \phi_j^* (di_j - dk_j) - \psi^* (dr - dn) + dz \quad \textbf{(3.2)}$$

for $j = ict, non.$ The first-order approximation implies treating the output elasticities with respect to factors of production as constants, and (*) implies that a variable is evaluated at its steady-state value. The term ϕ_j is the elasticity of adjustment costs with respect to investment in asset j,

$$\phi_j = \left(\frac{\Phi'_j}{1 - \Phi_j} \frac{I_j}{K_j} \right)^* \quad \textbf{(3.3)}$$

where Φ'_j denotes the derivative of Φ_j with respect to the investment to capital ratio in asset j. Similarly, ψ denotes the elasticity of labour adjustment to costs to employment,

$$\psi = \left(\frac{\Psi'}{1 - \Psi} \frac{R}{N} \right)^* \quad \textbf{(3.4)}$$

where Ψ' is the derivative of Ψ with respect to the ratio of hiring to the number employed.

To obtain expressions for the elasticities in **(3.2)** in terms of observable variables, we need to solve the cost-minimisation problem of the firm. The representative firm chooses the numbers of hours (H), level of effort (E), intermediate inputs (M), intensity of capital utilisation (S), and the flows of investment (I) and hiring (R) in order to minimise the present value of current and expected future variable costs, subject to the production function, the capital accumulation identities for ICT and non-ICT capital, and the dynamics of the number of workers. In each period t, the representative firm solves the following problem,

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[2] The zero-profit-assumption is in part dictated by the way the data set has been constructed. The Cobb-Douglas assumption greatly simplifies the analysis as it means that the cost shares are constant. Alternatively, one could use a more general functional form that allows for time-varying elasticities. The drawback with that approach is that efficient estimation requires additional restrictions and identifying assumptions, meaning that the results may become more sensitive to misspecification. To estimate a higher order functional form for the production function, one also needs to make the assumption that prices are allocative in each period, which may not be the case.

$$\underset{H,E,M,S_j,I_j,R}{Min} E_t\left[\sum_{\tau=0}^{\infty}\beta^{\tau}\Big(wNG(E,H)V(S_j)+P_M M+P_{I_j}I_j\Big)\right]$$

subject to:

$$\overline{Y}=F\big(S_jK_j,NHE,M,Z\big)\left(1-\Psi\left(\frac{R}{N}\right)\right)\prod_j\left(1-\Phi_j\left(\frac{I_j}{K_j}\right)\right) \quad \textbf{(3.5)}$$

$$K'_j=\big(1-\delta_j(S_j)\big)K_j+I_j$$

$$N'=N+R$$

for $j=non,ict$. Variable w is the base salary, N is the number of workers, $G(E,H)$ a schedule that determines the hourly wage as a function of effort and hours worked, $V(S)$ is the premium pay to workers in off-hours shift, P_M is the price of intermediate inputs and P_I is the price of new capital goods. Time indices have been suppressed, and X' denotes the period t+1 value of variable X. We here assume that the depreciation rate for non-ICT capital is an increasing function of the level of utilisation of non-ICT capital, while the depreciation rate for ICT capital is constant.

By deriving the Euler equations for capital and labour from the above dynamic cost minimisation problem, it can be shown that (see Appendix A) the steady-state elasticities satisfy

$$\left[\frac{F_{K_j}S_jK_j}{F}\right]^*=\mu^*s^*_{K_j}-\phi^*_j,\ i=non,ict \qquad \text{and}\left[\frac{F_L(NHE)}{F}\right]^*=\mu^*s^*_L-\psi^*+r^*\left(\frac{\psi N}{R}\right)^* \quad \textbf{(3.6)}$$

where r^* is the steady-state real interest rate. Thus, output elasticities with respect to capital and labour depend not only on the income shares and the markup, but also on the adjustment cost terms; the elasticity of final output with respect to capital (or labour) exceeds the elasticity of the production function with respect to capital (or labour), by an amount equal to the elasticity of the adjustment cost function with respect to investment (or hiring). This is due to the fact that having more capital reduces the adjustment cost of investment, and having more labour reduces the cost of hiring more workers.

Under the assumption that economic profits are zero, income shares are equal to cost shares, and the markup equals the degree of returns to scale. Substituting **(3.6)** in **(3.2)** together with the elasticity for material inputs, and rearranging terms, we have,

$$dy + \sum_j \phi_j^* di_j + \psi^*(dr + dh) - r^* \left(\frac{\psi N}{R}\right)^* (dn + dh) =$$
$$\gamma^* \left[\sum_j c_{K_j}^* dk_j + c_L^* (dl + dh) + c_M^* dm \right] +$$
$$\gamma^* \left[\sum_j \left(c_K^* - \frac{\phi_j^*}{\gamma^*} \right) ds_j + \left(c_L^* - \frac{\psi^*}{\gamma^*} + r^* \left(\frac{\Psi N}{R\gamma} \right)^* \right) de_i \right] + dz \tag{3.7}$$
$$= \gamma^* dx + \gamma^* du + dz.$$

In equation **(3.7)**, the adjustment cost terms have been moved to the left-hand side. In writing the equation in this form, we emphasise the fact that the firm is actually producing two types of output—the market output and the internally used services of installing new investment goods and training new employees. As discussed in a later section, estimates for the capital adjustment cost elasticities (ϕ^*_j) are obtained from Groth (2005). Unfortunately, we do no have estimates for the labour adjustment cost elasticity ψ^* and instead assume that it is zero in the steady state.

The right-hand side of equation **(3.7)** contains three terms. The first, the cost share weighted average input growth, is observable, and the steady-state cost shares are approximated by the sample average cost shares. The other two terms, the growth rate of utilisation and TFP growth are not observable. TFP growth can be estimated by regression of equation **(3.7)**. But in order to be able to do so, we have to express the growth rate of utilisation in terms of observed variables. Following Basu and Kimball (1997), we use the first-order conditions for the cost-minimisation problem described in **(3.5)** to derive a relation between the unobserved and the observed variables. It is shown in Appendix A that *du* can be expressed in terms of growth rates of observable variables,

$$du = \beta_1 dh + \beta_2 \left(dp_m + dm - dp_{non} - dk_{non} \right) + \beta_3 \left(di_{non} - dk_{non} \right) \tag{3.8}$$

where dh is the growth rate of hours per head, dp_m the growth rate of the price of materials and dp_{non} the growth rate of the price of non-ICT investment goods. The coefficient β_1, β_2 and β_3 are complex functions of cost shares, elasticities and returns to scale.

If there is a shift premium, the first term in **(3.8)** proxies both effort and capital utilisation. Consider a firm that would like to use more labour. Since it is costly to adjust the number of employees, the firm could also consider increasing hours worked or effort. From a cost-minimisation perspective, the firm will choose to increase both so that, in equilibrium, the marginal cost of increasing labour is the same irrespective of whether the firm increases hours or effort. Thus, when observed hours per worker are increasing, unobserved effort should also be increasing. The intuition for the change in hours per head as a proxy for capital utilisation is similar. In order to increase the utilisation of capital, the firm has to use more labour (longer hours or a new shift). A cost-minimising firm will operate in all available margins, including longer hours. Thus when the unobserved utilisation of capital is increasing, hours per worker should also increase. Altogether, this implies that β_1 is positive.

The last two terms in **(3.8)** capture variable capital utilisation. The intuition for the first term, the ratio of nominal intermediate inputs to nominal capital, is related to the quasi-fixed nature of capital and the flexible nature of the intermediate inputs. If there is an increase in the utilisation of capital, the capital cost will remain the same, but the cost for intermediate inputs will increase due to the increase in the quantity used of intermediate inputs. Thus, the coefficient β_2 should be positive. For the second component, we need to take into account two opposite effects. First, higher utilisation of non-ICT capital is associated with a higher rate of depreciation, and therefore with a higher rate of replacement investment. When the investment to capital ratio is high, the level of utilisation should therefore also be higher. Second, it is costly to replace depreciated capital, and therefore to utilise capital heavily, when investment to capital ratios are high, since adjustment costs tend to be high. This effect tends to go in the opposite direction, and the net effect depends on the relative size of these two effects. We find that the first effect tends to dominate, and therefore expect a positive sign of β_3. We assume that higher utilisation of capital is costly for non-ICT capital, but that ICT capital can be used at a higher rate of utilisation without incurring costly depreciation. Therefore, the two last terms of **(3.8)** refer only to non-ICT capital.

Substituting **(3.8)** into **(3.7)** yields the basic regression equation for estimating technical change as the residual in the regression of the growth rate of total output on the growth rates of inputs, hours per head, the ratio of nominal intermediate to capital and the investment to capital ratio. The basic regression equation satisfies:

$$\begin{aligned} dy + \sum_j \phi_j^* di_j + \psi^* (dr + dh) &= \gamma^* dx + b_1 dh \\ &+ b_2 (dp_m + dm - dp_{non} - dk_{non}) + b_3 (di_{non} - dk_{non}) + dz \end{aligned} \qquad \textbf{(3.9)}$$

4 Calibration of the adjustment cost parameter

Equation **(3.9)** could be estimated directly by moving the adjustment cost terms to the right-hand side of the equation. We find, however, that when we try to do so, the regression equation does not perform well. In particular, the significance of many of the estimated parameters is low, and the estimated model fits the data poorly. This partly reflects the fact that the information typically used in the estimation of adjustment costs is ignored, since the firm's dynamic investment decision is not modelled explicitly. We therefore choose to calibrate the adjustment cost parameter, based on adjustment cost estimates from Groth (2005), who estimates adjustment costs for ICT and non-ICT capital, using the same industry data set as is used here.

Groth (2005) obtains estimates of the elasticity of *variable costs* with respect to investment, whereas we are interested in the elasticity of the *adjustment cost function* with respect to investment. Appendix B derives a relation between the two,

$$\phi = -\frac{\phi_c}{\alpha_y} \qquad \textbf{(4.1)}$$

where ϕ is the elasticity of the adjustment cost function with respect to investment, ϕ_c the elasticity of the variable cost function with respect to investment, and α_y is the elasticity of variable costs with respect to output. Based on the reported estimates, we obtain a value of the adjustment cost elasticity of around *0.03*%. As shown in Groth (2005), this represents an elasticity of aggregate *value added* with respect to aggregate investment of around -0.055. This is somewhat higher than the elasticity reported by Basu *et al* (2004) for the United States. (3)

5 Data

We use the Bank of England industry data set, which contains annual data for 34 industries spanning the whole UK economy over the period 1970 to 2000. (4) In practice, we only work with the private non-farm economy. An overview of the industries included in the data set is provided in Table A. (5) For each industry, there are data on gross output and inputs of capital services, labour services, and intermediates, in nominal and real terms. The capital services series is a quality-adjusted measure of capital that takes into account the composition capital, by weighting different assets together by their rental prices. Labour services are measured as hours worked, both including and excluding quality adjustment. Quality-adjusted labour growth has been taken from Bell, Burriel-Llombart and Jones (2005), who estimate labour quality growth for ten broad sectors of the economy. Since labour quality growth is not available at the industry level, we calculate the quality-adjusted growth rate of labour input in industry *i* as the sum of the growth rate of hours in industry *i* and the growth rate of labour quality for the sector that industry *i* belongs to. The real intermediate index is a weighted average of domestic purchases from all of the other industries and from imports. To obtain a measure of aggregate investment that is consistent with the rental-price weighted index of capital, we use an aggregation method further discussed in Groth (2005). Moreover, to obtain a measure of the user cost of capital, economic profits are assumed to be zero. This pins down the share of capital as a residual, from which the price of capital can be obtained.

One discrepancy between the theory and the available data is that the depreciation rate for non-ICT goods is assumed to vary with the degree of utilisation. The capital data, however, are based on a perpetual inventory method that assumes constant geometric depreciation. Results by Basu and Kimball (1997) suggest that variable utilisation only has a small effect on capital. Compared to

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(3) Based on adjustment cost estimates by Shapiro (1986), they report a value of the elasticity of aggregate value added with respect to investment of around -0.035.
(4) The data set is described in detail in Oulton and Srinivasan (2005). It is consistent with the official UK National Accounts (as given in the 2002 *Blue Book*, Office for National Statistics (2002) in real and nominal terms, before the following adjustments were done. To derive series for ICT investment, US price indices were employed for computers and software, converted to sterling terms. Also, an upward adjustment has been made to the official level of software investment, further discussed in Oulton (2002).
(5) The private non-farm economy covers industry 2-29 and 34. That is, it excludes agriculture, public administration and defence, education, health, social work and waste treatment.

other issues in the construction of capital, such as the assumption of geometric depreciation rates and the uncertain data on UK ICT investment, the measurement error arising from the assumption of constant depreciation is probably small.

To obtain a proxy for effort, the hours data is crucial. Basu and Kimball (1997) use changes in hours per head to proxy changes in effort. However, observed changes in hours per head may not only reflect changes in effort, but also other factors such as changes in the composition of labour (for example, an increase in the proportion of part-time workers or female workers may produce a decrease in aggregate hours per head), and changes in institutional factors (such as the working time directive). In the United Kingdom, the data on hours per head exhibit a strong downward trend, discussed by Felices (2003), which we believe may reflect these types of compositional and institutional factors. To control for this, we use full-time male hours per head instead of total hours per head, and detrend the series using an HP filter. [6]

To obtain male hours per head, we use data from the New Earnings Survey (NES) that is available by sector, gender and qualification. For the period 1986-2000, data on full-time male total hours (normal basic hours plus overtime) is available whereas for the period 1971 to 1986, there is only data on normal basic hours. For this period, data on total hours is created by combining the NES data with data from the Labour Force Survey (LFS) that includes overtime hours, as described in Appendix C. Full-time male hours for the private non-farm economy, where the sectors are weighted together by their shares in value added, are shown in Chart 2, for the actual and the detrended series. Average hours are trending downwards throughout the period. The detrended series shows a procyclical pattern except for the period 1995 to 2000, when the data suggest that average hours fell in spite of rapid output growth.

6 Estimation results at the sectoral level

In this section we explore the implications of allowing for variable factor utilisation and adjustment costs in identifying the returns to scale parameter and TFP growth. As stated in Section 3, the regression equation is

$$\begin{aligned} dy + \sum_j \phi_j di_j &= \gamma^* dx + b_1 dh \\ &+ b_2\left(dp_m + dm_i - dp_{non} - dk_{non}\right) + b_3\left(di_{non} - dk_{non}\right) + dz \end{aligned} \quad \textbf{(6.1)}$$

As there are only 29 observations for each industry, we choose to estimate the equation by group of industries (hereafter sector), rather than by industry. Six sectors are defined: mining and oil; manufacturing; utilities; construction, distribution and hotels; transport services; and other market services (for a detailed list of industries in each sector together with the number of observations for

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[6] When detrending the data, data until 2002 are used to control for potential problems with the HP filter near the endpoint. We also use alternative methods to detrend the data (band-pass filter), for which we obtain similar results.

each sector, see Table A). The classification of sectors is, with two exceptions, based on the classification of sectors on SIC classifications. (7) The data is pooled within each sector, but we allow for industry-specific fixed effects. Across sectors, separate slope coefficients are estimated.

The model is estimated using an instrumental variable approach, to reduce the problem of simultaneity of input growth and technological change. Suitable instruments would be variables that are correlated with changes in input growth but not with technology. We use a set of demand-side instruments that includes changes in the relative price of energy, world trade growth, a fiscal impulse (measured by the change in the cyclically adjusted government deficit) and a monetary shock (calculated using a SVAR as described by Christiano *et al* (1999)). We also create a demand instrument that, for each industry, is calculated as the weighted growth of demand from the rest of the economy (comprising intermediate demand from other industries, consumption demand, export demand and investment demand), described in Groth (2005). The current values of these variables are used as instruments in the regression equations. Estimating **(6.1)** using an instrumental variable approach also requires the model variables to be stationary. At the industry level, the hypothesis of a unit root in the growth rates of the relevant model variables is rejected. Finally, a dummy variable for the years 1971-79 has been included in all regressions, in order to take into account that some of the variables used in the regressions are measured with some imprecision before 1979. (8)

6.1 Zero adjustment costs

Turning to the estimation results, we start by estimating the model under the assumption that both capital and labour adjustment costs are zero in the steady state, as reported in Table B. That is, the dependent variable in the regression equation **(6.1)** is dy.

The first column in Table B reports the results from the benchmark regression where we assume constant utilisation of factor inputs, which implies the restriction that b_1=b_2=b_3=0, but allow for non-constant returns to scale. Under these assumptions, the estimated coefficient for returns to scale is larger than or equal to one in all sectors. This suggests that, when not controlling for factor utilisation, the cyclical variation of the standard Solow residual may partly be explained by increasing returns to scale.

In a second regression equation, reported in Column 2 of Table B, we control for both variable factor utilisation and non-constant returns to scale (that is, we estimate b_1, b_2 and b_3 in **(6.1)**). The first result to highlight is that the point estimates for the returns-to-scale parameter are lower than when we assume constant factor utilisation. The estimate of the coefficients on hours per head (b_1) and the ratio of intermediate inputs to capital services (b_2) are positive and significant for all sectors

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(7) Construction, distribution services and hotels (including restaurants) are classified separately in the SIC classifications while we group them together. This is also true for financial intermediation, business services and miscellaneous services, which we all classify as other market services.
(8) See Oulton and Srinivasan (2005).

but utilities, in line with the theoretical predictions. The estimated coefficient on the ratio of investment to capital services (b_3) is insignificant and negative in all cases. As discussed above, one possible explanation for this is that the capital stock series are constructed using an exogenous depreciation rate and the data may therefore not capture the effect of a variable depreciation rate. We also test the restriction that $b_1=b_2=b_3=0$ and find that it is rejected in all sectors except for utilities. This gives further evidence that by assuming constant utilisation, a biased estimator of the returns-to-scale parameter, and of productivity growth, is obtained.

Basu and Kimball (1997) show that if the sole cost of changing capital utilisation is that workers need to be compensated for working at night (a shift premium), changes in hours per worker is a sufficient proxy for unobserved changes in *both* effort and capital utilisation. Under this assumption, coefficients b_2 and b_3 in **(6.1)** are zero. The model is estimated imposing this restriction, and the results are reported in Column 3 of Table B. The results are similar to those reported in Column 2. The joint hypothesis that b_2 and b_3 are zero is also tested, but the hypothesis is rejected for all sectors except for utilities. This suggests that, in addition to a shift premium, there are additional costs for utilising capital and labour at a higher rate.

To sum up, when the model is estimated under the assumption of constant utilisation of capital and labour, there is evidence of increasing returns of scale, suggesting that the cyclical variation in the Solow residual is mainly driven by scale effects. When controlling for variation in utilisation, the evidence of increasing returns to scale disappears. This is a finding that appears to be robust across industries, with utilities being the main exception.

6.2 Non-zero adjustment costs

Next, we proceed with the regression equation which allows for effects of capital adjustment costs, as shown in Table C. In these regressions, the dependent variable in regression equation **(6.1)** is the growth rate of market output plus the growth rate of services provided internally to install new capital.

Column 1 shows the benchmark regression where we assume constant utilisation of factor inputs. We now get a higher estimate of the returns-to-scale parameter in most of the sectors compared to the baseline regression in Table B. This reflects the fact that allowing for capital adjustment costs tends to make measured output growth more procyclical, as investment growth tends to be procyclical.

Column 2 shows the results when controlling for variable utilisation. As expected, the increased cyclicality in measured output results in a higher estimate of the coefficient on in the growth rate of hours (b_1) in most sectors. The coefficient on the ratio of material inputs to capital services (b_2) remains largely unchanged compared to the baseline case reported in Table B. The coefficient on the investment to capital ratio (b_3) is only significant in two sectors (manufacturing and transportation), where it takes the opposite signs. We also test the restriction that $b_1=b_2=b_3=0$ but reject it in all sectors except for utilities. Thus, although the results differ slightly compared to the case without capital adjustment costs, we find that the main result, that utilisation matters in all sectors except for utilities, holds across the two different specifications of the model.

The model is also estimated under the alternative specification that the only cost of utilising capital at a higher rate is the shift premium that needs to be paid to workers, reported in Column 3. That is, the restriction that b_2 and b_3 in **(6.1)** are both zero is imposed. Once again, the hypothesis is rejected for all sectors except for utilities.

Turning to the returns-to-scale parameter, we find that when controlling for variable utilisation, the hypothesis of constant returns to scale cannot be rejected for any of the sectors except for transportation. This result is robust across different specifications of the model for all sectors except for manufacturing. The final regression specification, used to obtain a series for aggregate TFP growth (discussed in Section 7 below), therefore imposes the assumption of constant returns to scale for four sectors but allows for non-constant returns to scale for manufacturing and transportation.

6.3 Final regression equation

The regression results from the final regression equation, used to get an estimate of aggregate TFP growth, are reported in Table D. The point estimate of b_1 suggests that the impact of hours on utilisation is particularly strong; it implies that a 1% increase in hours per worker is followed by a greater than 1% increase in utilisation in all sectors except for utilities. As discussed by Basu and Kimball (1997), this reflects the impact of hours on *both* labour and capital utilisation, and it is not possible to identify these effects separately. The estimates of b_2 are positive and significant for most sectors, suggesting that a percentage increase in the ratio of material inputs to capital is accompanied by an increase in capital utilisation of 0.05 to 0.1%. By contrast, the estimates of b_3 provide little support for a link between the investment to capital ratios and utilisation. We reject the joint hypothesis that b_1=b_2=b_3=0 for all sectors, and the joint hypothesis that b_2=b_3=0 is rejected for all sectors except for utilities. Together, this gives evidence that variable utilisation of both capital and labour matter, so that ignoring such effects would bias the measure of productivity growth.

Turning to the elasticity-of-scale parameter, we find that it is close to one in manufacturing, and smaller than one in the transportation sector. Recall that this parameter is equal to the markup of prices over marginal cost, under the zero-profit condition imposed on our data set. The results thus suggest that the markup has, on average, been negative in the transportation sector.

Table E summarises the estimates of TFP growth obtained at the industry level, based on the regression results reported in Table D. TFP growth has, on average, been higher than the Solow residual in all industries except for manufacturing. The impact of non-technological factors on the Solow residual is particularly large in the transportation industries (reflecting positive scale effects) the distribution industries (reflecting negative utilisation effects), and the communication, finance and business services industries (reflecting utilisation and adjustment cost effects). In around one half of the industries, the TFP growth is more volatile than the Solow residual, while the opposite is true for the other half. As expected, TFP growth is less correlated with GDP growth than the Solow residual in most industries.

7 Aggregate productivity and the aggregate Solow residual

The analysis so far has produced estimates of TFP growth at the individual industry level. But we are also interested in explaining movements in aggregate productivity growth, to be able to compare this with the aggregate Solow residual. (9) One issue is that the aggregate analysis is performed in terms of value added, while the industry analysis is done for gross output. To obtain a measure of aggregate TFP growth, we need to relate industry gross output growth to the growth rate of industry value added, and value added growth is thereafter aggregated over industries to obtain a measure of aggregate TFP growth that, in turn, can be related to the aggregate Solow residual.

7.1 Aggregating over industries

Value added is defined, in nominal terms, as the difference between nominal gross output and the nominal value of intermediate inputs. As shown in Appendix D, differentiating nominal value added, the following expression for the growth rate of constant price value added for industry *i*, dv_i, is obtained,

$$dv_i = dy_i - \frac{s_{M_i}}{1 - s_{M_i}}\left(dm_i - dy_i\right) \qquad \textbf{(7.1)}$$

From **(2.4)**, **(2.5)** and **(2.6)**, it follows that the growth rate of gross output can be expressed as

$$dy_i = \mu_i\,(dx_i^s + du_i) - \phi_i\,di_i + dz_i \qquad \textbf{(7.2)}$$

where dx_i^s is a weighted measure of input growth, where the weights are given by the income shares, and where we have suppressed subindex *j* on capital. Substituting the above equation for gross output growth into **(7.1)**, we obtain

$$dv_i = \mu_i^v dx_i^v + du_i^v - da_i^v + dz_i^v + \left(\mu_i^v - 1\right)\frac{s_{M_i}}{1 - s_{M_i}}\left(dm_i - dy_i\right) \qquad \textbf{(7.3)}$$

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(9) Even in the absence of variable utilisation, capital adjustment costs, or non-constant returns to scale, the Solow residual may be a biased estimator of aggregate TFP growth. The reason for this is that the aggregate Solow residual is obtained using aggregate data on output and input growth. Alternatively, one could generate a measure of the aggregate Solow residual by weighing industry level Solow residuals appropriately. The two aggregate measures may not coincide if there are differing returns to scale across industries, or heterogeneity across industries in the marginal products of identical factor inputs.

where μ^v is the markup in terms of value added, and

$$dx^v = \frac{s_L}{1-s_M}dl + \frac{s_K}{1-s_M}dk\,, \quad du^v = \frac{\mu^v}{1-s_M}du\,, \quad da^v = \frac{1}{1-\mu s_M}\phi di\,, \quad dz^v = \frac{1}{1-\mu s_M}dz$$

(industry subscript *i* has been suppressed in the above definitions). Expression **(7.3)** states that in the presence of non-constant returns to scale, value added growth is not only a function of primary input growth, utilisation growth, adjustment costs and technological change, unless intermediate input and gross output grow at the same rate. The reason for this is that value added growth is computed by subtracting intermediate input growth from gross output growth using income shares (equation **(7.1)**). In the case of constant returns to scale, the income share of intermediate inputs is equal to the output elasticity with respect to intermediate inputs. However, with non-constant returns to scale, the productive contribution of intermediate inputs exceeds the income share. Thus, there is an additional part of the contribution of intermediate inputs that should be subtracted from gross output growth. This explains the last term in **(7.3)**.

Aggregate value added growth, dv^A, is computed as a Divisia index of industry value added growth rates, that is

$$dv^A = \sum_i w_i dv_i \qquad \textbf{(7.4)}$$

where w_i is the value added weight of industry *i*, defined as the nominal value added of industry *i*, pv_i, divided by aggregate nominal value added, pv^A. Substituting **(7.3)** in **(7.4)** we get,

$$dv^A = \sum_i \mu_i^v dx_i^v + du^A - da^A + dz^A + \sum_i w_i\left(\mu_i^v - 1\right)\frac{s_{M_i}}{1-s_{M_i}}\left(dm_i - dy_i\right) \qquad \textbf{(7.5)}$$

where μ^v is the markup in terms of value added and where

$$du^A = \sum_i w_i du_i^v\,, \quad da^A = \sum_i w_i da_i^v\,, \quad dz^A = \sum_i w_i dz_i^v$$

Next, we define the aggregate Solow residual, dp^A, as the difference between the growth rate of aggregate value added and the growth rate of aggregate inputs. Appendix D shows that the growth rate of aggregate inputs can be expressed as a weighted average of input growth at the industry level, plus a term which captures how input prices at the industry level deviates from the average price (due to, for example, differences in returns to scale). By combining this with equation **(7.5)**, we obtain an expression that relates the aggregate Solow residual, dp^A, to aggregate TFP growth, dz^A, in the following way,

$$dp^A = \Gamma^A + R^A + du^A - da^A + dz^A \qquad \textbf{(7.6)}$$

where

$$\Gamma^{A} = (\bar{\mu}-1)\sum_{i} w_i dx_i^{v} + w_i^{v}\sum_{i}\left(\mu_i^{v}-\bar{\mu}\right)dx_i^{v} + \sum_{i}\left(\mu_i^{v}-1\right)\frac{s_{M_i}}{1-s_{M_i}}\left(dm_i - dy_i\right) \qquad \textbf{(7.7)}$$

and

$$R^{A} = \sum_{i} w_i s_{K_i}\left(\frac{P_{Ki}-P_K}{P_{Ki}}\right)dk_i + R_L^{A} = \sum_{i} w_i s_{L_i}\left(\frac{P_{L_i}-P_L}{P_{L_i}}\right)dl_i \qquad \textbf{(7.8)}$$

where $\bar{\mu}$ is defined as the average markup. The first term on the right-hand side of expression **(7.6)** captures the contribution of imperfect competition and non-constant returns to scale to the bias in the Solow residual. It is composed of three effects: first, with increasing returns to scale, a given growth rate of the inputs will result in a more than proportional growth in output. Second, when resources are being reallocated between industries with different market power or returns to scale, there is a reallocation effect which needs to be taken into account. The reallocation effect is positive if there is a comovement between industry market power and industry input growth. Third, one needs to take into account the contribution of material inputs to output growth when calculating value added growth in the presence of non-constant returns to scale.

The second term in **(7.6)** captures a reallocation effect that does not depend on market structure. That is, it can be different from zero even in the case of perfect competition. It reflects the impact on the Solow residual of a reallocation of inputs across sectors with different marginal values; Failure in factor mobility, adjustment costs and other institutional factors may cause wages and the cost of capital to differ across sectors. In such circumstances, a shift of primary inputs towards sectors with above average marginal values will cause a boost in measured productivity, not related to technical change. This effect will bias the estimate of productivity growth whenever TFP growth is estimated using aggregate data, rather than using a bottom-up approach.

The next two terms in **(7.6)** capture the bias in the Solow residual which results when variable input utilisation and adjustment costs are not taken into account. An increase in input utilisation will increase output and, consequently, causes a higher measured productivity growth. In turn, when investment is growing, the Solow residual will underestimate productivity growth due to capital adjustment costs. These terms thus enter the expression for aggregate TFP growth with opposite signs.

7.2 Aggregate results

Table F decomposes the aggregate Solow residual into the components discussed above; returns to scale utilisation, capital adjustment costs, reallocation effects, and TFP growth. The Solow residual is here computed using aggregate data, using both non-quality and quality-adjusted labour input, and the information is presented in five-year period averages. The first half of Table F shows the growth rates of value added and factor inputs and calculates the Solow residual as the growth rate of value added minus factor inputs. The bottom half of the table shows the non-technological factors that contribute to the Solow residual, and the bottom line shows the estimate of TFP growth, controlling for these factors. The Solow residual is defined according to **(7.6)**, that is, it equals TFP growth plus scale, utilisation and reallocation effects, minus capital adjustment costs.

The scale effect has, on average, been negative, mainly reflecting decreasing returns to scale in the transportation sector. The impact of utilisation exhibits a procyclical pattern, at least up until the second half of the 1990s. Resources were heavily utilised during the late 1980s, so the contribution to the Solow residual was positive during this period. By contrast, utilisation rates fell throughout the 1990s, and this had a negative contribution to measured productivity. The sectoral results, represented in Table G, show that the utilisation effect is small in utilities and manufacturing industries, but has a large cyclical impact on the Solow residual in the other sectors. The adjustment cost effect is also cyclical, since investment tends to be cyclical. In particular, investment grew rapidly during the second half of the 1980s and the second half of the 1990s. Capital adjustment costs therefore had a negative contribution to the Solow residual during these periods. The impact is especially large for services – a sector with surging investment rates during the second half of the 1990s. Finally, the reallocation effect has, on average, been positive, reflecting a reallocation of resources towards industries with higher marginal products.

The fall in utilisation intensity of inputs during the second half of the 1990s, a period of strong growth in output, is puzzling. It contrasts with the US experience of an increase in utilisation during the same period, as discussed by Basu *et al* (2001). The UK experience is partially explained by a decline in observed hours per worker since around 1997, whereas hours were broadly flat for the United States. [10] A possible explanation for this is that the hours per head series (detrended full-time male hours per head) does not fully isolate the cyclical component from the trend, where the trend is driven by institutional factors that cause a downward trend in hours per head throughout the period. It is worth noticing that in the United States, average hours trended downwards until around 1990, when the trend flattened. Another explanation for this puzzle is that hours may not be a good proxy for effort during the late 1990s; firms may have used other ways of increasing labour input. We find, however, that the fall in utilisation is not only driven by a fall in hours per head. As shown in Chart 3, the ratio of material to capital expenditure exhibit a downward trend since around 1992. Since the fall in utilisation is driven by both hours and material inputs, it appears to be robust across alternative specifications of the model, that only use average hours as a proxy for utilisation, or that assumes that only capital is costly to utilise. Moreover, the fall in utilisation also appears to be consistent with survey-based measures of utilisation available for the United Kingdom, that suggest that capital utilisation fell from around 1995 to around 1999. [11]

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[10] This is discussed by Basu *et al* (2001), who use data on average weekly hours of production workers.
[11] In the CBI survey of manufacturing, the percentage of firms that reported that they were operating at full capacity fell from 52% in 1995 to 38% in 1999. The BCC (British Chamber of Commerce) survey of manufacturing and services shows that the percentage of manufacturing firms that were operating at full capacity fell from 38% in 1995 to 34% in 1999. For services, utilisation peaked somewhat later, and the percentage fell from 43% in 1996 to 38% in 1999.

Returning to Table F, the results suggest that the (labour-quality adjusted) Solow residual underestimates TFP growth throughout the 1990s. During the first half of the decade, input utilisation fell, as expected in a period of economic recession, and this had a large negative contribution to the Solow residual. This was only partly offset by the positive contribution of capital adjustment costs, while the net contribution of scale and reallocation effects was close to zero. Altogether, the Solow residual therefore underestimates productivity growth by around 0.6 percentage points during this period. The contribution by utilisation was still negative in the second half of the 1990s, but the impact was smaller compared to the early 1990s. Capital adjustment costs also had a negative contribution, since investment grew rapidly. Altogether this means that the underestimate of the Solow residual was roughly the same as during the first half of the 1990s, or around 0.7 percentage points. The net impact on the slowdown in productivity growth is therefore small. Thus, the finding that UK productivity growth fell in the late 1990s appears not to be driven by non-technological factors such as variable utilisation or capital adjustment costs, but instead reflects a fall in the growth rate of underlying TFP growth. The level of TFP growth, however, is affected by the presence of non-technological factors throughout the 1990s.

7.3 Sectoral results

Table G presents the Solow residual decomposition by sector both excluding and including the adjustment for labour quality. Here we focus on the labour-quality adjusted series. First, non-technological factors have had a sizable contribution to the Solow residual in all sectors. Second, TFP growth has, on average, been higher than the Solow residual in all sectors except for mining and oil and manufacturing. The impact of non-technological factors has been especially large in the transportation sector, mainly driven by the estimates of decreasing returns to scale. Other sectors with a large impact are the construction and distribution sector and other market services, where the utilisation and adjustment cost effects have been large. Third, input utilisation fell during the second half of the 1990s in all sectors apart from mining and oil and manufacturing. The fall was, however, smaller than that which took place during the recession years of the early 1990s.

In three sectors (mining and oil; manufacturing; construction and distribution), TFP growth decreased in the second half of the 1990s. That is, for these sectors, the observed slowdown in the Solow residual is not only explained by non-technological factors, but also by a decline in productivity growth. Table H shows an industry breakdown of TFP growth and the Solow residual, for the periods 1990-95 and 1995-2000, and the acceleration in TFP between these periods. Within the manufacturing sector, the ICT-producing industry electrical engineering and electronics saw a sharp rise in TFP growth between the first and the second half of the 1990s. The distribution industries (retail and wholesale trade) also experienced a rise in TFP growth over this period.

Three sectors (utilities; transport services; other markets services) experienced an increase in TFP growth over the same period. For utilities, the strong growth performance almost entirely reflects large estimates of the Solow residual. This may reflect the privatisation of utilities that took place during the 1980s; a number of studies show that labour productivity rose sharply following the privatisation of this sector. [12] The strong performance of the transport sector, driven by rail transportations and communications, may be surprising. We find that TFP growth in that sector is mainly driven by large estimates of the Solow residual, and decreasing returns to scale. The large Solow residual can partly be explained by low growth rates in capital inputs. Within the services sector, there was a broad-based rise in TFP growth in all industries, especially pronounced in finance and business services.

Previous work showed that the US experience of an acceleration in the level of TFP between the first and the second half of the 1990s was, to a large extent, driven by strong growth in ICT-producing industries as well as in wholesale and retail trade, finance and insurance (Basu *et al* (2004)). Table H shows a similar picture for the United Kingdom. In particular, TFP accelerated in the ICT-producing industry (electrical engineering and electronics) as well as in retail and wholesale trade, communications, and the service industries. One difference, however, is that in the United States, durables manufacturing industries as a whole contributed strongly to the pickup in productivity growth. By contrast, the UK estimates suggest that most durables industries (with the exception of electrical engineering and electronics) saw a deceleration in TFP over the same periods. The results thus suggest that the acceleration in US TFP appears to have been more broad-based across manufacturing industries for the United States than for the United Kingdom, and this partly explains the difference in aggregate data. [13]

Table I summarises some statistics for the Solow residual and the TFP estimate for the whole period. As has been mentioned before, average yearly TFP growth is higher than the Solow residual for the aggregate non-farm private sector and for services. However, for manufacturing industries, the Solow residual has been an unbiased estimator of technological progress during the period considered. The volatility of TFP growth is similar to that of the Solow residual. This is a somewhat surprising result since, by controlling for variable utilisation and capital adjustment costs, we expect to reduce the cyclical movements in measured productivity. To a large extent, this can be explained by the data used to measure unobservable movements in utilisation, which tends to be quite volatile (especially the data on hours). Finally, the last column of Table I shows the correlation coefficients with GDP growth, included to analyse the cyclical pattern of productivity growth. The comovement with aggregate output is close to zero for the TFP estimate, while it is around 0.6 for the aggregate Solow residual. In turn, both measured utilisation and the impact of adjustment costs on productivity growth show a procyclical pattern that is more prominent for the case of utilisation.

Finally, the main result, that there was a slowdown in TFP growth during the second half of the 1990s relative to the United States and that utilisation fell throughout the 1990s, appear to be robust across alternative specifications within the class of models that we consider here. In particular,

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[12] See eg Card and Freeman (2002).
[13] Note, however, that TFP growth has been high in the UK manufacturing sector in the past. Over the period 1970-95, TFP grew by an average of 2.8% per year (see Table G).

alternative set-ups where the sole cost of more intense utilisation of inputs is a shift premium, and where variable depreciation only applies to plant and vehicles and not to buildings, are considered.

8 Conclusions

In this paper we try to account for non-technological factors, such as variable utilisation and adjustment costs, to explain the movements in measured TFP growth for the United Kingdom, with focus on the 1990s. The results show a significant role for variable input utilisation and capital adjustment costs in explaining sectoral gross output growth.

Standard estimates of aggregate productivity growth show a decline in measured productivity growth during the second half of the 1990s, compared to the first half. By accounting for non-technological factors, we find that the aggregate Solow residual underestimates underlying technological progress, or TFP growth, throughout the 1990s, but the net impact on TFP acceleration is small. By contrast, Basu *et al* (2001) show that, for the United States, the productivity acceleration was even more pronounced when adjusting for non-technological factors that may affect measured productivity growth. Thus, the broad movement in the Solow residual between the first and the second half of the 1990s is similar to that of the estimated TFP growth, implying that the United Kingdom's TFP performance continues to fall short of that of the United States.

The results suggest that utilisation rates fell during the second half of the 1990s, despite strong growth rates in output. Although puzzling, this result is robust across different specifications of the model and captures falling utilisation rates of both capital and labour.

At the sectoral level, we find that the lack of an increase in aggregate TFP growth during the 1990s mainly reflected falling growth rates in three sectors; mining and oil; construction and distribution, and manufacturing. By contrast, utilities, transport services and other market services saw a rise in TFP growth between the first and the second half of the 1990s. At the industry level, a number of industries saw rising growth rates, such as electrical engineering and electronics, the distribution industries, rail transportation and telecommunications, and finance and business services. We find, however, that the TFP acceleration appears to have been less widespread across industries in the United Kingdom compared to the United States.

Appendix A: Derive steady-state elasticities and express utilisation in terms of observable variables

Steady-state elasticities

Consider a representative firm that solves the following dynamic cost minimisation problem where time subscript has been suppressed whenever possible:

$$\underset{H,E,M,S_j,I_j,R}{Min} E_t\left[\sum_{\tau=0}^{\infty}\beta^{\tau}\left(wNG(E,H)V(S_j)+P_M M+P_{I_j}I\right)\right]$$

subject to:

$$\overline{Y}=F\left(S_jK_j,NHE,M,Z\right)\left(1-\Psi\left(\frac{R}{N}\right)\right)\prod_j\left(1-\Phi^j\left(\frac{I_j}{K_j}\right)\right) \quad \textbf{(A.1)}$$

$$K_j^{'}=\left(1-\delta_j(S_j)\right)K_j+I_j$$

$$N^{'}=N+R$$

for $j=ict,non$, where $X^{'}$ denotes the period t+1 value of variable X. The first-order conditions for the minimisation problem are given by the following equations,

(S_j): $\lambda F_{K_j}K_jY/F=q_j\delta'\left(S_j\right)K_j+wNGV'\left(S_j\right)$ **(A.2)**

(E): $\lambda YF_LHN/F=wNG_EV(S)$ **(A.3)**

(H): $\lambda YF_LEN/F=wNG_HV(S)$ **(A.4)**

(M): $\lambda YF_M\ /F=P_M$ **(A.5)**

(I_j): $P_{I_j}+\frac{\lambda Y}{K_j}\frac{\Phi'_j}{1-\Phi_j}=q_j$ **(A.6)**

(R): $\frac{\lambda Y}{N}\frac{\Psi'_{R/N}}{1-\Psi}=-\theta$

where λ is the Lagrange multiplier for gross output, and where $\delta'\left(S_j\right)$ denotes the derivative of the depreciation rate of capital of type *j* with respect to the utilisation rate of capital of type *j* (assumed to be zero for ICT capital), and $V'\left(S_j\right)$ is the derivative of the shift premium with respect to capital of type *j*.

The Euler equations for capital and employment are:

$$-\frac{\lambda S_jF_{K_j}Y}{F}-\lambda\frac{I_jY}{K_j^2}\frac{\Phi'_j}{1-\Phi_j}=\left(1-\delta_j\right)q_j-\beta^{-1}q_{jt-1} \quad \textbf{(A.7)}$$

for *j*=*ict*,*non*, and

$$-\frac{\lambda EHF_L Y}{F}-\lambda\frac{RY}{N^2}\frac{\Psi'}{1-\Psi}+wGV=\theta-\theta_{t-1}\beta^{-1} \qquad \textbf{(A.8)}$$

where the time subscript on all period *t* variables has been suppressed. In the equations above, q_j is the Lagrange multiplier for capital of type *j*, and θ is the multiplier for the number employed. The Lagrange multiplier for gross output, λ, can be interpreted as the marginal cost. By using this we can rewrite **(A.7)** as:

$$-\frac{pY}{\mu}\frac{F_J S}{F}-\frac{pY}{\mu}\frac{\phi_j}{K_j}=q_j\left(1-\delta_j\right)-q_{jt-1}\left(1+r\right) \qquad \textbf{(A.9)}$$

where μ is the markup of the price over marginal costs. Now solving **(A.9)** for the steady state and multiplying through by K_j, we obtain

$$\frac{pY}{\mu}\frac{F_J SK_j}{F}+\frac{pY}{\mu}\phi_j=q\left(\delta_j+r\right)K_j$$

From this follows that the steady-state elasticity with respect to type *j* capital is given by:

$$\left[\frac{F_J SK_j}{F}\right]^*=\mu^*\left(\frac{q_j\left(\delta_j+r\right)K_j}{pY}\right)^*-\phi_j^*=\mu^* s_{K_j}^*-\phi_j^* \qquad \textbf{(A.10)}$$

Performing a similar manipulation to the Euler equation for employment and solving it for steady state, we get that steady-state elasticity with respect to employment results in:

$$\left[\frac{F_L(EHN)}{F}\right]^*=\mu^* s_L^*-\psi^*+r^*\left(\frac{\psi N}{R}\right)^* \qquad \textbf{(A.11)}$$

Expressing effort in terms of observable variables

In order to express effort in terms of observed variables, we use the first-order conditions for effort **(A.3)** and for hours **(A. 4)**. By combining these expressions, we obtain that the elasticity of labour costs with respect to hours is equal to the elasticity of labour cost with respect to effort:

$$\frac{HG_H}{G}=\frac{EG_E}{G} \qquad \textbf{(A.12)}$$

The elasticity of labour costs with respect to hours and effort must be equal, since at the benefit side, the elasticities are equal. This further implies that there is a unique relation between hours and effort, since when the firm expands hours it also expands effort. Therefore, we can express effort as an increasing function of hours:

$$E=E(H) \quad \text{with} \quad E'(H)>0$$

Log-linearising the above expression, we get:

$$de=\frac{E'(H)H}{E(H)}dh=\zeta\, dh \qquad \textbf{(A.13)}$$

where ζ is the elasticity of effort with respect to hours.

Expressing capital utilisation in terms of observable variables

To find a proxy for capital utilisation, first consider equation **(A.2)** that can be rewritten as:

$$\frac{F_{K_j}K_j}{F}=\frac{q_j\delta'(S_j)K_j}{\lambda Y}+\frac{wNGV'(S_j)}{\lambda Y} \qquad \textbf{(A.14)}$$

Substituting λY from equation **(A.5)**, we obtain

$$\frac{F_{K_j}K_j}{F}=\frac{F_M M}{P_m MF}q_j\delta'(S_j)K_j+\frac{wNGV'(S_j)}{\lambda Y} \qquad \textbf{(A.15)}$$

Next, combine with equation **(A.4)** to obtain

$$\frac{F_{K_j}S_jK_j}{S_jF}=\frac{F_M M}{P_m MF}q_j\delta'(S_j)K_j+\frac{F_L ENH}{F}\frac{G}{G_H H}\frac{V'(S_j)}{V(S_j)} \qquad \textbf{(A.16)}$$

Let α_x denote the elasticity of F with respect to factor input X (X=K,L,M). Expression **(A.16)** can now be simplified to

$$1=\frac{\alpha_m}{\alpha_{k_j}}\frac{S_j}{P_m M}q_j\delta'(S_j)K_j+\frac{\alpha_l}{\alpha_{k_j}}\frac{G}{G_H H}\frac{V'(S_j)S_j}{V(S_j)} \qquad \textbf{(A.17)}$$

where we note that the first term on the right-hand side is zero for *j=ict.* Also, from the Cobb-Douglas assumption, it follows that the ratios α_m/α_{k_j} and α_l/α_{k_j} are constant and proportional to the respective factor cost shares (see Basu *et al* (2001)).

We can now combine equation **(A.5)** and **(A.6)** to obtain the following expression for the shadow value of capital,

$$q_j=P_{I_j}+\frac{P_m M}{\alpha_m}\frac{\phi_j}{I_j} \qquad \textbf{(A.18)}$$

This equation can be combined with **(A.17)** to obtain the following expressions for *j=non*, *ict*,

$$\frac{\alpha_{k_{ict}}}{v(S_{ict})}=\frac{\alpha_l}{g(H)} \qquad \textbf{(A.19)}$$

and

$$\frac{\alpha_{k_{non}}}{v(S_{non})} = \frac{\alpha_l}{g(H)} + \frac{\alpha_m}{v(S_{non})} \frac{P_{I_{non}} K_{non}}{P_m M} \delta'(S_{non}) S_{non} + \phi_j \frac{\delta'(S_{non}) S_{non}}{v(S_{non})} \frac{K_{non}}{I_j} \quad \textbf{(A.20)}$$

where

$$v(S_j) = \frac{V'(S_j)}{V(S_j)} S_j \text{ and } g(H) = \frac{G_H}{G} H$$

For ICT capital, the cost of increasing capital utilisation is an increase in the shift premium. Equation **(A.19)** therefore states that the output elasticity with respect to ICT capital, divided by the elasticity of costs with respect to an increase in the utilisation of capital (given by the elasticity of the shift premium with respect to utilisation), equals the output elasticity with respect to labour, divided by the elasticity of the cost of increasing labour (the elasticity of the wage rate with respect to hours). For non-ICT capital, depreciation is also affected by utilisation, captured by the two additional terms in **(A.20)**.

Before log-linearising **(A.20)**, following Basu and Kimball (1997), we define the following steady-state elasticities, where the steady-state value of a variable is denoted by an asterisk,

$$\xi_j = \frac{\alpha_l}{\alpha_{k_j}} \frac{v(S_j^*)}{g(H^{*})}, \qquad \eta = \frac{g'(H^*)}{g(H^*)} H^*, \qquad \nu_j = \frac{v'(S_j^*)}{v(S_j^*)} S_j^*,$$

$$\Delta_j = \frac{\delta''(S_j^*)}{\delta'(S_j^*)} S_j^*, \qquad \text{and } \Theta_j = \phi_j \frac{\delta'(S_j^*) S_j^*}{\delta^* \alpha_{k_j}}$$

where we note that, from **(A.19)**, ξ_{ict} is equal to one. Next, log-linearise **(A.19)** and **(A.20)** for non-ICT and ICT capital, using the above definitions, to get,

$$\xi_{non}\eta dh - \xi_{non}\nu_{non} ds_{non} = (1 - \xi_{non} - \Theta_{non})(dp_{non} + dk_{non} - dp_m - dm) - \Theta_{non}\left(1 - \frac{\phi'_{non} I_{non}}{\phi_{non} K_{non}}\right)^* (di_{non} - dk_{non}) + (1 - \xi_{non})(1 + \Delta_{non}) ds_{non} \quad \textbf{(A.21)}$$

where ϕ'_{non} denotes the derivative of ϕ_{non} with respect to the investment to capital ratio, evaluated at the steady state, and

$$\eta dh - \nu_{ict} ds_{ict} = 0 \quad \textbf{(A.22)}$$

Collecting terms for *ds* in **(A.21)** and **(A.22)**, we have:

$$ds_{non} = \frac{1}{(1 - \xi_{non})(1 + \Delta_{non}) + \xi_{non}\nu_{non}} \begin{bmatrix} \xi_{non}\eta dh + (1 - \xi_{non} - \Pi_{non})(dp_m + dm - dp_{non} - dk_{non}) + \\ + \Theta_{non}\left(1 - \left(\frac{\phi'_{non} I_{non}}{\phi_{non} K_{non}}\right)^*\right)(di_{non} - dk_{non}) \end{bmatrix} \quad \textbf{(A.23)}$$

$$ds_{ict} = \frac{\eta}{\nu_{ict}} dh \qquad \textbf{(A.24)}$$

The coefficient in front of *dh* is positive in both expressions. The coefficient in front of $dp_m + dm - dp_{non} - dk_{non}$ is also positive since equation **(A.20)** implies that, in steady state,

$$1 - \xi_j - \Theta_{non} = \frac{\alpha_m}{\alpha_{k_{non}}} \frac{P_{I_{non}} K_{non}}{P_m M} \delta'(S_{non}) S_{non}$$

which is positive. Finally, the sign of the coefficient in front of $di_{non} - dk_{non}$ is ambiguous. In general, however, it tends to be positive. The reason for this is that the investment to capital ratio in non-ICT capital is small, on average around 0.10 to 0.15.

Expressing utilisation in terms of observable variables

Finally, substituting **(A.13)**, **(A.23)** and **(A.24)** into the term

$$du = \sum_j (c^*_{K_j} - \frac{\phi^*_j}{\gamma^*}) ds_j + \left[c^*_L - \frac{\psi^*}{\gamma^*} + r^* (\frac{\Psi N}{R\gamma})^* \right] de \qquad \textbf{(A.25)}$$

in equation **(3.5)**, we get that input utilisation growth can be expressed as:

$$du = \frac{(c^*_{K_{non}} - \frac{\phi^*_{non}}{\gamma^*})(1 - \xi_{non} - \Pi_{non})}{(1 - \xi_{non})(1 + \Delta_{non}) + \xi_{non}\nu_{non}} \left(dp_m + dm - dp_{non} + dk_{non} \right)$$

$$+ \frac{(c^*_{K_{non}} - \frac{\phi^*_{non}}{\gamma^*}) \left(1 - \left(\frac{\phi'_{non} I_{non}}{\phi_{non} K_{non}} \right)^* \right)}{(1 - \xi_{non})(1 + \Delta_{non}) + \xi_{non}\nu_{non}} \left(di_{non} - dk_{non} \right) \qquad \textbf{(A.26)}$$

$$+ \left[\frac{(c^*_{K_{non}} - \frac{\phi^*_{non}}{\gamma^*}) \xi_{non} \eta}{(1 - \xi_{non})(1 + \Delta_{non}) + \xi_{non}\nu_{non}} + \frac{c^*_{K_{ict}} - \frac{\phi^*_{ict}}{\gamma^*}}{\nu_{ict}} + \left(c^*_L - \frac{\psi^*}{\gamma^*} + (\frac{r\Psi N}{R\gamma})^* \right) \zeta \right] dh$$

Collecting terms and simplifying notation, we get expression **(3.7)** of the main text:

$$du = \beta_1 dh + \beta_2 \left(dp_m + dm - dp_{non} - dk_{non} \right) + \beta_3 \left(di_{non} - dk_{non} \right) \qquad \textbf{(A.27)}$$

Returning to **(A.25)**, it follows from **(3.6)** that the coefficient in front of *ds* can be expressed as

$$\frac{1}{\gamma^*}\left(\gamma^* c^*_{K_j} - \phi^*_j\right) = \frac{1}{\gamma^*}\left(\mu^* s^*_{K_j} - \phi^*_j\right)$$

which is positive, since it equals $1/\gamma^*$ times the elasticity of output with respect to capital. Also, the term in front of *de* in **(A.26)** can be expressed as

$$\frac{1}{\gamma^*}\left[\mu^* s^*_L - \psi^* + r^* (\frac{\Psi N}{R})^*\right]$$

which is positive, since the term within brackets is the elasticity of market output with respect to labour. From this follows that β_1 and β_2 are positive, and β_3 is either positive or negative.

Appendix B: Relating the elasticity of the adjustment costs function with respect to investment to the elasticity of cost function with respect to investment

For simplicity, assume a production on the following general form, $Y = F(K, L, M, I, Z)$. Log-linearising this expression yields

$$dz = dy - \left(\frac{F_L L}{F} dl + \frac{F_M M}{F} dm + \frac{F_K K}{F} dk \right) - \phi_y di$$

where ϕ_y is the elasticity of output with respect to investment, equal to the negative of the elasticity of the adjustment cost function with respect to investment. The expression can be rewritten in terms of cost shares,

$$dz = dy - \gamma \left(\frac{P_l L}{C} dl + \frac{P_m M}{C} dm + \frac{P_k K}{C} dk \right) - \phi_y di \qquad \textbf{(B.1)}$$

where γ is the returns-to-scale parameter. It can be shown that, in a long-run equilibrium, the returns-to-scale parameter equals the inverse of the variable cost function with respect to output (Caves *et al* (1981)).

An expression for total factor productivity growth can also be derived from the dual cost side. The variable cost function can be expressed as $C(P_L, P_M, Y, K, I, T) = P_L L + P_M M$, where T denotes time. By totally differentiating this expression around a stationary equilibrium, and using Shephard's lemma together with the result that, in a long-run equilibrium, the elasticity of the cost function with respect to output equals γ^{-1}, the following expression is obtained,

$$-\gamma \frac{\partial C}{\partial T} \frac{1}{C} = dy - \gamma \left(\frac{P_L L}{C} dl + \frac{P_M M}{C} dm + \frac{P_K K}{C} dk \right) + \gamma \phi_c di \qquad \textbf{(B.2)}$$

where ϕ_c is the elasticity of the variable cost function with respect to investment. Caves *et al* (1981) further show that the dual measures of productivity are related according to

$$dz = -\gamma \frac{\partial C}{\partial T} \frac{1}{C}$$

where dz is defined by **(B.1)**. Using this together with **(B.2)**, we obtain the following relation,

$$\phi_y = -\phi_c \left(\frac{\partial \log C}{\partial \log Y} \right)^{-1}$$

Appendix C: Data on hours per head and aggregate investment

Hours per head

The data for hours per head is combined from two sources: the New Earnings Survey (NES)[14] and the Labour Force Survey (LFS). Both surveys are carried out by the Office for National Statistics. The NES is an annual employer-based survey of earnings (and hours) from which we derive the hours per worker, by industry. The LFS is a survey of households containing information on the UK labour market for variables such as individual and household characteristics and work characteristics such as hours worked (including actual, usual, overtime hours). For the period 1971 to 1986, the NES data on normal hours is combined with the LFS data that includes overtime hours. The LFS has data on hours by gender, and for employees and self-employed and for part-time and full-time workers, but it is available only at a higher level of aggregation (10 divisions). In order to convert NES normal hours to total hours, we therefore calculate an adjustment defined as the difference between the growth rate of weekly hours per head in the NES series and the growth rate of weekly hours per head in the LFS, and apply the adjustment derived at the higher level of aggregation to each industry that is covered by the division. The adjustment is also calculated for each type of worker. That is, taking into account that male hours per head for sector j (h_j) is a weighted average of hours per head of male full-time employees (fh_j), male part-time employees (ph_j) and male self-employed (sh_j), we obtain:

$$h_j = fh_j \cdot wf_j + ph_j \cdot wp_j + sh_j \cdot ws_j \qquad \textbf{(C.1)}$$

where wf_j, wp_j and ws_j denote the weights of male full-time employees, part-time employees and self-employed in male total employment in sector j. The growth rate in male hours per head (dh_j) for sector j is calculated as,

$$\begin{aligned} dh_j = & \frac{fh_j \cdot wf_j}{h_j}(dfh_j + adjf + dwf_j) \\ & + \frac{ph_j \cdot wp_j}{h_j}(dph_j + adjp + dwp_j) \\ & + \frac{sh_j \cdot ws_j}{h_j}(dsh_j + adjs + dws_j) \end{aligned} \qquad \textbf{(C.2)}$$

where the prefix d denotes growth rate and *adjf*, *adjp* and *adjs* denote adjustments for male full-time employees, part-time employees and male self-employed, respectively. These adjustments are calculated as the difference, at the division level (SIC 80 classification), of the growth rates of hours per head of the corresponding type of workers in LFS data and in NES data.
However, the NES data on hours per head refers to total employees, while data on full-time and part-time employees are needed for **(C.2)**. To obtain data for full-time and part-time hours, we

[14] In 2004, the NES was replaced by the Annual Survey of Hours and Earnings (ASHE).

assume that the ratio of male part-time hours to male full-time hours in the NES data is the same as the one observed in LFS data. The following equation can then be used,

$$h_j = fh_j \cdot wfh_j + fh_j \cdot \left(\frac{ph}{fh} \right)_{LFS} \cdot wph_j$$

where *h* is hours per head for male employees, *fh* is hours per head for male full-time employees, *ph* is hours per head for male part-time employees, and *wfh* and *wph* are full-time and part-time weights in total male employees. The weights have been obtained using male full-time and part-time number of employees, as reported by the Annual Business Inquiry. Moreover, self-employed figures are estimated as the difference between workforce jobs and the number of employees, but this calculation can be made only for nine broad sectors. We therefore assume that the ratio of the number of self-employed to total employment is the same for all industries classified within the same broad sector.

Appendix D: Measuring aggregate productivity growth

To obtain an estimate of aggregate technical change and relate it to the aggregate Solow residual, we first derive the relation between gross output and value added at the industry level and then aggregate industry value added.

From sectoral gross production to sectoral value added

Value added is defined, in nominal terms, as the difference between nominal gross output and nominal value of intermediate inputs. By differentiating the expression for value added, and assuming that value added deflator is constructed as a Divisia index of gross output and intermediate inputs price index, we get constant price value added growth for sector *i*

$$dv_i = \frac{dy_i - s_{M_i} dm_i}{1 - s_{M_i}} = dy_i - \frac{s_{M_i}}{1 - s_{M_i}}\left(dy_i - dm_i\right) \qquad \textbf{(D.1)}$$

From the main text, we know that after controlling for non-constant returns to scale, variable utilisation of inputs and adjustment costs, gross output growth can be expressed as,

$$dy_i = \gamma_i dx_i + \gamma_i du_i - \phi_i \, di_i + dz_i = \mu_i dx_i^s + \mu_i \, du_i - \phi_i \, di_i + dz_i \qquad \textbf{(D.2)}$$

where dx_i^s is weighted input growth, with weights being income shares, and where, for simplicity, we assume only one type of capital. By expanding dx_i^s in **(D.2)** we get,

$$dy_i = \mu_i\left(s_{K_i} dk_i + s_{L_i} dl_i\right) + \mu_i s_{M_i} + \mu_i du_i - \phi_i \, di_i + dz_i \qquad \textbf{(D.3)}$$

Subtracting $\mu_i s_{M_i} dy_i$ from both sides, and dividing and multiplying the first term of the right-hand side of **(D.3)** by $1 - s_{M_i}$, we get:

$$dy_i = \mu_i \frac{1 - s_{M_i}}{1 - \mu s_{M_i}} dx_i + \frac{\mu_i}{1 - \mu_i s_{M_i}}(dm_i - dy_i + du_i) - \frac{1}{1 - \mu_i s_{M_i}} da_i + \frac{1}{1 - \mu_i s_{M_i}} dz_i \qquad \textbf{(D.4)}$$

where $da_i = \phi_i di_i$. Defining $\mu^v = \mu\left(1 - s_M\right)/\left(1 - \mu s_M\right)$ and substituting **(D.4)** into **(D.1)**, we get

$$dv_i = \mu_i^v dx_i^v + \left(\mu_i^v - 1\right)\frac{s_{M_i}}{1 - s_{M_i}}\left(dm_i - dy_i\right) + du_i^v - da_i^v + dz_i^v \qquad \textbf{(D.5)}$$

where $dx^v = \left(s_L dl + s_K dk\right)/\left(1 - s_M\right)$ defines weighted primary input growth, with labour and capital shares expressed in terms of value added, and $du^v = \mu^v/\left(1 - s_M\right)du$, $da^v = 1/\left(1 - \mu s_M\right)\phi_i di_i$ and $dz^v = 1/\left(1 - \mu s_M\right)dz$.

From sectoral value added to aggregate value added

Aggregate value added growth is computed as a Divisia index of sectoral value added growth rates, that is

$$dv^A = \sum_i w_i dv_i \quad \textbf{(D.6)}$$

where w_i defines the industry value added shares, in nominal terms,

$$w_i = \frac{(\text{nominal})va_i}{\sum_i (\text{nominal})va_i} = \frac{pv_i}{pv^A}$$

Substituting **(D.5)** into **(D.6)**, we get,

$$dv^A = \sum w_i \mu_i^v dx_i^v + \sum_i w_i \left(\mu_i^v - 1\right) \frac{s_{M_i}}{1 - s_{M_i}} \left(dm_i - dy_i\right) + du^A - da^A + dz^A \quad \textbf{(D.7)}$$

where $du^A = \sum_i w_i du_i^v$, $da^A = \sum_i w_i da_i^v$, and $dz^A = \sum_i w_i dz_i^v$.

Next, define aggregate weighted input growth, dx^A, according to

$$dx^A = s_K^A dk^A + s_L^A dl^A = \frac{P_K K^A}{pv^A} \sum_i \frac{K_i}{K^A} dk_i + \frac{P_K L^A}{pv^A} \sum_i \frac{L_i}{L^A} dl_i \quad \textbf{(D.8)}$$

This can be rewritten as

$$dx^A = \sum_i \frac{P_{K_i} K_i}{pv^A} \frac{P_K}{P_{K_i}} dk_i + \sum_i \frac{P_{L_i} L_i}{pv^A} \frac{P_L}{P_{L_i}} dl = \sum_i w_i \frac{P_K}{P_{K_i}} s_{K_i} dk_i + \sum_i w_i \frac{P_L}{P_{L_i}} s_{L_i} dl_i \quad \textbf{(D.9)}$$

Moreover, the value-added weighted average of sectoral input growth in equation **(D.7)** satisfies

$$\sum_i w_i dx_i^v = \sum_i w_i \left(\frac{P_{K_i} K_i}{pv_i} dk_i + \frac{P_{L_i} L_i}{pv_i} dl_i \right) = \sum_i w_i \left(s_{K_i} dk_i + s_{L_i} dl_i \right) \quad \textbf{(D.10)}$$

Subtracting **(D.10)** from **(D.9)**, we get:

$$dx^A - \sum_i w_i dx_i^v = \sum_i w_i \left(s_{k_i} \frac{P_K - P_{K_i}}{P_{K_i}} dk_i + s_{l_i} \frac{P_L - P_{L_i}}{P_{L_i}} dl_i \right)$$

(D.11)

By denoting $R_K^A = \sum_i w_i s_{K_i} \left(\left(P_{Ki} - P_K\right) / P_{Ki}\right) dk_i$ and $R_L^A = \sum_i w_i s_{L_i} \left(\left(P_{L_i} - P_L\right) / P_{L_i}\right) dl_i$, expression

(D.11) can be written as:

$$dx^A = \sum_i w_i dx_i^v - R_K^A - R_L^A \quad \textbf{(D.12)}$$

Now, subtracting from both sides of **(D.7)**, dx^A , we have that aggregate Solow residual, dp^A, defined as the growth differential of aggregate value added and aggregate input, can be expressed as:

$$dp^A = dv^A - dx^A = \sum w_i \mu_i^v dx_i^v - \sum_i w_i dx_i^v + R_L^A + R_L^A + \sum_i w_i \left(\mu_i^v - 1\right) \frac{s_{M_i}}{1 - s_{M_i}} \left(dm_i - dy_i\right) + du^A - da^A + dz^A. \quad \textbf{(D.13)}$$

By defining $\bar{\mu} = \sum_i w_i \mu_i^v$ as the average markup, and by adding and subtracting $\bar{\mu} \sum_i w_i dx_i^v$ to **(D.13)**, we obtain the following expression which relates the aggregate Solow residual, dp^A, to aggregate technical change, dz^A, as follows

$$dp^A = (\bar{\mu} - 1) \sum_i w_i dx_i^v + \sum_i w_i \left(\mu_i^v - \bar{\mu}\right) dx_i^v + w_i \sum_i \left(\mu_i^v - 1\right) \frac{s_{M_i}}{1 - s_{M_i}} \left(dm_i - dy_i\right) + R_K^A + R_L^A + du^A - da^A + dz^A \quad \textbf{(D.14)}$$

Defining $R_\mu = w_i^v \sum_i \left(\mu_i^v - \bar{\mu}\right) dx_i^v$ and $M^A = \sum_i \left(\mu_i^v - 1\right) \frac{s_{M_i}}{1 - s_{M_i}} \left(dm_i - dy_i\right)$, expression **(D.14)** can be rewritten as:

$$dp^A = (\bar{\mu} - 1) \sum_i w_i dx_i^v + R_\mu + M^A + R_K^A + R_L^A + du^A - da^A + dz^A \quad \textbf{(D.15)}$$

Finally, defining $\Gamma^A = (\bar{\mu} - 1) \sum_i w_i dx_i^v + R_\mu + M^A$, and $R^A = R_K^A + R_L^A$, we get

$$dp^A = \Gamma^A + R^A + du^A - da^A + dz^A \quad \textbf{(D.16)}$$

Table A			
	Industry	**SIC 92 correspondence**	**Sector**
1	Agriculture	01,02,05	
2	Oil and gas	11,12	**1. Mining and oil (90 observations)**
3	Coal & other mining	10,13,14	
4	Manufactured fuel	23	
5	Chemicals & pharmaceuticals	24	**2. Manufacturing (300 observations)**
6	Non-metallic mineral products	26	
7	Basic metals & metal goods	27,28	
8	Mechanical engineering	29	
9	Electrical engineering & electronics	30,31,32,33	
10	Vehicles	34,35	
11	Food, drink & tobacco	15,16	
12	Textiles, clothing & leather	17,18,19	
13	Paper, printing and publishing	21,22	
14	Other manufacturing	20,25,36,37	
15	Electricity supply	40.1	**3. Utilities (90 observations)**
16	Gas supply	40.2,40.3	
17	Water supply	41	
18	Construction	45	**4. Construction, distribution, hotels and restaurants (120 observations)**
19	Wholesale, vehicle sales & repairs	50,51	
20	Retailing	52	
21	Hotels & catering	55	
22	Rail transport	60.1	**5. Transport services (150 observations)**
23	Road transport	60.2,60.3	
24	Water transport	61	
25	Air transport	62	
26	Other transport services	63	
27	Communications	64	
28	Finance	65, 66	**6. Other market services (120 observations)**
29	Business Services	67, 70,71,72,73,74	
30	Public administration and defence	75	
31	Education	80	
32	Health and social work	85	
33	Waste treatment	90	
34	Miscellaneous services	91-99	**6. Other market services**

Table B								
Estimation results (with no adjustment costs)								
	1			2			3	
	no adjustment costs constant utilisation			no adjustment costs shift premium faster depreciation with use			no adjustment costs shift premium	
	coefficient	*std*		coefficient	*std*		coefficient	*std*
Mining & oil								
μ(or γ)	1.08	*0.23*	*	.99	*0.23*	*	0.98	*0.31* *
Hours per head (b1)				2.57	*0.38*	**	4.28	*2.05* *
M/K growth rate (b2)				.17	*0.04*	*		
I/K growth rate (b3)				-0.03	*0.03*			
P-value	0.01			0.87			0.98	
Manufacturing								
μ(or γ)	1.13	*0.04*		1.01	*0.07*	*	0.98	*0.06* *
Hours per head (b1)				1.70	*0.33*	*	1.62	*0.27* *
M/K growth rate (b2)				0.01	*0.02*	*		
I/K growth rate (b3)				-0.04	*0.01*			
P-value	0.01			0.47			0.04	
Utilities								
μ(or γ)	1.07	*0.17*	*	0.98	*0.24*	*	1.05	*0.22* *
Hours per head (b1)				0.26	*1.83*		1.62	*1.70*
M/K growth rate (b2)				0.04	*0.04*			
I/K growth rate (b3)				-0.02	*.02*			
P-value	0.60			0.19			0.28	
Construction, distribution & Hotels								
μ(or γ)	1.10	*0.09*	*	0.97	*0.09*	*	0.98	*0.11* *
Hours per head (b1)				1.12	*0.58*	**	2.34	*0.93* *
M/K growth rate (b2)				0.08	*0.02*	*		
I/K growth rate (b3)				-0.007	*0-01*			
P-value	0.02			0.01			0.02	
Transport and communication								
μ(or γ)	1.44	*0.28*	*	0.78	*0.09*	*	0.80	*0.12* *
Hours per head (b1)				1.54	*0.81*	**	1.95	*0.97* *
M/K growth rate (b2)				0.06	*0.02*	*		
I/K growth rate (b3)				-0.001	*0.007*			
P-value	0.04			0.28			0.30	
Other market services								
μ(or γ)	1.00	*0.15*	*	0.97	*0.22*	*	0.83	*0.26* *
Hours per head (b1)				0.94	*0.76*		2.80	*1.49* **
M/K growth rate (b2)				.04	*0.02*	*		
I/K growth rate (b3)				-0.01	*0.02*			
P-value	0.01			0.03			0.50	

Estimation procedure: Fixed effects with instrumental variables. Instruments: world trade growth, fiscal impulse, monetary shock and oil-price changes. P-value for overidentifying restrictions. *denotes significant at the 10% level, ** at the 5% level.

Table C									
Estimation results (with adjustment costs)									
	1			**2**			**3**		
	adjustment costs constant utilisation			adjustment costs shift premium faster depreciation with use			adjustment costs shift premium		
	coefficient	*std*		coefficient	*std*		coefficient	*std*	
Mining & oil									
μ(or γ)	1.07	*0.23*	*	0.99	*0.23*	*	0.99	*0.32*	*
Hours per head (b1)				2.60	*1.39*	**	4.50	*2.08*	*
M/K growth rate (b2)				0.17	*0.04*	*			
I/K growth rate (b3)				0.00	*0.03*				
P-value	0.01			0.87			0.91		
Manufacturing									
μ(or γ)	1.17	*0.04*	*	1.02	*0.07*	*	1.02	*0.05*	*
Hours per head (b1)				1.68	*0.33*	*	1.61	*0.33*	*
M/K growth rate (b2)				0.008	*0.02*				
I/K growth rate (b3)				-0.02	*0.02*	*			
P-value	0.03			0.49			0.05		
Utilities									
μ(or γ)	1.03	*0.14*	*	0.98	*0.24*	*	1.05	*0.22*	*
Hours per head (b1)				0.28	*0.21*		0.10	*0.22*	
M/K growth rate (b2)				0.04	*0.02*	*			
I/K growth rate (b3)				-0.01	*0.02*				
P-value	0.63			0.20			0.29		
Construction, distribution & hotels									
μ(or γ)	1.15	*0.09*		0.99	*0.09*	*	1.02	*0.10*	*
Hours per head (b1)				1.14	*0.58*	*	2.41	*0.70*	*
M/K growth rate (b2)				0.08	*0.02*	*			
I/K growth rate (b3)				0.01	*0.01*				
P-value	0.02			0.01			0.02		
Transport & communications									
μ(or γ)	1.59	*0.37*	*	0.84	*0.12*	*	0.78	*0.18*	*
Hours per head (b1)				1.97	*1.07*	**	2.97	*1.51*	*
M/K growth rate (b2)				0.04	*0.03*				
I/K growth rate (b3)				0.05	*0.01*	*			
P-value	0.05			0.29			0.25		
Other market services									
μ(or γ)	1.19	*0.14*	*	0.99	*0.24*	*	0.94	*0.25*	*
Hours per head (b1)				0.89	*0.74*		2.80	*1.36*	*
M/K growth rate (b2)				0.04	*0.02*	*			
I/K growth rate (b3)				0.01	*0.01*				
P-value	0.02			0.02			0.22		

Estimation procedure: Fixed effects with instrumental variables. Instruments: world trade growth, fiscal impulse, monetary shock, oil-price changes and sectoral demand. P-value for test of overidentifying restrictions. * denotes significant at the 10% level, ** at the 5% level.

Table D								
Final regression equation, with adjustment costs								
Sector	**Regressors**	**coefficient**	***std***		**coefficient**	***std***	
Mining & oil	**Hours per head (b1)**	2.57	*1.41*	**			
	M/K growth rate (b2)	0.17	*0.04*	*			
	I/K growth rate (b3)						
	P-value	0.97					
Manufacturing	μ(or γ)				1.02	*0.05*	*
	Hours per head (b1)				1.60	*0.33*	*
	M/K growth rate (b2)						
	I/K growth rate (b3)						
	P-value				0.05		
Utilities	**Hours per head (b1)**	0.27	*1.32*				
	M/K growth rate (b2)	0.04	*0.02*	*			
	I/K growth rate (b3)	-0.02	*0.02*				
	P-value	0.10					
Construction, distribution & hotels	**Hours per head (b1)**	1.83	*0.73*	*			
	M/K growth rate (b2)	0.08	*0.02*	*			
	I/K growth rate (b3)	0.01	*0.01*				
	P-value	0.12					
Transport & communications	μ(or γ)				0.84	*0.11*	*
	Hours per head (b1)				1.97	*0.83*	**
	M/K growth rate (b2)				0.04	*0.03*	
	I/K growth rate (b3)				0.06	*0.01*	*
	P-value				0.29		
Other market services	**Hours per head (b1)**	1.78	*0.99*	**			
	M/K growth rate (b2)	0.04	*0.02*	*			
	I/K growth rate (b3)	0.01	*0.01*				
	P-value	0.06					

Estimation procedure: Fixed effects with instrumental variables for inputs growth, instruments: world trade growth, fiscal impulse, monetary shock, oil-price changes and sectoral demand . P-value for test of overidentifying assumptions. * denotes significant at the 10% level, ** at the 5% level.

Table E						
Estimated TFP growth at the industry level						
	mean (1971-2000)		std		corr. with GDP growth	
Industry	TFP estimate	Solow res	TFP estimate	Solow res	TFP estimate	Solow res
3 Coal & other mining	1.89	1.08	6.15	8.29	-0.09	0.13
4 Manufactured fuel	0.78	0.23	4.92	1.94	-0.10	0.43
5 Chemicals & pharmaceuticals	1.32	1.36	1.72	1.96	0.18	0.42
6 Non-metallic mineral products	-0.21	-0.20	1.85	2.10	0.27	0.52
7 Basic metals & metal goods	0.46	0.53	2.20	1.90	0.03	0.47
8 Mechanical engineering	0.43	0.44	2.34	1.67	-0.06	0.37
9 Electrical engineering & electronics	3.42	3.49	2.85	2.56	0.17	0.40
10 Vehicles	1.12	1.12	2.98	1.79	-0.16	0.17
11 Food, drink & tobacco	0.26	0.32	1.31	0.76	-0.36	0.11
12 Textiles, clothing & leather	0.77	0.80	1.65	1.47	-0.12	0.28
13 Paper, printing and publishing	0.20	0.27	1.66	2.08	0.27	0.61
14 Other manufacturing	0.36	0.41	1.87	1.95	0.21	0.58
15 Electricity supply	1.36	1.15	3.28	3.51	0.29	0.31
16 Gas supply	2.36	2.10	2.48	2.49	-0.07	0.06
18 Construction	0.56	0.01	1.98	1.73	-0.11	0.39
19 Wholesale, vehicle sales & repairs	1.53	0.62	2.45	2.82	0.32	0.44
20 Retailing	0.76	-0.10	1.78	2.16	0.51	0.71
21 Hotels & catering	0.39	-0.60	2.73	2.22	0.07	0.37
22 Rail transport	2.85	1.92	6.18	4.54	0.06	0.25
23 Road transport	1.73	0.74	2.81	2.10	-0.18	0.28
24 Water transport	0.65	-0.53	6.90	5.85	0.13	0.04
25 Air transport	2.89	1.13	6.22	3.17	0.09	0.40
26 Other transport services	1.83	0.84	3.04	3.24	0.16	0.34
27 Communications	3.24	2.29	2.17	2.01	-0.01	0.46
28 Finance	0.91	0.44	1.84	2.04	-0.16	0.03
29 Business Services	1.38	0.65	2.41	1.98	-0.38	-0.10
34 Miscellaneous services	0.24	-0.31	2.33	1.83	-0.20	0.11

Calculated using sectoral estimation results in Table D.

Table F

Aggregate Solow residual decomposition

Non-farm private economy

	1980-1984	1985-1989	1990-1994	1995-2000
Value added growth	**1.57**	**5.70**	**1.70**	**4.40**
- (weighted) input growth	0.15	3.69	-0.52	2.91
= solow residual=	**1.43**	**2.01**	**2.22**	**1.48**
- labour quality adjustment	-0.15	0.17	0.65	0.34
= solow residual (quality adjusted)=	**1.58**	**1.84**	**1.57**	**1.14**
+ scale effects(*)	-0.07	-0.06	-0.06	-0.09
+ utilisation of inputs	-1.11	0.51	-1.01	-0.44
- adjustment costs	0.03	0.47	-0.37	0.42
+ reallocations effects(k an L)	0.60	-0.32	0.09	0.25
+ TFP estimate	**2.20**	**2.18**	**2.18**	**1.83**

Period averages, based on estimation results reported in Table D. Solow residual (quality adjusted) uses quality-adjusted labour input.

Table G

Solow residual decomposition by industry group

	1980-1984	1985-1989	1990-1994	1995-2000	1980-1984	1985-1989	1990-1994	1995-2000
	Mining and Oil				Manufacturing			
Value added growth	**-4.60**	**8.93**	**-4.02**	**-1.28**	**0.44**	**4.65**	**0.63**	**1.70**
- input growth	-2.90	-8.59	-12.88	0.15	-2.28	1.00	-3.13	0.15
= solow residual =	**-1.70**	**17.52**	**8.86**	**-1.43**	**2.72**	**3.64**	**3.77**	**1.55**
- labour quality adjustment	-0.03	0.39	1.08	0.41	0.11	0.23	0.71	0.47
= solow residual (q adjusted) =	**-1.68**	**17.13**	**7.78**	**-1.84**	**2.61**	**3.41**	**3.05**	**1.09**
+scale effect	0.00	0.00	0.00	0.00	-0.14	0.13	-0.08	0.13
+ utilisation of inputs	-7.13	2.13	0.31	4.97	-0.01	1.22	-0.86	0.05
- adjustment costs	-0.13	0.05	-0.85	0.18	-0.03	0.30	-0.40	0.21
+ reallocations effects	0.48	1.20	2.07	0.11	0.38	-0.42	0.27	0.45
+ TFP growth	**4.84**	**13.85**	**4.55**	**-6.75**	**2.35**	**2.77**	**3.32**	**0.67**
	Utilities				Distribution, construction & hotels			
Value added growth	**-0.05**	**5.82**	**2.48**	**2.70**	**0.20**	**5.44**	**0.89**	**2.91**
- input growth	-2.61	-1.19	-0.60	-2.69	1.00	4.05	-0.90	2.49
= solow residual =	**2.55**	**7.02**	**3.08**	**5.39**	**-0.80**	**1.39**	**1.79**	**0.43**
- labour quality adjustment	-0.02	0.23	0.63	0.24	-0.34	0.14	0.59	0.31
= solow residual (q adjusted) =	**2.57**	**6.79**	**2.44**	**5.14**	**-0.45**	**1.24**	**1.20**	**0.12**
+scale effect	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
+ utilisation of inputs	-0.79	-1.13	0.42	-0.41	-2.03	-0.52	-1.09	-0.94
- adjustment costs	-0.04	0.02	0.03	0.01	0.04	0.25	-0.22	0.28
+ reallocations effects	0.30	0.00	-0.14	0.43	0.46	-0.32	0.36	0.19
+ TFP growth	**3.02**	**7.95**	**2.19**	**5.13**	**1.15**	**2.33**	**1.71**	**1.14**
	Transport & communications				Other market services			
Value added growth	**1.52**	**4.69**	**3.04**	**7.05**	**5.41**	**6.95**	**3.28**	**7.27**
- input growth	-0.20	2.05	-0.15	3.74	4.46	8.28	2.47	5.65
= solow residual =	**1.72**	**2.65**	**3.19**	**3.30**	**0.94**	**-1.33**	**0.81**	**1.61**
- labour quality adjustment	-0.37	0.15	0.58	0.50	-0.08	0.14	0.65	0.24
= solow residual (q adjusted) =	**2.09**	**2.50**	**2.61**	**2.80**	**1.02**	**-1.47**	**0.16**	**1.37**
+scale effect	-0.26	-0.95	-0.38	-1.12	0.00	0.00	0.00	0.00
+ utilisation of inputs	-1.11	1.09	-1.21	-0.62	-1.24	0.42	-1.24	-0.48
- adjustment costs	-0.04	0.25	0.06	0.46	0.16	1.00	-0.69	0.72
+ reallocations effects	0.40	-0.02	0.26	0.14	0.19	-0.56	0.07	0.18
+ TFP growth	**3.02**	**2.63**	**4.01**	**4.86**	**2.22**	**-0.33**	**0.64**	**2.39**

Period averages. Input growth and solow residual use non-quality adjusted labour. Labour quality adjustment and solow residual (q adjusted) use quality-adjusted labour input. Calculated using estimation results in Table D.

Table H						
Sectoral TFP estimates: summary						
	mean (1990-95)		mean (1995-2000)		TFP acceleration	
Industry	TFP estimate	Solow res	TFP estimate	Solow res	TFP estimate	Solow res
3 Coal & other mining	1.45	3.02	-1.49	-1.07	-2.94	-4.09
4 Manufactured fuel	1.46	1.32	0.04	-0.08	-1.42	-1.40
5 Chemicals & pharmaceuticals	1.61	1.79	0.88	0.63	-0.73	-1.16
6 Non-metallic mineral products	-0.94	-0.95	-1.08	-1.15	-0.14	-0.20
7 Basic metals & metal goods	.08	.02	0.28	-0.04	0.20	-0.06
8 Mechanical engineering	0.72	0.73	0.58	0.47	-0.14	-0.26
9 Electrical engineering & electronics	2.64	2.58	3.97	3.73	1.33	1.15
10 Vehicles	1.10	1.06	0.40	0.15	-0.70	-0.91
11 Food, drink & tobacco	0.41	0.67	-0.35	-0.40	-0.76	-1.07
12 Textiles, clothing & leather	1.35	1.35	0.88	0.42	-0.47	-0.93
13 Paper, printing and publishing	0.25	0.29	0.72	0.26	0.47	-0.03
14 Other manufacturing	0.36	0.46	-0.72	-0.85	-1.08	-1.31
15 Electricity supply	1.07	0.65	1.44	1.32	0.37	0.67
16 Gas supply	2.17	2.10	3.59	3.35	1.42	1.25
18 Construction	0.99	0.57	-0.20	-0.46	-1.19	-1.03
19 Wholesale, vehicle sales & repairs	2.44	1.89	3.35	2.49	0.91	0.60
20 Retailing	0.01	-0.39	1.02	0.22	1.01	0.61
21 Hotels & catering	-0.24	-0.52	-1.96	-2.89	-1.72	-2.37
22 Rail transport	3.98	-0.35	10.11	6.90	6.13	7.25
23 Road transport	1.49	0.59	1.10	-0.02	-0.39	-0.61
24 Water transport	1.03	2.66	1.98	2.31	0.95	-0.35
25 Air transport	4.51	2.70	2.60	-0.24	-1.91	-2.94
26 Other transport services	2.85	1.58	2.66	0.48	-0.19	-1.10
27 Communications	3.55	2.66	4.47	3.28	0.92	0.62
28 Finance	0.21	0.17	2.13	1.86	1.92	1.69
29 Business Services	0.46	0.12	1.18	0.34	0.72	0.22
34 Miscellaneous services	0.49	0.50	1.17	0.51	0.68	0.01

Period averages, based on estimation results reported in Table D.

Table I			
	mean (1971-2000)	std	correlation with GDP growth
Non-farm private economy			
Solow residual (labour quality adjusted)	1.67	1.90	0.68
TFP estimate	2.11	1.97	0.03
utilisation correction		2.53	0.69
adjustment cost correction		0.49	0.49
Manufacturing			
Solow residual (labour quality adjusted)	2.28	2.39	0.63
TFP estimate	2.23	3.3	0.03
utilisation correction		3.36	0.6
adjustment cost correction		0.51	0.39
Market Services			
Solow residual (labour quality adjusted)	0.67	1.96	0.50
TFP estimate	1.89	1.98	0.05
utilisation correction		2.08	0.7
adjustment cost correction		0.6	0.45

Chart 1
Aggregate Solow residual (quality adjusted) and GDP growth
Private non-farm economy

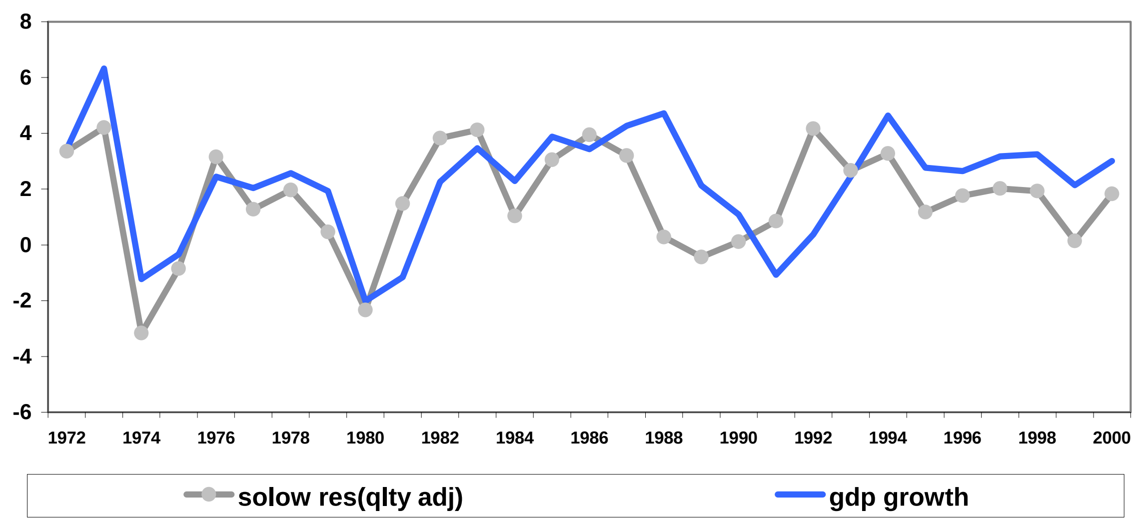


Chart 2
Male weekly hours per head
Private non-farm economy

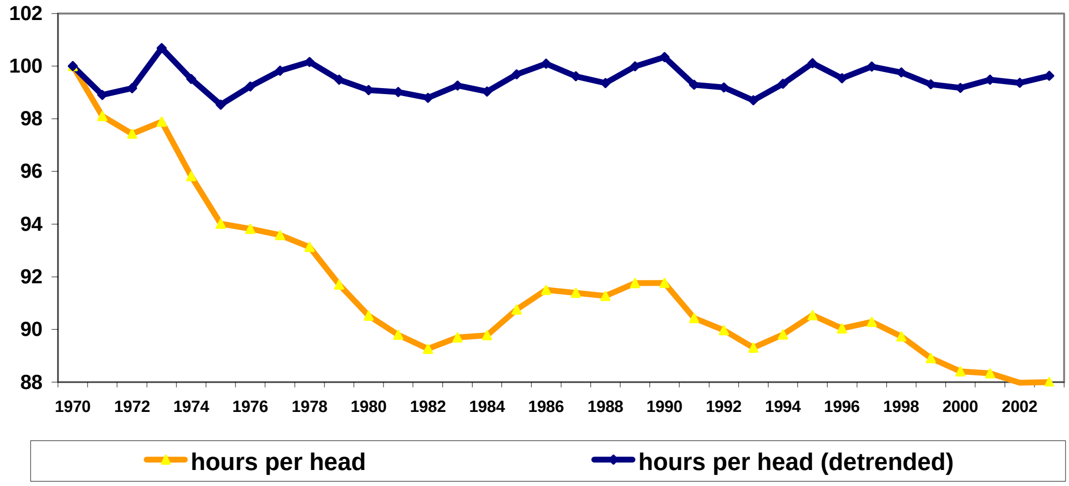
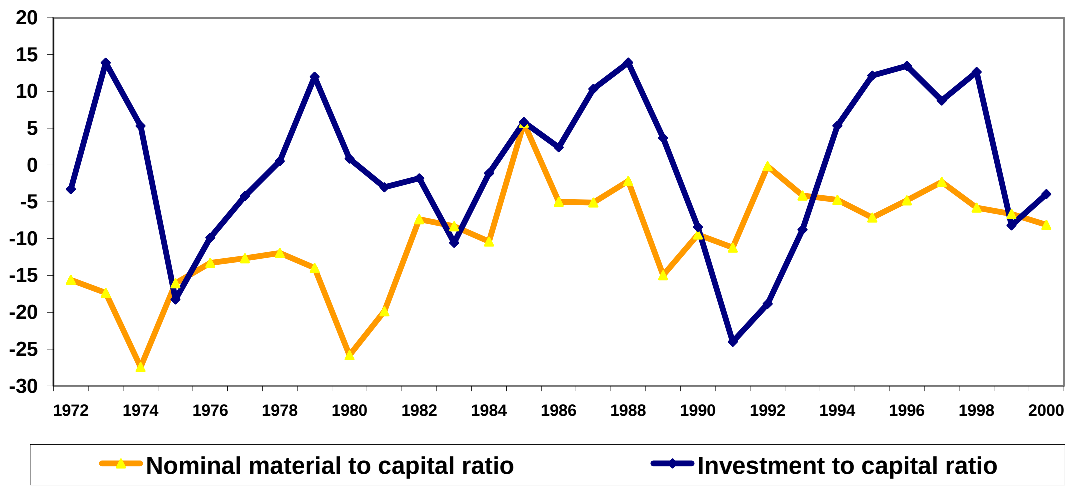


Chart 3
Utilisation proxies
Private non-farm economy



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