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ABSTRACT

TFP Growth in British and German Manufacturing, 1950–96*

This Paper considers the accuracy of traditional TFP growth estimates using an econometric methodology which takes account of scale economies, fixed factors of production and adjustment costs to reveal underlying 'pure technological change'. The results suggest that these biases vary substantially over time but do not impact heavily on Anglo-German comparisons. In both countries the early post-war years are a period when adjustment costs from a rising supply price of capital goods hold down TFP growth below that which could have accrued from pure technological progress. As might be expected, this problem largely disappeared in the later globalization period.

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1. Introduction

The current U.K. government has put improving productivity at the top of the policy agenda. Its most recent report drew attention to a shortfall in total factor productivity (TFP) as an important part of the British labour productivity gap that is revealed by international comparisons (HM Treasury, 2000). This reflects the now pervasive use of neoclassical growth accounting to benchmark productivity performance.

The state of the art growth accounting study of postwar British productivity performance is that of O'Mahony (1999). She provides an analysis that documents comparative levels of labour productivity in five countries, measured in terms of purchasing power parity adjusted real GDP per hour worked, and then proceeds to account for growth of labour productivity in terms of capital deepening and TFP growth using standard Solow growth model assumptions. This analysis is conducted for the whole economy and also on a more disaggregated basis. A summary of her results for U.K. manufacturing and a comparison with West Germany are shown in Table 1.

Table 1 reports rapid TFP growth in both countries during the so-called 'Golden Age', which ended in the early 1970s and was then followed by a marked slowdown. This should be interpreted in a context of catch-up, where both countries had an opportunity to emulate aspects of American manufacturing technology in a situation where, initially, the United States had a very large productivity lead (Nelson and Wright, 1992). In more recent decades the productivity gap between the United States and western Europe has been smaller and the scope for rapid TFP growth based on catch-up much less.

In a pure Solow model with perfect competition and constant returns to scale, TFP growth equals the contribution of technological progress. More generally this is not the case. With endogenous innovation embodied in new types of capital, better technology partly has its effect through the capital contribution, in which case TFP growth then understates the impact of technological progress (Barro, 1999). Even where technological change is exogenous and disembodied, TFP growth only measures its contribution to growth correctly when there are constant returns to scale, factor shares reflect marginal products, and there are no fixed factors of production. In standard growth accounting comparisons these problems are either assumed away or, for the purpose of benchmarking, taken to impart equal bias in each case. When these assumptions are violated it is possible, however, to use econometric techniques to filter out the effects to obtain 'pure' TFP growth (Morrison, 1992, 1993). In this paper we use a version of the methodology developed by Morrison to reconsider the contribution of innovation to productivity growth in West Germany and the U.K.

West Germany has been the traditional comparator when the productivity performance of British manufacturing is assessed, with detailed growth accounting studies dating back as far as Panic (1976). The general belief is that Germany has had a much more dynamic national system of innovation (Pavitt and Patel, 1988), and commentators have singled out West German manufacturing firms as exceptionally capable by international standards in terms of high quality incremental (although not radical) innovation (Carlin and Soskice, 1997). Although recent discussions have recognized a relatively strong labour productivity performance in British manufacturing in the 1980s (Oulton, 1995), the period of relatively rapid growth of output per worker in the U.K. in the 1980s is generally regarded as owing a good deal to a shakeout of inefficient firms and working practices rather than to strong technological advance (Bean and Crafts, 1996).

One particularly interesting aspect of explanations for differences in Anglo-German productivity performance is the role that may be played by systems of corporate governance in the two countries. Recent research into Britain's productivity performance has highlighted the role of principal agent problems in firms in which the absence of a dominant external shareholder implies weak control over the effort that managers exert to control costs (Nickell, 1996). Theory predicts that, when competition is weak, the adoption of cost-reducing innovations in these so-called 'conservative' firms will be inhibited by managers' dislike of the effort involved (Aghion et al., 1997). Empirical research confirms that, in the U.K., greater product market competition has been associated with faster productivity growth where firms lack a dominant external shareholder but not otherwise (Nickell et al., 1997). By contrast, German manufacturing has been much less exposed to agency problems within firms because the predominant pattern is one of concentrated share ownership (Edwards and Fischer, 1994). This analysis has led the present U.K. government to the view that strengthening competition policy is an essential component of its policy to eliminate the productivity gap. In this context, a useful by-product of the Morrison methodology is that it generates estimates of changes in market power over time.

In what follows we address the following questions:

(1) Are traditional measures of TFP growth seriously biased?

(2) Does adjusting for bias materially affect comparisons either between British and German TFP performance or of British TFP performance over time?

(3) What light do the results throw on the relationship between competition and comparative TFP growth?

Section 2 reviews the corrections for bias in TFP measurement that are needed to allow for economies of scale, the impact of fixed factors of production, and costs of adjustment to optimal capacity. Section 3 sets out the econometric approach that we have used to implement these adjustments and reports the results of these estimations, while discussion of the data is left to the appendix. Section 4 considers the implications of these results in the context of the literature on manufacturing productivity growth in the U.K. and West Germany. Section 5 concludes.

2. Correcting for Biases in TFP Measurement

(a) The Traditional Framework for Productivity Growth Measurement

Following Morrison (1992), we begin by assuming that firms face a production function $Y = Y(v,t)$ or, equivalently, a dual cost function $C = C(p,t,Y)$. Here Y is output, C is total costs, $v = (v_1,\cdots,v_J)$ is a vector of J inputs with corresponding price vector $p = (p_1,\ldots,p_J)$, and t denotes technology. Primal and dual multifactor productivity growth (*MFPG*) measures can be defined as the elasticities of these functions with respect to t, i.e., $\partial \ln Y/\partial t = \varepsilon_{Yt}$ and $\partial \ln C/\partial t = \varepsilon_{Ct}$. These measures reflect the residuals of total output (cost) growth less the contributions of the variables other than t. With instantaneous adjustment, constant returns to scale (CRTS) and perfect competition, these residuals isolate technical change.

By taking the differential of the production function, recognising that with profit maximisation and perfect competition, $p_Y(\partial Y/\partial v_j) = p_j$, where p_Y is the price of output, and solving for ε_{Yt}, yields

$$\varepsilon_{Yt} = d\,lnY/dt - d\,ln v/dt = \frac{\dot{Y}}{Y} - \sum_j \frac{p_j v_j}{p_Y Y}\left(\frac{\dot{v}_j}{v_j}\right) = \frac{\dot{Y}}{Y} - \sum_j S_j\left(\frac{\dot{v}_j}{v_j}\right) \tag{1}$$

where $S_j = p_j v_j / p_Y Y$ is the share of the jth input in the value of total output. Similarly, the cost-side productivity growth residual may be expressed as

$$\varepsilon_{Ct} = \frac{\dot{C}}{C} - \frac{\dot{Y}}{Y} - \sum_j \frac{p_j v_j}{C}\left(\frac{\dot{p}_j}{p_j}\right) = \frac{\dot{C}}{C} - \frac{\dot{Y}}{Y} - \sum_j M_j\left(\frac{\dot{p}_j}{p_j}\right) \tag{2}$$

where $C = \sum_j p_j v_j$ and $M_j = p_j v_j / C$. With CRTS, instantaneous adjustment and perfect competition, $\varepsilon_{Yt} = -\varepsilon_{Ct}$. The equivalence of the two measures arises because CRTS implies that no returns are generated from scale economies, instantaneous adjustment guarantees no returns exist from varying the utilisation of inputs, and perfect competition ensures no returns to market power. If any of these assumptions are relaxed, however, the revenue generated must be taken into account.

Figure 1, taken from Morrison (1993), illustrates the general point. Consider a firm at point A, at a point of tangency between short run average cost curve $SRAC_0$, defined for a fixed capital stock, and long run average cost curve $LRAC_0$, with output Y_0. The cost curves then fall to $SRAC_1$ and $LRAC_1$, such that in full long run equilibrium the firm is now able to be at point D with output Y_1. However, in the short run, if neither output nor capital stock change, the measured decrease in average cost is only from c_a to c_b, rather than to c_d. If full adjustment and CRTS were assumed, then this would appear to be the full potential decline at point B. In fact, achieving the full decline involves adjustment of the fixed input (B to C) and taking advantage of economies of scale (C to D). This last component is not, of course, TFP growth due to innovation and a shift of the cost curve, but it would be wrongly measured as such if long run adjustment is captured but CRTS imposed. So the aim in eliminating biases in measurement is to capture the change in long run average cost, which at Y_0 is the distance c_a to c_c. In this case, unrecognised economies of scale (fixity of inputs) would lead to an overestimate (underestimate).

(b) Taking Account of Scale Economies

Returns to the firm due to scale economies cause a deviation between marginal cost (*MC*) and average cost ($AC = C/Y$) and thus a difference between p_Y (which under perfect competition equals *MC*) and *AC*. We should therefore correct ε_{Ct} for the erroneous assumption of CRTS:

$$\varepsilon_{Ct}^{R} = \frac{\dot{C}}{C} - \varepsilon_{CY}\frac{\dot{Y}}{Y} - \sum_j \frac{p_j v_j}{C}\left(\frac{\dot{p}_j}{p_j}\right) = \varepsilon_{Ct} + (1-\varepsilon_{CY})\frac{\dot{Y}}{Y} \tag{3}$$

where $\varepsilon_{CY} = \partial \ln C / \partial \ln Y$ is the inverse of returns to scale and $(1-\varepsilon_{CY})(\dot{Y}/Y)$ is the bias correction if CRTS is inappropriately assumed.

(c) Subequilibrium Impacts

We now introduce a vector of fixed factors, $x = (x_1, \ldots, x_K)$ and define the variable cost function $G(y, p, x, t)$. The shadow value of the fixed input x_k is $Z_k = -\partial G/\partial x_k$. Total costs can then be written as $C = G + \sum_k p_k x_k$, where p_k is the market price of x_k, and shadow costs can be defined as $C^* = G + \sum_k Z_k x_k$. Capacity utilisation is then defined as $CU = C^*/C$. When there is excess capacity (over-utilisation) the shadow values of the fixed inputs will fall short of (exceed) their market prices so that $CU < 1$ ($CU > 1$). Morrison shows that

$$CU = 1 - \sum_k \varepsilon_{Ck} = \varepsilon_{CY} \tag{4}$$

where

$$\varepsilon_{Ck} = (p_k - Z_k)x_k / C$$

and that with sub-equilibrium, cost-side *MFPG* becomes

$$\begin{aligned}\varepsilon_{Ct}^{F} &= -\varepsilon_{CY}\frac{\dot{Y}}{Y} + \sum_j \frac{p_j v_j}{C}\frac{\dot{p}_j}{p_j} + \sum_k \frac{Z_k x_k}{C}\frac{\dot{x}_k}{x_k} \\ &= \varepsilon_{Ct} + \sum_k \varepsilon_{Ck}\left(\frac{\dot{Y}}{Y} - \frac{\dot{x}_k}{x_k}\right)\end{aligned} \tag{5}$$

F stands for 'fixity adaptation' and the last expression is the bias correction. Note that, since $\varepsilon_{Ck} \neq 0$ affects the weights on both output and quasi-fixed input growth rates, the bias depends on both these rates.

An additional adaptation for fixity is to recognise the portion of cost change due to dynamic adjustment costs

$$\begin{aligned}\varepsilon_{Ct}^{A} &= -\varepsilon_{CY}\frac{\dot{Y}}{Y} + \sum_j \frac{p_j v_j}{C}\frac{\dot{p}_j}{p_j} + \sum_k \frac{Z_k x_k}{C}\frac{\dot{x}_k}{x_k} + \sum_k \frac{\dot{Z}_k \dot{x}_k}{C}\frac{\ddot{x}_k}{\dot{x}_k} \\ &= \varepsilon_{Ct}^{F} + \sum_k \frac{\dot{Z}_k \dot{x}_k}{C}\frac{\ddot{x}_k}{\dot{x}_k}\end{aligned} \tag{6}$$

where *A* represents 'adjustment cost adaptation'. Dynamic adjustment costs are familiar from theoretical and empirical analyses of investment (Nickell, 1978; Bond and Meghir, 1994). They arise from increases in the cost of installing new capital goods as attempts to move to optimal capacity are speeded up. In principle, these could result from factors internal (e.g., Penrose effects) or external to the firm, such as running into increasingly steep supply curves for equipment and structures. Our model only corrects for the latter type which are reflected in the term in the second derivative of the market price of fixed inputs in (6).

Note that, so far, scale economies and utilisation are both represented by ε_{CY}. If both effects exist then they can individually be measured as components of this elasticity, since the *long-run* cost elasticity ε_{CY}^{L} can be written as

$$\varepsilon_{CY}^{L} = \varepsilon_{CY} + \sum_k \varepsilon_{CY}^{L}\varepsilon_{Ck} \tag{7}$$

so that

$$\varepsilon_{CY} = \varepsilon_{CY}^{L}\left(1 - \sum_k \varepsilon_{Ck}\right) = \varepsilon_{CY}^{L} CU \tag{8}$$

Hence we may define

$$\varepsilon_{Ct}^{T} = -\varepsilon_{CY}^{L}\frac{\dot{Y}}{Y} + \sum_{j}\frac{p_j v_j}{C}\frac{\dot{p}_j}{p_j} + \sum_{k}\frac{Z_k x_k}{C}\frac{\dot{x}_k}{x_k} + \sum_{k}\frac{\dot{Z}_k \dot{x}_k}{C}\frac{\ddot{x}_k}{\dot{x}_k} \tag{9}$$

where T represents 'total adaptation'.

(d) Allowing for Markups of Price Over Marginal Cost

Primal *MFPG* measures may also be misleading if market power exists so that $p_Y \neq MC$. The market power adjustment affects the demand side rather than being a cost adjustment. The markup can be defined as

$$M = \frac{p_Y}{MC} = \frac{1}{1+\varepsilon_{PY}} \tag{10}$$

where ε_{PY} is the inverse demand elasticity facing the firm.

3. Empirical Implementation

We use U.K. and German annual data from 1950 to 1996 on the manufacturing sector to compute the various measures of *MFPG*. There are $J = 2$ variable inputs, labour and energy, and $K = 1$ quasi-fixed input, the net capital stock. The traditional measures of *MFPG*, ε_{Yt} and ε_{Ct}, can be computed using equations (1) and (2) as they are parameter free indices. The adjusted cost-side indices, ε_{Ct}^{R}, ε_{Ct}^{F}, ε_{Ct}^{A} and ε_{Ct}^{T}, require estimates of the two elasticities, ε_{CY}^{L} and ε_{Ck}, and the shadow price of capital, *Z*. These cannot be observed directly but may be obtained by estimating an appropriate econometric model.

The model that we employ is that of Morrison (1988, 1992), and used in a similar context by Rossi and Toniolo (1992). As stated above, we have two variable inputs, labour and energy, denoted x_l, x_m, with prices w_l, w_m, a single fixed factor (capital, *k*, with rental price *r*), and two exogenous arguments: *b*, investment in *k*, and *x*, the stock of public works. The Generalized Leontief restricted (or variable) cost function is then

$$\begin{aligned}
G = Y\Big[&\alpha_{ll}w_l + \alpha_{mm}w_m + (\alpha_{lm}+\alpha_{ml})(w_l w_m)^{0.5} + (\beta_{lt}w_l + \beta_{mt}w_m)t^{0.5} \\
&+ (\beta_{lb}w_l + \beta_{mb}w_m)b^{0.5} + (\beta_{lx}w_l + \beta_{mx}w_m)x^{0.5} + (\beta_{ly}w_l + \beta_{my}w_m)y^{0.5} \\
&+ (w_l + w_m)\big(\gamma_{yy}Y + \gamma_{tt}t + \gamma_{bb}b + \gamma_{xx}x + \gamma_{yt}(Yt)^{0.5} + \gamma_{yb}(Yb)^{0.5} + \gamma_{yx}(Yx)^{0.5} + \gamma_{tb}(tb)^{0.5} + \gamma_{tx}(tx)^{0.5} + \gamma_{bx}(bx)^{0.5}\big)\Big] \\
&+ Y^{0.5}\Big[(\beta_{lk}w_l + \beta_{mk}w_m)k^{0.5} + (w_l + w_m)\big(\gamma_{yk}(Yk)^{0.5} + \gamma_{tk}(tk)^{0.5} + \gamma_{bk}(bk)^{0.5} + \gamma_{xk}(xk)^{0.5}\big)\Big] \\
&+ (w_l + w_m)\gamma_{kk}k
\end{aligned}$$

The system of variable input demand equations are then given by

$$\frac{x_i}{Y} = \frac{\partial G}{\partial x_i}\frac{1}{Y}, \quad i = l, m$$

so that we have

$$\begin{aligned} x_l/Y = {} & \alpha_{ll} + \alpha_{lm}(w_m/w_l)^{0.5} + \beta_{ly}Y^{0.5} + \beta_{lt}t^{0.5} + \beta_{lb}b^{0.5} + \beta_{lx}x^{0.5} + \beta_{lk}(k/Y)^{0.5} \\ & + \gamma_{yy}Y + \gamma_{tt}t + \gamma_{bb}b + \gamma_{xx}x \\ & + \gamma_{yt}(Yt)^{0.5} + \gamma_{yb}(Yb)^{0.5} + \gamma_{yx}(Yx)^{0.5} + \gamma_{tb}(tb)^{0.5} + \gamma_{tx}(tx)^{0.5} + \gamma_{bx}(bx)^{0.5} + \gamma_{yk}k^{0.5} \\ & + \gamma_{tk}(tk/Y)^{0.5} + \gamma_{bk}(bk/Y)^{0.5} + \gamma_{xk}(xk/Y)^{0.5} + \gamma_{kk}(k/Y) \end{aligned} \tag{11a}$$

and

$$\begin{aligned} x_m/Y = {} & \alpha_{mm} + \alpha_{ml}(w_l/w_m)^{0.5} + \beta_{my}Y^{0.5} + \beta_{mt}t^{0.5} + \beta_{mb}b^{0.5} + \beta_{mx}x^{0.5} + \beta_{mk}(k/Y)^{0.5} \\ & + \gamma_{yy}Y + \gamma_{tt}t + \gamma_{bb}b + \gamma_{xx}x \\ & + \gamma_{yt}(Yt)^{0.5} + \gamma_{yb}(Yb)^{0.5} + \gamma_{yx}(Yx)^{0.5} + \gamma_{tb}(tb)^{0.5} + \gamma_{tx}(tx)^{0.5} + \gamma_{bx}(bx)^{0.5} + \gamma_{yk}k^{0.5} \\ & + \gamma_{tk}(tk/Y)^{0.5} + \gamma_{bk}(bk/Y)^{0.5} + \gamma_{xk}(xk/Y)^{0.5} + \gamma_{kk}(k/Y) \end{aligned} \tag{11b}$$

Constant returns to scale requires that all long-run output elasticities equal unity, which will be the case if

$$\beta_{ly} = \beta_{my} = \gamma_{yy} = \gamma_{yt} = \gamma_{yx} = \gamma_{yb} = \gamma_{yk} = 0 \tag{12}$$

The shadow value of the fixed factor *k* is

$$Z_k = -\frac{\partial G}{\partial k} = -0.5\left(\frac{Y}{k}\right)^{0.5}\left(\beta_{lk}w_l + \beta_{mk}w_m + (w_l + w_m)\left(\gamma_{yk}Y^{0.5} + \gamma_{tk}t^{0.5} + \gamma_{bk}b^{0.5} + \gamma_{xk}x^{0.5}\right)\right) - (w_l + w_m)\gamma_{kk}$$

Since total costs are defined as $C = G + rk$, shadow costs can then be defined similarly as $C^* = G + Z_k k$. Capacity utilisation is defined as $CU = 1 - \varepsilon_{Ck}$, where

$$\varepsilon_{Ck} = \frac{\partial C}{\partial k}\cdot\frac{k}{C} = \left(\frac{\partial G}{\partial k} + r\right)\cdot\frac{k}{C} = \frac{(r - Z_k)k}{C}$$

The long-run elasticity ε_{CY}^L is defined as

$$\varepsilon_{CY}^L = \frac{\partial C}{\partial Y}\cdot\frac{Y}{C^*} = MC\cdot\frac{Y}{C^*}$$

i.e., it is evaluated at the steady state values of the fixed input, Z_k. Here, the marginal cost *MC* is given by

$$\frac{\partial C}{\partial Y} = \Big[\alpha_{ll} w_l + \alpha_{mm} w_m + (\alpha_{lm} + \alpha_{ml})(w_l w_m)^{0.5} + (\beta_{lt} w_l + \beta_{mt} w_m) t^{0.5}$$
$$+ (\beta_{lb} w_l + \beta_{mb} w_m) b^{0.5} + (\beta_{lx} w_l + \beta_{mx} w_m) x^{0.5} + (\beta_{ly} w_l + \beta_{my} w_m) Y^{0.5}$$
$$+ (w_l + w_m)\left(\gamma_{yy} Y + \gamma_{tt} t + \gamma_{bb} b + \gamma_{xx} x + \gamma_{yt}(Yt)^{0.5} + \gamma_{yb}(Yb)^{0.5} + \gamma_{yx}(Yx)^{0.5} + \gamma_{tb}(tb)^{0.5} + \gamma_{tx}(tx)^{0.5} + \gamma_{bx}(bx)^{0.5}\right)\Big]$$
$$+ 0.5 y^{0.5}(\beta_{ly} w_l + \beta_{my} w_m) + (w_l + w_m)\left(\gamma_{yy} Y + \tfrac{1}{2}\gamma_{yt}(tY)^{0.5} + \tfrac{1}{2}\gamma_{yb}(bY)^{0.5} + \tfrac{1}{2}\gamma_{yx}(xY)^{0.5}\right)$$
$$+ 0.5(\beta_{lk} w_l + \beta_{mk} w_m)(k/Y)^{0.5} + 0.5(w_l + w_m)\left(\gamma_{yk}(k/Y)^{0.5} + \gamma_{tk}(tk/Y)^{0.5} + \gamma_{bk}(bk/Y)^{0.5} + \gamma_{xk}(xk/Y)^{0.5}\right)$$
$$+ 0.5(w_l + w_m)\gamma_{yk} k$$

The pair of demand equations given by (11) was estimated using an iterative SURE technique with autoregressive error corrections (attempts to estimate using three-stage least squares produced inferior results). After the model was simplified by deleting insignificant coefficients, the parameter estimates were then used to compute the two elasticities, ε_{CY}^{L} and ε_{Ck}, and the shadow price of capital, *Z*. From these, capacity utilisation and long and short run returns to scale were calculated, which were than used as inputs to calculate the adjusted cost-side indices, ε_{Ct}^{R}, ε_{Ct}^{F}, ε_{Ct}^{A} and ε_{Ct}^{T}. Tables 2 and 3 present estimates of the two equations for the U.K. and Germany, respectively. All equations produce good fits to the data, with R^2 statistics in excess of 0.99, many coefficients estimates highly significant, and no evidence of residual autocorrelation once first order autocorrelation is modelled. Note that the assumption of constant returns to scale is conclusively rejected in both countries: the hypothesis (12) is rejected at less than the 0.001 level for the U.K. and at the 0.028 level for Germany.

To compute the markup factor *M*, we require an estimate of the inverse demand elasticity ε_{PY}. This was obtained from an appropriate regression of p_Y on *Y* and using the estimated slope coefficient in the usual way. The resulting sets of statistics are shown in Tables 4 and 5 for the U.K. and Tables 6 and 7 for Germany.

Leaving aside the statistical properties of the model, how plausible are its results? A comparison of the uncorrected primal estimates for TFP offers a check. Oulton and O'Mahony (1994) presented estimates for U.K. manufacturing on a gross output basis for 1954-86 which showed TFP growth of 1.18 per cent per year for 1954-73, for which our average estimate is 0.94 per cent, and –0.54 per cent for 1974-86, a period for which our average estimate is 0.54. Given that the data sets used are not identical, we are encouraged by the similarity of these figures.

4. Discussion

Unlike the conventional growth accounting results in Table 1, the estimates in Tables 5 and 7 show higher TFP growth in both countries after 1973. The results are not strictly comparable because we have worked with gross output and the dual measure of TFP, whereas O'Mahony (1999) was based on value added, but our primal measure also shows faster TFP growth after 1973 in both cases. The differences come primarily from our use of estimated cost functions rather than an imposed Cobb–Douglas production function.

In both countries, however, our results suggest that crude TFP estimates, which are not corrected for biases resulting from scale economies, fixed factors and adjustment costs, are a very poor guide to the 'true TFP', which is obtained when those biases have been eliminated and which may be thought of as a better measure of the contribution of innovation to productivity growth. Our 'true TFP' estimates ($-\varepsilon_{Ct}^{T}$) are, for the pre-1973 and post-1973 periods, 4.25 and 2.69 per cent per year, respectively, in Germany, and 3.74 and 2.68 per cent per year, respectively, in the U.K. An appreciable decline in the contribution of innovation between the two periods is precisely what economic historians would expect, since the scope for further catch-up had been much reduced by the 1970s when the United States was in its notorious TFP growth slowdown during the hiatus between the end of the Fordist era and the full onset of the New Economy.

Our results are consistent with those of other quantitative studies, based on rather different methodologies, that have queried the apparent strength of TFP growth in U.K. manufacturing in the 1980s and concluded that it may not represent an acceleration of technological progress compared with earlier decades (Darby and Wren-Lewis, 1991; Lynde and Richmond, 2000). Our conclusion is, however, much stronger in that we find a large decrease in the rate of innovation. In fact our results are more similar to those of Cameron (1999) who, after adjusting for various biases, found that trend TFP growth fell from 3.04 per cent per year in 1960-73 to an average of 2.47 per cent per year between 1973 and 1995.

With regard to comparisons between the U.K. and West Germany, 'true TFP' shows somewhat faster growth in Germany in the early postwar period but that performance was fairly similar after 1973. Broadly speaking, this is a similar picture to the conventional growth accounting estimates in O'Mahony (1999). It also matches the results obtained from a growth accounting exercise in terms of levels which explicitly considered the contribution in 1979 and 1999 of skills and research and development to labour productivity in Britain and Germany and found that the gap between the two countries was virtually unchanged (Crafts and O'Mahony, 2001).

Our estimates suggest that the total bias was large in the early postwar period in both countries, that it then changes sign in the U.K. and becomes much smaller in Germany, and that crude TFP growth comparisons are seriously misleading. In both countries there are diseconomies of scale, correcting for which raises the true TFP growth estimate. But the really big corrections come from dynamic adjustment costs in the Golden Age and from the switch of sign from positive to negative in the U.K.'s adjustment costs term after 1973.

In our model, the impact of dynamic adjustment costs arises from factors external to the firm. In particular, it is the rising price of capital goods that tends to choke off the full realization of potential TFP gains from technological progress. It is then not surprising to find a big effect in the early postwar period and that this should have decreased markedly more recently. In small open economies with competitive markets the supply of capital goods can be expected to be elastic. By contrast, the world of the 1950s and 1960s predates the late twentieth century globalization era and was a time when complaints about the physical supply limitations on investment were a commonplace in western Europe (United Nations, 1964).

Average values of Tobin's *Q* are consistent with this picture. In the recent past they have been low. Eberly (1997) reported an average over 1981-94 for Germany of 0.73 and for the U.K. of 1.09. By contrast, for the 1960s Oulton (1981) found an average of 1.45 for the U.K. and Chan-Lee (1986) reported an average of 1.39 for West Germany. These estimates are not strictly comparable, but the clear impression is of a large backlog of projects that would have been profitable based on a comparison between the costs of capital (in the absence of adjustment costs) and stock market valuations in the earlier, but not in the more recent, period.

Tables 4 and 6 report estimates of the price cost markup, $1/(1+\varepsilon_{PY})$. They show striking changes over time in the U.K. case, where the estimates fall from an average of well over 2 in the 1950s and 1960s to around 1.1 after 1980, while the estimates for West Germany remain in the range 1 to 1.1 throughout. The finding of a high markup for early postwar Britain is not very surprising, given the prevalence of cartels and the weakness of import penetration (Broadberry and Crafts, 2001). In view of the results obtained by Nickell et al. (1997) on the handicap that corporate governance problems imposed on British firms in the absence of competition, it is quite reasonable to suppose that the post Golden Age weakening of market power in the U.K. would have speeded up productivity growth, ceteris paribus, driven especially by much stronger competition from imports. This could have been either because cost curves fell faster as a backlog of available innovations were adopted and/or because firms now reduced organizational slack and adjusted to the bottom of the long run average cost curve. No such impact would be expected in West Germany because of the relative absence both of agency problems in firms and of early postwar market power. This may at least partly explain the greater fall in true TFP growth in Germany after 1973.

There are good reasons to think that market power did hold back innovation in the U.K., since a series of studies using the Science Policy Research Unit innovations database have all found that the adverse effect of competition on expected returns to innovation was more than offset by its positive effect on managerial innovative effort (Blundell et al., 1999, Broadberry and Crafts, 2001, Geroski, 1990). Nevertheless, our estimates suggest that the advent of greater competition in the recent past has only been sufficient to allow the U.K. to match Germany's performance in 'true TFP' growth. This is presumably because Germany has had other advantages in terms of human capital, R & D, etc., which relate to other aspects of incentive structures that have tended to promote long term investments (Carlin and Soskice, 1997). Seen in this light, traditional judgements on the relative merits of national innovation systems in the two countries may still have some validity.

5. Conclusions

Our answers to the questions raised in the introduction are as follows.

(1) Overall, these estimates suggest that it is important to worry about biases in traditional estimates of TFP – more so than seems generally to be appreciated. Working with the dual measure of TFP growth in manufacturing, using prices rather than quantities, we found that both in the U.K. and in West Germany there was a total bias of over 2 per cent per year in the early postwar period. It is important also to recognize that such biases are not constant across time and place but depend on circumstances.

(2) The size of the bias is fairly similar in each period in both countries but changes over time. Thus, there is no reason to reject the benchmark rankings of British and German TFP performance that have been made on the basis of conventional growth accounting. On the other hand, comparisons over time in each country need to be handled with great care and conventional procedures do run the risk of substantial error. Our results suggest that the early postwar 'Golden Age' might have been better still had the European catch up taken place in an era of greater globalization in which the supply of capital goods was more elastic.

(3) Our results include estimates of price cost markups. We find that in the U.K. there was substantial market power in manufacturing in the early postwar period but not in recent decades. In a context of British failures of corporate governance, it seems plausible that increasing competition has been an important factor in narrowing the gap in TFP growth between British and German manufacturing since the 1970s. The recent (belated) recognition by policymakers that competition policy can be an important part of the agenda to reduce the British productivity gap is welcome.

Data Appendix

The sources of data were as follows.

United Kingdom

Y: Real gross output (£1990 bn) derived from nominal series supplied by Mary O'Mahony deflated using wholesale prices from the *Historical Record of the Census of Production* (1950-70) and the *Annual Abstract of Statistics* thereafter.

p_Y : Price of output as above.

x_l : Total hours worked from O'Mahony (1999, Tables B and C).

w_l : Money wage rate derived from the share of wages in value added (O'Mahony, 1999, Table F) multiplied by nominal value added from Mitchell (1988, pp. 824-5) to 1980 and thereafter *UK National Accounts* (1997), divided by total hours worked, as above.

x_m : Energy inputs (bn tonnes oil equivalent) from *Digest of Energy Statistics*; series extended back from 1960 using energy inputs/total GDP to infer movements in energy inputs.

w_m : Price of energy based on fuel price index for industry from *Digest of Energy Statistics* extended back beyond 1970 using retail price of fuel and light from Mitchell (1988, p. 740).

k: Real net capital stock from O'Mahony (1999 Table E) converted into £1990 bn using *UK National Accounts* (1997).

x: Real net social overhead capital stock in £1990 bn from *UK National Accounts* various issues.

b: Gross fixed investment from *UK National Accounts* and before 1965 from Feinstein (1972, Table 42).

w_b : Price of capital goods from *UK National Accounts* and before 1965 from Feinstein (1972, Table 61).

δ: Depreciation rate from O'Mahony (1999, p. 40) assumed constant and based on 55 percent weight for equipment and 45% for structures.

i: Nominal interest rate using consols from Mitchell (1988, p. 678) and after 1980 long-dated British government securities from *Economic Trends*.

$r = w_b(\pi^e + \delta)$, where π^e is the forecasted capital goods inflation from a first order autoregression of $\pi = (wb - wb(-1))/wb(-1)$.

West Germany

Y: Real gross output (DM 1995 bn) derived from nominal series in *Volkswirtschaftliche Gesamttrechnung FS 18* deflated using producer prices from *Volkswirtschaftliche Gesamtrechnung FS 17*.

p_Y: Price of output as above.

x_l: Total hours worked from O'Mahony (1999, Tables B and C).

w_l: Money wage rate derived from the share of labour in value added in O'Mahony (1999, Table F) multiplied by nominal value added from *Volkswirtschaftliche Gesamtrechnung FS 18* and divided by total hours worked, as above.

x_m: Total energy inputs (bn tonnes of oil equivalent) based on *Volkswirtschaftliches Gesamtrechnung FS 4* from 1980 linked to industrial consumption of energy from OECD, *Energy Balances of OECD Countries* for 1960 to 1979; pre-1960 energy use is assumed to have been a constant ratio to output.

w_m: Price of energy after 1980 based on price of electricity to industry from International Energy Agency, Energy Prices and Taxes and before 1980 on index of coal, gas, electricity and petroleum constructed from *Volkswirtschaftliches Gesamtrechnung FS 17*.

k: Real net capital stock from O'Mahony (1999, Table E) converted into DM 1995 bn using *Volkswirtschaftliches Gesamtrechnung FS 18*.

x: Real net social overhead capital stock from DIW, *Verkehr in Zahlen* (2000).

b: Gross fixed investment from *Volkswirtschaftliches Gesamtrechnung FS18* assunimg share of manufacturing in total private investment before 1960 constant at 1960/5 average.

w_b: Price of capital goods from *Volkswirtschaftliches Gesamtrechnung FS 17* with adjustment to pre-1955 series to match subsequent revisions made for later years.

δ: Depreciation rate from O'Mahony (1999, p. 40) assumed constant and based on 64 per cent weight for equipment and 36 per cent for structures.

i: Nominal interest rate from government bond yield reported in IMF, *Financial Statistics.*

$r = w_b(\pi^e + \delta)$, where π^e is the forecasted capital goods inflation from a second order autoregression of $\pi = (wb - wb(-1))/wb(-1)$.

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Table 1.

Sources of Manufacturing Labour Productivity Growth (% per year)

	1950-73	**1973-95**
Growth of Output/Hour Worked		
West Germany	6.62	2.93
UK	4.69	2.54
Growth of Capital/Hour Worked		
West Germany	6.55	3.49
UK	4.39	3.35
TFP Growth		
West Germany	4.12	1.89
UK	3.28	1.85

Source: O'Mahony (1999)

Table 2

U.K. Estimates of System (11)

Equation	x_l/Y	x_m/Y
α_{ii}	2.046 (9.02)	2.629 (8.69)
α_{ij}	-	-0.462 (3.86)
β_{iy}	-	-
β_{it}	-	-0.089 (3.13)
β_{ib}	-	-
β_{ix}	-8.951 (7.32)	-7.383 (5.12)
β_{ik}	-	-
γ_{yy}	-1.200 (4.86)	
γ_{tt}	-	
γ_{bb}	-	
γ_{xx}	-	
γ_{yt}	-	
γ_{yb}	-	
γ_{yx}	5.636 (4.88)	
γ_{tb}	-	
γ_{tx}	0.137 (3.53)	
γ_{bx}	-	
γ_{yk}	-	
γ_{tk}	-0.099 (6.30)	
γ_{bk}	-	
γ_{xk}	2.109 (7.85)	
γ_{kk}	-	
ρ	-	0.804 (13.22)
R^2	0.996	0.992
$\hat{\sigma}$	0.0055	0.0172

Absolute *t*-ratios are in parentheses. ρ is the first-order autoregressive error coefficient. $\hat{\sigma}$ is the regression standard error.

Table 3

German Estimates of System (11)

Equation	x_l / Y	x_m / Y
α_{ii}	-4.603 (3.46)	-
α_{ij}	-	-0.331 (3.27)
β_{iy}	18.71 (2.67)	18.62 (2.65)
β_{it}	-	-0.181 (2.58)
β_{ib}	-13.68 (2.19)	-15.20 (2.42)
β_{ix}	-16.64 (1.49)	-19.25 (1.72)
β_{ik}	-4.060 (2.68)	3.806 (2.62)
γ_{yy}	-4.726 (2.86)	
γ_{tt}	0.062 (2.02)	
γ_{bb}	-	
γ_{xx}	-	
γ_{yt}	-	
γ_{yb}	-	
γ_{yx}	17.07 (2.64)	
γ_{tb}	-	
γ_{tx}	-2.673 (2.94)	
γ_{bx}	-	
γ_{yk}	-14.44 (2.83)	
γ_{tk}	0.736 (4.17)	
γ_{bk}	9.680 (2.21)	
γ_{xk}	11.14 (1.53)	
γ_{kk}	-1.639 (1.76)	
ρ	0.922 (49.87)	0.324 (2.36)
R^2	0.999	0.995
$\hat{\sigma}$	0.0098	0.0306

Absolute *t*-ratios are in parentheses. ρ is the first-order autoregressive error coefficient. $\hat{\sigma}$ is the regression standard error.

Table 4.
U.K. Primal TFP Growth and its Components

	(1) $-\varepsilon_{Ct}$	(2) $-\varepsilon_{CY}^{L}$	(3) CU	(4) ε_{CY}	(5) $1/(1+\varepsilon_{PY})$	(6) ADJ	(7) ε_{Yt}	(8) $\varepsilon_{Yt}/(1+\varepsilon_{PY})$
1953	3.376	1.189	0.980	1.166	1.992	2.322	1.454	2.896
1954	3.946	1.181	0.986	1.164	2.182	2.539	1.554	3.391
1955	1.803	1.172	0.985	1.155	2.273	2.625	0.687	1.561
1956	-1.085	1.162	0.987	1.147	2.218	2.545	-0.427	-0.946
1957	-0.147	1.154	0.989	1.142	2.198	2.509	-0.059	-0.129
1958	-0.285	1.148	0.990	1.137	2.257	2.566	-0.111	-0.251
1959	2.401	1.144	0.991	1.134	2.371	2.688	0.893	2.117
1960	1.608	1.143	0.992	1.134	2.622	2.972	0.541	1.418
1961	-1.757	1.137	0.992	1.128	2.490	2.809	-0.626	-1.558
1962	-2.064	1.132	0.992	1.123	2.404	2.699	-0.765	-1.838
1963	0.573	1.129	0.993	1.121	2.490	2.791	0.205	0.511
1964	4.921	1.131	0.994	1.123	2.750	3.090	1.593	4.380
1965	-1.054	1.128	0.994	1.121	2.683	3.008	-0.350	-0.940
1966	0.100	1.125	0.994	1.118	2.614	2.924	0.034	0.089
1967	-0.261	1.122	0.995	1.116	2.598	2.898	-0.090	-0.234
1968	3.329	1.122	0.995	1.116	2.710	3.025	1.101	2.983
1969	3.625	1.123	0.995	1.117	2.825	3.156	1.149	3.245
1970	0.455	1.122	0.995	1.117	2.677	2.989	0.152	0.407
1971	-3.242	1.117	0.995	1.112	2.265	2.518	-1.287	-2.916
1972	0.320	1.115	0.996	1.110	2.152	2.390	0.134	0.288
1973	5.539	1.118	0.996	1.113	2.201	2.450	2.261	4.975
1974	5.002	1.117	0.996	1.112	1.833	2.039	2.453	4.496
1975	-6.691	1.110	0.996	1.105	1.523	1.683	-3.976	-6.054
1976	1.909	1.110	0.996	1.106	1.435	1.587	1.203	1.726
1977	-2.118	1.107	0.997	1.103	1.330	1.467	-1.443	-1.919
1978	0.482	1.105	0.997	1.101	1.295	1.427	0.338	0.438
1979	0.418	1.104	0.997	1.101	1.267	1.395	0.299	0.379
1980	-0.855	1.099	0.996	1.095	1.207	1.321	-0.648	-0.782
1981	-4.992	1.093	0.996	1.089	1.169	1.273	-3.922	-4.584
1982	2.585	1.091	0.997	1.088	1.152	1.252	2.064	2.377
1983	5.937	1.091	0.997	1.087	1.146	1.246	4.763	5.461
1984	6.648	1.091	0.997	1.088	1.143	1.244	5.345	6.111
1985	1.902	1.091	0.997	1.088	1.138	1.238	1.536	1.748
1986	-3.144	1.088	0.997	1.085	1.127	1.222	-2.573	-2.899
1987	8.138	1.090	0.998	1.087	1.132	1.231	6.613	7.485
1988	5.075	1.092	0.998	1.089	1.135	1.236	4.106	4.659
1989	3.408	1.092	0.998	1.090	1.133	1.234	2.761	3.127
1990	-3.641	1.090	0.998	1.087	1.121	1.219	-2.988	-3.350
1991	-9.003	1.085	0.998	1.082	1.104	1.195	-7.536	-8.319
1992	3.162	1.084	0.998	1.081	1.101	1.190	2.657	2.924
1993	2.134	1.083	0.998	1.081	1.098	1.187	1.798	1.974
1994	8.032	1.085	0.998	1.083	1.101	1.192	6.735	7.419
1995	5.080	1.086	0.998	1.084	1.102	1.194	4.255	4.688
1996	1.483	1.086	0.998	1.084	1.101	1.193	1.243	1.369

Note: Col. (1) is "traditional TFP growth". Col. (4) = Col. (2) $\times$ Col. (3); Col. (6) = Col. (4) $\times$ Col. (5); Col. (7) = Col. (1) $\div$ Col. (6); Col. (8) = Col. (5) $\times$ Col. (7).

Table 5

U.K. Cost Dual TFP Growth: Traditional and Corrected

($-\varepsilon_{Ct}$ is "traditional TFP growth")

	$-\varepsilon_{Ct}$	$-\varepsilon_{Ct}^{R}$	Bias	$-\varepsilon_{Ct}^{F}$	Bias	$-\varepsilon_{Ct}^{A}$	Bias	$-\varepsilon_{Ct}^{T}$	Bias
1954	3.450	5.145	1.695	3.359	-0.091	5.249	1.799	5.089	1.639
1955	5.885	6.955	1.070	5.848	-0.037	4.092	-1.793	3.984	-1.901
1956	-0.241	0.044	0.284	-0.205	0.036	1.947	2.188	1.921	2.161
1957	1.891	2.190	0.299	1.932	0.041	4.253	2.362	4.228	2.337
1958	0.670	1.123	0.453	0.696	0.025	3.382	2.712	3.347	2.677
1959	3.265	3.930	0.665	3.262	-0.003	5.681	2.416	5.633	2.368
1960	0.677	1.768	1.091	0.643	-0.034	3.197	2.520	3.123	2.446
1961	-0.203	-0.192	0.012	-0.159	0.045	1.946	2.150	1.945	2.149
1962	-0.451	-0.447	0.004	-0.395	0.056	2.676	3.127	2.676	3.127
1963	1.257	1.675	0.418	1.268	0.012	3.761	2.505	3.734	2.478
1964	4.607	5.725	1.118	4.568	-0.039	6.776	2.169	6.713	2.106
1965	-0.973	-0.664	0.309	-0.965	0.008	0.961	1.933	0.944	1.916
1966	1.325	1.502	0.177	1.347	0.022	3.802	2.477	3.792	2.468
1967	0.816	0.857	0.042	0.839	0.023	2.879	2.063	2.877	2.061
1968	3.594	4.344	0.750	3.580	-0.014	5.953	2.360	5.917	2.324
1969	4.116	4.913	0.797	4.103	-0.012	6.789	2.673	6.751	2.636
1970	1.187	1.607	0.420	1.192	0.005	3.708	2.521	3.690	2.503
1971	-1.450	-1.799	-0.349	-1.413	0.036	0.324	1.773	0.340	1.790
1972	1.328	1.491	0.164	1.334	0.006	2.519	1.191	2.512	1.184
1973	4.536	5.572	1.036	4.504	-0.032	5.684	1.148	5.645	1.109
1974	9.251	9.590	0.339	9.246	-0.004	9.747	0.497	9.734	0.484
1975	-2.859	-3.761	-0.902	-2.812	0.047	-1.745	1.114	-1.707	1.152
1976	2.513	2.901	0.389	2.503	-0.009	2.315	-0.198	2.300	-0.212
1977	3.871	3.655	-0.215	3.878	0.008	-1.706	-5.577	-1.699	-5.570
1978	6.749	6.768	0.019	6.751	0.003	1.900	-4.849	1.899	-4.850
1979	0.684	0.954	0.269	0.681	-0.003	1.322	0.638	1.313	0.628
1980	6.864	6.104	-0.760	6.900	0.036	5.876	-0.988	5.907	-0.957
1981	-3.623	-4.379	-0.756	-3.593	0.029	-4.635	-1.012	-4.602	-0.979
1982	3.943	3.798	-0.145	3.939	-0.004	0.604	-3.339	0.610	-3.333
1983	7.405	7.606	0.201	7.390	-0.015	4.718	-2.686	4.711	-2.694
1984	7.160	7.540	0.380	7.141	-0.019	5.690	-1.470	5.676	-1.484
1985	1.699	1.913	0.214	1.691	-0.007	1.715	0.016	1.708	0.009
1986	-2.570	-2.901	-0.331	-2.557	0.013	-2.318	0.252	-2.307	0.264
1987	8.952	9.622	0.670	8.935	-0.017	9.980	1.029	9.960	1.009
1988	5.150	5.735	0.585	5.138	-0.012	6.644	1.494	6.628	1.478
1989	5.226	5.562	0.336	5.223	-0.003	7.491	2.266	7.482	2.256
1990	-1.885	-2.108	-0.223	-1.870	0.014	0.560	2.445	0.567	2.452
1991	-7.512	-8.239	-0.727	-7.486	0.025	-6.951	0.561	-6.929	0.583
1992	4.833	4.858	0.025	4.832	-0.001	4.277	-0.556	4.276	-0.557
1993	2.310	2.410	0.100	2.306	-0.004	1.719	-0.592	1.716	-0.595
1994	8.906	9.404	0.497	8.891	-0.016	8.215	-0.691	8.201	-0.705
1995	6.027	6.391	0.364	6.017	-0.010	4.881	-1.146	4.872	-1.155
1996	1.361	1.552	0.191	1.356	-0.004	1.419	0.058	1.414	0.053

Means

	$-\varepsilon_{Ct}$	$-\varepsilon_{Ct}^{R}$	Bias	$-\varepsilon_{Ct}^{F}$	Bias	$-\varepsilon_{Ct}^{A}$	Bias	$-\varepsilon_{Ct}^{T}$	Bias
54-96	2.552	2.807	0.255	2.554	0.002	3.193	0.641	3.177	0.624
54-73	1.764	2.287	0.523	1.767	0.003	3.779	2.105	3.743	1.979
74-96	3.237	3.260	0.023	3.239	0.002	2.683	-0.554	2.684	-0.553

Table 6: Germany Primal TFP Growth and its Components

	(1) $-\varepsilon_{Ct}$	(2) $-\varepsilon_{CY}^{L}$	(3) CU	(4) ε_{CY}	(5) $1/(1+\varepsilon_{PY})$	(6) ADJ	(7) ε_{Yt}	(8) $\varepsilon_{Yt}/(1+\varepsilon_{PY})$
1953	-0.370	1.381	1.008	1.392	1.027	1.429	-0.259	-0.266
1954	-0.290	1.328	1.008	1.339	1.031	1.381	-0.210	-0.217
1955	-0.003	1.296	1.006	1.304	1.035	1.350	-0.002	-0.002
1956	1.613	1.273	1.002	1.277	1.038	1.325	1.217	1.263
1957	1.331	1.255	1.002	1.257	1.039	1.306	1.019	1.059
1958	1.916	1.239	1.004	1.244	1.042	1.296	1.479	1.540
1959	0.460	1.227	1.004	1.233	1.046	1.290	0.357	0.373
1960	1.015	1.221	1.004	1.225	1.051	1.288	0.788	0.829
1961	3.554	1.214	1.004	1.219	1.051	1.281	2.774	2.916
1962	4.992	1.208	1.002	1.211	1.056	1.279	3.904	4.123
1963	1.581	1.201	1.003	1.204	1.058	1.274	1.241	1.313
1964	1.988	1.198	1.003	1.201	1.062	1.276	1.558	1.655
1965	5.959	1.195	1.002	1.198	1.067	1.278	4.661	4.975
1966	-4.478	1.190	1.003	1.193	1.065	1.271	-3.523	-3.753
1967	-2.306	1.183	1.003	1.187	1.066	1.265	-1.824	-1.944
1968	9.702	1.183	1.001	1.184	1.078	1.277	7.600	8.192
1969	5.205	1.184	1.000	1.184	1.087	1.286	4.046	4.398
1970	8.760	1.184	1.001	1.185	1.090	1.292	6.781	7.390
1971	2.012	1.182	1.000	1.182	1.088	1.286	1.565	1.702
1972	0.428	1.179	1.000	1.179	1.089	1.284	0.333	0.363
1973	-0.131	1.178	0.999	1.176	1.088	1.280	-0.102	-0.111
1974	-1.115	1.173	0.999	1.171	1.077	1.261	-0.884	-0.952
1975	7.818	1.167	1.000	1.167	1.071	1.249	6.257	6.701
1976	2.719	1.166	0.999	1.166	1.075	1.253	2.171	2.333
1977	1.186	1.163	1.000	1.163	1.073	1.248	0.950	1.019
1978	1.831	1.161	0.999	1.160	1.075	1.248	1.468	1.578
1979	-1.099	1.161	1.000	1.161	1.075	1.248	-0.881	-0.947
1980	10.720	1.158	1.001	1.159	1.070	1.241	8.639	9.248
1981	-5.791	1.155	1.001	1.156	1.065	1.231	-4.705	-5.011
1982	1.942	1.150	1.001	1.152	1.060	1.221	1.591	1.686
1983	6.289	1.148	1.001	1.149	1.060	1.218	5.165	5.472
1984	0.314	1.147	1.001	1.148	1.060	1.217	0.258	0.274
1985	2.487	1.146	1.001	1.147	1.061	1.217	2.043	2.168
1986	5.215	1.145	1.001	1.146	1.064	1.219	4.276	4.550
1987	0.220	1.143	1.001	1.145	1.065	1.219	0.181	0.192
1988	1.666	1.143	1.001	1.144	1.066	1.220	1.366	1.457
1989	3.181	1.144	1.000	1.144	1.067	1.221	2.605	2.781
1990	9.961	1.145	1.000	1.145	1.070	1.225	8.131	8.702
1991	8.091	1.145	1.000	1.145	1.072	1.228	6.590	7.066
1992	-0.493	1.143	1.000	1.143	1.070	1.223	-0.403	-0.431
1993	-3.505	1.138	1.000	1.138	1.065	1.211	-2.894	-3.081
1994	2.961	1.136	1.000	1.136	1.066	1.210	2.447	2.608
1995	2.619	1.135	0.999	1.134	1.066	1.209	2.165	2.309
1996	1.716	1.133	1.000	1.132	1.066	1.207	1.422	1.516

Note: Col. (1) is "traditional TFP growth". Col. (4) = Col. (2) × Col. (3); Col. (6) = Col. (4) × Col. (5); Col. (7) = Col. (1) ÷ Col. (6); Col. (8) = Col. (5) × Col. (7).

Table 7

German Cost Dual TFP Growth: Traditional and Corrected

($-\varepsilon_{Ct}$ is "traditional TFP growth")

	$-\varepsilon_{Ct}$	$-\varepsilon_{Ct}^{R}$	Bias	$-\varepsilon_{Ct}^{F}$	Bias	$-\varepsilon_{Ct}^{A}$	Bias	$-\varepsilon_{Ct}^{T}$	Bias
1954	0.385	4.108	3.723	0.395	0.010	5.327	4.941	5.446	5.061
1955	1.035	5.238	4.203	1.048	0.014	6.564	5.530	6.680	5.646
1956	0.182	2.338	2.156	0.176	-0.006	2.749	2.567	2.773	2.591
1957	-1.119	-0.013	1.106	-1.126	-0.007	0.396	1.515	0.406	1.525
1958	3.019	4.321	1.302	3.012	-0.007	3.185	0.166	3.215	0.196
1959	0.880	2.944	2.064	0.889	0.009	3.942	3.062	3.991	3.111
1960	1.319	3.900	2.581	1.326	0.007	5.071	3.752	5.123	3.805
1961	1.908	2.746	0.838	1.886	-0.022	4.262	2.354	4.281	2.373
1962	3.950	5.436	1.486	3.948	-0.002	6.258	2.308	6.277	2.326
1963	0.892	1.490	0.598	0.885	-0.006	2.026	1.134	2.035	1.143
1964	2.205	3.876	1.671	2.211	0.006	4.721	2.516	4.750	2.545
1965	5.677	7.538	1.861	5.681	0.004	8.408	2.731	8.430	2.753
1966	-4.742	-4.924	-0.182	-4.761	-0.019	-3.924	0.818	-3.927	0.815
1967	-2.281	-2.349	-0.067	-2.289	-0.008	-1.974	0.307	-1.975	0.306
1968	9.997	12.755	2.758	10.009	0.012	12.893	2.896	12.911	2.914
1969	5.286	7.524	2.238	5.283	-0.002	6.868	1.583	6.862	1.577
1970	9.681	11.109	1.428	9.680	0.000	12.138	2.458	12.146	2.466
1971	2.554	2.910	0.356	2.552	-0.002	3.231	0.678	3.232	0.678
1972	1.180	1.827	0.647	1.180	0.000	1.295	0.115	1.294	0.114
1973	0.132	1.175	1.043	0.128	-0.004	1.108	0.976	1.100	0.968
1974	0.341	0.235	-0.106	0.343	0.002	-1.366	-1.707	-1.365	-1.706
1975	6.831	6.183	-0.648	6.833	0.002	5.953	-0.878	5.955	-0.876
1976	3.046	4.357	1.311	3.040	-0.005	4.129	1.083	4.122	1.076
1977	1.434	1.600	0.166	1.434	0.000	1.225	-0.209	1.225	-0.209
1978	1.983	2.502	0.519	1.982	-0.001	2.197	0.214	2.195	0.211
1979	0.036	0.849	0.813	0.036	0.000	0.421	0.385	0.421	0.384
1980	9.342	9.436	0.094	9.341	-0.001	9.667	0.325	9.667	0.325
1981	-5.127	-5.403	-0.276	-5.129	-0.003	-5.408	-0.281	-5.410	-0.283
1982	0.851	0.355	-0.496	0.846	-0.005	0.167	-0.684	0.162	-0.689
1983	5.795	5.997	0.202	5.797	0.002	5.611	-0.183	5.613	-0.181
1984	0.996	1.533	0.537	0.999	0.003	1.404	0.408	1.408	0.412
1985	2.410	2.972	0.562	2.412	0.002	3.489	1.079	3.493	1.083
1986	4.303	4.588	0.285	4.303	-0.001	5.357	1.054	5.359	1.056
1987	-0.217	-0.103	0.114	-0.219	-0.002	0.924	1.141	0.926	1.142
1988	1.570	2.124	0.554	1.571	0.001	2.716	1.146	2.719	1.149
1989	2.933	3.584	0.651	2.934	0.000	4.005	1.072	4.007	1.074
1990	9.855	10.630	0.774	9.855	0.000	10.275	0.420	10.276	0.421
1991	8.971	9.675	0.704	8.970	0.000	8.436	-0.534	8.435	-0.536
1992	-0.268	-0.450	-0.182	-0.267	0.001	-0.884	-0.615	-0.883	-0.615
1993	-3.506	-4.539	-1.033	-3.506	0.000	-5.005	-1.499	-5.005	-1.498
1994	2.938	3.243	0.304	2.937	-0.001	3.642	0.703	3.641	0.703
1995	2.686	3.034	0.348	2.685	-0.002	2.974	0.287	2.972	0.286
1996	1.823	1.818	-0.004	1.822	0.000	1.857	0.034	1.857	0.034

Means

	$-\varepsilon_{Ct}$	$-\varepsilon_{Ct}^{R}$	Bias	$-\varepsilon_{Ct}^{F}$	Bias	$-\varepsilon_{Ct}^{A}$	Bias	$-\varepsilon_{Ct}^{T}$	Bias
54-96	2.353	3.213	0.861	2.352	-0.001	3.403	1.050	3.415	1.063
54-73	2.107	3.697	1.591	2.106	-0.001	4.227	2.120	4.252	2.146
74-96	2.566	2.792	0.226	2.566	0.000	2.686	0.120	2.686	0.120

Figure 1. Adjusting for measurement biases.