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Zusammenfassung

Die Hypothese eines langfristigen Rückgangs der Totalen Faktorproduktivität (TFP) bzw. eines Strukturbruchs in der Produktivitätsentwicklung seit Mitte der 70er Jahre wird für die Branchen des Verarbeitenden Gewerbes der Bundesrepublik Deutschland im Rahmen eines ökonometrisches Modells auf Basis einer flexiblen Kostenfunktion mit Kapital als quasi-fixem Faktor getestet. Diese Hypothese wird durch die Ergebnisse der vorliegenden Untersuchung für den Großteil der untersuchten Branchen nicht bestätigt: Bereinigt man das traditionell berechnete primale Maß für das Wachstum der TFP (das Solow-Residuum) um Skaleneffekte und variierende Kapazitätsauslastung, ist das Produktivitätswachstum weitgehend konstant verlaufen. Die Hypothese, daß die TFP einem Random Walk mit positivem Zeittrend folgt, kann aufgrund verschiedener statistischer Tests nicht verworfen werden.

Abstract

We test the hypothesis of a negative long-term trend and/or a structural break in total factor productivity (TFP) after the first oil price shock for West-German manufacturing industries within an econometric model based on a flexible cost function with capital as a quasi-fixed factor. This hypothesis is not supported by our empirical findings for the great majority of industries studied: After adjusting the traditional primal TFP growth measure (the Solow-residual) for scale economies and varying capacity utilization, "true" productivity growth is shown to have remained fairly constant within the observation period. The hypothesis that TFP follows a random walk with drift is not rejected by various statistical tests.

I. Introduction

It is conventional wisdom that productivity growth has slowed down in most market economies since the mid-seventies. The main culprit for the alleged productivity slowdown is usually seen in negative supply shocks emanating from the huge increases of raw material prices in the seventies which rendered part of the existing capital stock obsolete. This popular view seems more or less compatible with the stylized facts obtained from empirical studies on total factor productivity (TFP) growth as measured by the famous Solow-residual or related measures in advanced market economies (see e.g. Baily 1981, 1982; Griliches and Mairesse 1983; Bruno 1984; Denison 1984; Maddison 1984; Berndt and Wood 1986; Jorgenson 1988; Englander and Mittelstädt 1988). Although a wide variety of hypotheses have been proposed to explain the "productivity puzzle", not much of a consensus seems to have emerged (for a wide-ranging survey and some relevant facts see especially Berndt and Wood, 1986).

Most of these studies do not adequately account for the potential effects the recessions following the first and second oil price shocks may have had on productivity growth as they usually rule out scale economies and varying capacity utilization. These factors which have only recently received due attention in empirical studies of TFP growth and as possible "explanations" for the alleged procyclical behavior of the Solow-residual (Morrison 1989; Hall 1989) will therefore feature prominently in the present study.

The existing literature on TFP growth measurement makes use of a variety of methodologies. First, the most popular approach is still the index or growth accounting method due to Solow (1957), where the main business since then has been to narrow down the Solow-residual by including a great number of factors into the production function framework (see e.g. Denison 1984). The index approach has recently been extended by Berndt and Fuss (1986) and Hulten (1986) to incorporate quasi-fixed factors of production and by Hall (1987, 1989) to account for imperfect competition and increasing returns to scale. Second, there is the econometric approach based on duality theory and flexible cost functions allowing both for variable returns to scale and quasi-fixed factors of production (Morrison 1986, 1989). Third, there are the recent studies by Harvey et al. (1986) and Slade (1989) who treat TFP as an unobserved variable which is estimated by statistical time-series techniques.

The present study is based on the econometric approach. Compared to the two alternative approaches, it allows for a rather more flexible modeling of the underlying production technology and the incorporation of capital as a quasi-fixed factor of production by making use of some well-known duality concepts. Following Morrison (1989) we derive traditional and adjusted dual TFP growth measures allowing for scale economies and varying capacity utilization. As Morrison (1989) has shown for the aggregate manufacturing sectors of the U.S., Japan and Canada, adjusting the dual of the Solow-residual for scale economies and capacity utilization has a substantial impact on measured productivity growth. In particular, she shows that for the U.S. the heralded productivity slowdown virtually disappears in the adjusted measure.

We apply this approach to West-German two-digit industries comprising the majority of the manufacturing sector of the national economy within the period 1960 to 1985. This reasonably disaggregated analysis allows us to control for compositional effects emanating from structural change and to identify true productivity growth at the sectoral level, the importance of which has been stressed, inter alia, by Baily (1982) and more recently by Jorgenson (1988). To this end, we estimate a rather general cost function together with the derived demand functions for variable inputs and a price function for industry output within a four equation system. From the estimated structural parameters of the cost function we derive measures of scale economies and capacity utilization which are used to adjust TFP growth at the industry level.

We infer from our empirical results that ignoring scale economies and varying capacity utilization will severely bias traditional measures of sectoral TFP growth. In paricular, we show that with respect to the adjusted measure there is no evidence for a long-term slowdown or a structural break in TFP growth at the industry level. We also test the popular hypothesis that adjusted TFP growth behaves procyclically, reject it for the great majority of industries, and briefly discuss possible implications of this result for recently popular real business-cycle theories. Finally, we conclude that the (log-)level of TFP in the great majority of West-German manufacturing industries can successfully be modelled as a random walk with drift.

The paper is structured as follows. In the next section the theoretical framework with special reference to the derivation of the cost flexibility and capacity utilization measures used to adjust the traditional TFP growth index (the Solow-residual) is explained in some detail. The subsequent section sets out the econometric specification and derives the estimating equations of the empirical model. The results of the present study are presented and discussed in section IV, and the main conclusions of the paper are summarized in section V. The appendix contains a short data description and some additional results on estimation and model evaluation.

II. Theoretical Framework

Following recent work by Morrison (1989) we estimate sectoral TFP growth within an econometric model based on a flexible cost function which allows both for scale economies and short-run fixity of capital. Let Y = Y(X, K, t) denote the industry production function characterizing how output Y depends on a vector of variable inputs, X, the stock of the quasi-fixed input capital, K, and a time index t representing the state of technology. It will be assumed that the variable inputs can be aggregated into labor L and materials M, with prices w and v. For the labor input variable we use total yearly hours actually worked in an industry. Although a somewhat restrictive assumption as this implies equal elasticities of workers and hours with respect to output, it allows us to treat labor as a variable input within the period under consideration, which will be a year in the empirical model. Immediate adjustment of the capital stock to its optimal level is assumed to be not economically feasible due to increasing costs of adjustment which are treated external to the industry.

If the production function satisfies certain regularity conditions, and if firms minimize variable costs q'X, where q' denotes the two-element vector of exogeneously given prices of the variable inputs, there exists a variable cost function (Lau 1976) given by

$$(1) \quad G = G(q, K, Y, t)$$

which is dual to the production function and contains all economically relevant information on the underlying technology. To qualify as a proper variable cost function, G must be homogeneous of degree one and non-decreasing as well as concave in q, non-decreasing in Y, and non-increasing and convex in K.

For a given level of output and exogeneously given input prices the cost-minimizing demands for variable factors of production can be derived from the variable cost function by applying Shephard's Lemma:

$$(2) \quad X_i = \frac{\delta G}{\delta q_i}, \quad (i = 1, 2).$$

The derived demand equations for variable factors have the usual properties, i.e. they are homogeneous of degree zero in all input prices and non-increasing in own input prices.

To derive the dual TFP growth measure we define the total cost function

$$(3) \quad C = G(q, K, Y, t) + r \cdot K,$$

where r denotes the one-period market price (user costs) of capital. Totally differentiating eq. (3) with respect to t and taking growth rates, we obtain

$$(4) \qquad g_C = \sum_{i=1}^{2} S_{X_i} \cdot g_{q_i} + S_K \cdot g_r + \epsilon_{CK} \cdot g_K + \epsilon_{CY} \cdot g_Y + \epsilon_{Ct}^{a}$$

where $g_{(\cdot)}$ is the growth rate of the respective variable and

$S_{X_i} \equiv \frac{q_i X_i}{C}$ = cost share of variable input i

$S_K \equiv \frac{r \cdot K}{C}$ = cost share of capital

$\epsilon_{CK} \equiv (-\frac{\delta G}{\delta K} + r) \cdot \frac{K}{C}$ = elasticity of total cost with respect to capital

$\epsilon_{CY} \equiv \frac{\delta C}{\delta Y} \cdot \frac{Y}{C}$ = short-run elasiticity of total cost with respect to output

$\epsilon_{Ct}^{a} \equiv \frac{\delta C}{\delta t} \cdot \frac{1}{C}$ = partial elasticity of total cost with respect to time.

The adjusted cost-side (dual) TFP growth measure is given by the negative of the last term in eq. (4), i.e.

$$(5) \qquad -\epsilon_{Ct}^{a} = \sum_{i=1}^{2} S_{X_i} \cdot g_{q_i} + S_K \cdot g_r + \epsilon_{CK} \cdot g_K + \epsilon_{CY} \cdot g_Y - g_C.$$

Adjustment of TFP growth for varying capacity utilization and scale economies, requires estimates of structural parameters of the production technology, to which we now turn. The reciprocal of the proportionate change in costs attributable to a proportionate change in output, i.e. the ratio of average costs to marginal costs, is termed economies of size in the literature and serves in the dual cost function approach an analogous purpose as the concept of scale economies in the primal production function approach (for a more complete discussion of the relationship between these concepts see Chambers 1988, Chapter 2).

In the presence of quasi-fixed inputs this concept has to be extended to distinguish between short-run and long-run cost flexibility. The former concept has already been defined above, the definition of the latter follows. The full (long-run) change in costs due to a change in output is given by the total differential of the cost function in eq. (3):

$$(6) \qquad \frac{dC}{dY} = \frac{\delta G}{\delta Y} + \frac{\delta G}{\delta K}\frac{dK}{dY} + r\frac{dK}{dY}.$$

Some obvious manipulations yield the following expression for the long-run cost flexibility measure:

$$(7) \quad \frac{dC}{dY}\frac{Y}{C} \equiv \eta = \epsilon_{CY} + \eta_K(\epsilon_{GK} + r\frac{K}{G})\frac{G}{C}$$

where η_K is the total (long-run) elasticity of capital with respect to output, and ϵ_{GK} denotes the partial elasticity of variable cost with respect to the capital stock.

The long-run optimal value of the quasi-fixed input is derived by minimizing the total cost function (3) with respect to the capital stock, which yields

$$(8) \quad \frac{\delta C}{\delta K} = \frac{\delta G}{\delta K} + r = 0,$$

where $S_K \equiv -\delta G/\delta K$ is the shadow-value of capital. Solving this optimality condition for K in terms of Y, q and r, we can derive the optimal value of K and, hence, calculate η_K.

As suggested by Berndt and Morrison (1981), Berndt and Fuss (1986) and Morrison (1988a), an economically meaningful measure of capacity utilization (Γ) is given by the ratio of the short-run and the long-run total cost flexibility measures, i.e.:

$$(9) \quad \Gamma = \epsilon_{CY} / \eta$$

$$= 1 - (\eta_K/\eta) \cdot \epsilon_{CK}$$

(using eq. (7), with ϵ_{CK} as defined above). This capacity utilization measure indicates the cost consequences of not having adjusted the capital stock optimally in the short-run. (Note that for a homothetic cost function this measure would collapse to $\Gamma = 1 - \epsilon_{CK}$). At the output level where the shadow-value of the quasi-fixed factor is equal to its one-period rental price this capacity utilization measure equals one. It is above unity for all output levels for which the shadow value of the quasi-fixed factor exceeds its user costs, and is below unity where the former falls short of the latter.

If the capital stock were always fully adjusted to its optimal level, implying $\epsilon_{CK} = 0$, and there were constant economies of size in production, in which case $\epsilon_{CY} = 1$, $-\epsilon_{Ct}{}^{a}$ in eq. (5)

would reduce to the traditional (dual) TFP growth measure, $-\epsilon_{Ct}$, which is equal to the quantity-based Solow-residual. Otherwise, the following relationship between these two measures holds

$$(10) \quad -\epsilon_{Ct}^{a} = -\epsilon_{Ct} + \epsilon_{CK} \cdot g_K - (1 - \epsilon_{CY}) \cdot g_Y,$$

where $-\epsilon_{Ct}$ is obtained from eq. (5) by setting $\epsilon_{CK} = 0$ and $\epsilon_{CY} = 1$.

For further reference note that in case of $\eta_K = 1$, using eq. (9), the adjusted measure can be written as

$$(10') \quad -\epsilon_{Ct}^{a} = -\epsilon_{Ct} + (1 - \Gamma)\eta \cdot g_K - (1 - \epsilon_{CY}) \cdot g_Y,$$

where $\epsilon_{CY} = \eta \cdot \Gamma$. Hence, in this special case, the adjusted and traditional TFP growth measures are identical if, and only if, both the capital stock is optimally utilized ($\Gamma = 1$) and constant economies of size prevail ($\eta = 1$). Given estimates for Γ, η and data on the growth rates of the capital stock and output, it is straigthforward to calculate the adjusted TFP growth measure and decompose the adjustment factor into its components showing the contributions of scale economies and capacity utilization to TFP growth.

III. Econometric Specification

We estimate the model outlined in the previous section for West-German two-digit manufacturing industries (for a brief data description see the appendix) based on a given specification of the variable cost function for each industry. A somewhat specialized variant of the Generalized Leontief functional form proposed by Diewert (1971) and extended by Morrison (1988b) to allow for the incorporation of quasi-fixed factors of production has been chosen for the empirical implementation of the model. It is given by (notation as defined in the previous section):

$$(11)\quad G = Y[a_{11}v + 2a_{12}(v\cdot w)^{1/2} + a_{22}w + v(b_{11}Y^{1/2} + b_{12}/Y + b_{13}t^{1/2} + b_{14}/t) + w(b_{21}Y^{1/2} + b_{22}/Y + b_{23}t^{1/2} + b_{24}/t)] + (Y\cdot K)^{1/2}\cdot(c_1v + c_2w).$$

This functional form, which is a local second-order approximization to an arbitrary cost function, is homogenous of degree one in factor prices, concave in factor prices if $a_{12} > 0$, and non-increasing and convex in K if $(c_1v + c_2w) < 0$. It allows for fairly complex interactions between output, factor prices and the trend terms which represent the state of technology. In contrast, the term involving the capital stock is held somewhat simple as preliminary explorations have shown that our sample size does not allow more terms to be included in the cost function. In particular, the form the capital stock enters the cost function implies $\eta_K = 1$.

Applying Shephard's Lemma to eq. (11), the following equations for the materials-output and labor-output ratios can be derived:

(12)

$$\frac{M}{Y} = a_{11} + a_{12}(\frac{w}{v})^{1/2} + b_{11}Y^{1/2} + b_{12}/Y + b_{13}t^{1/2} + b_{14}/t + c_1(\frac{K}{Y})^{1/2}$$

(13)

$$\frac{L}{Y} = a_{22} + a_{12}(\frac{v}{w})^{1/2} + b_{21}Y^{1/2} + b_{22}/Y + b_{23}t^{1/2} + b_{24}/t + c_2(\frac{K}{Y})^{1/2}$$

In addition to the variable cost function and the two input equations we estimate a price equation. This not only may help to improve on efficiency in estimation, but can also serve as a further check on the inherent plausibility of the model specification. Following previous research (Flaig and Steiner 1990), the price equation is derived under the assumption that industry price is determined as a markup on marginal costs, which for the above cost function implies the following price equation:

$$(14) \quad P = [v(a_{11} + b_{13}t^{1/2} + b_{14}/t) + w(a_{22} + b_{23}t^{1/2} + b_{24}/t)$$
$$+ 2a_{12}(v\cdot w)^{1/2} + \tfrac{3}{2}Y^{1/2}(b_{11}v + b_{21}w)$$
$$+ \tfrac{1}{2}(c_1 v + c_2 w)\cdot(\tfrac{K}{Y})^{1/2}]$$
$$\cdot[\beta_0 + \beta_1 t + \beta_2 t^{1/2} + \beta_3(\ln Y - \ln Y_{-1})].$$

The first factor in square brackets denotes marginal costs as derived from eq. (11) and the second expression is the markup factor which includes two trend terms and the growth rate of industry output where β_i (i=0,1,2,3) are parameters to be estimated. Whereas the time trends should pick up long-term trends in factors affecting the mark up, the latter variable is assumed to capture cyclical effects on the mark up. In the present context, this rather general specification of the mark up term which is compatible with virtually any pricing hypothesis has the advantage to minimize the danger of corrupting the parameter estimates.

The system of estimating equations comprises the variable cost function, the two input demand equations and the price equation. The model is estimated by nonlinear three-stage least squares with all symmetry conditions and cross equation restrictions imposed. (TSP 4.1. was used for estimation.) To econometrically account for the potential endogeneity of the output variable, we instrument it by using the factor prices, the trend terms and lagged values of both the endogeneous variables and output as instruments. Given the available data (see the appendix), the model was estimated for 25 out of 31 industries comprising the manufacturing sector of the West-German economy. As the growth rate of industry output enters the price equation as an explanatory variable, we lose one observation. The estimation period is therefore from 1961 to 1985.

IV. Results

As the main focus of the present study is on deriving time series estimates of dual productivity growth measures and the adjustment factors discussed above for each industry, we simply summarize output, own price and cross price elasticities derived from the input equations in Table A1 and summary statistics of the estimated equations in Table A2 in the appendix. In the present study derived factor demands primarily serve as an important tool to identify and estimate the parameters of the cost function with the implied output and price elasticities being used to check for the plausiblilty of the model estimates. Results with respect to the price equation are not reported here, as they are not directly relevant for adjusting TFP growth on the dual side (for adjustment of the Solow residual for imperfect competition see Morrison 1989 and Hall 1989). Here, we simply note that estimated industry markups are very much the same as those obtained in a recent study by the authors (Flaig and Steiner 1990) on pricing in West-German manufacturing and that they are compatible with the estimated scale economies at the industry level discussed below.

With the exception of a few industries which either violate the restrictions implied by the specification of the cost function (iron and steel, road vehicles, wood working, wood products, food and beverages) and/or show strong evidence for dynamic misspecification, industry cost functions seem to be quite adequately estimated by our model specification. As the aim of the present study is to use a given cost function for each industry and to avoid introducing ad-hoc dynamics, these industries will be excluded from the subsequent analysis.

For the remaining industries in the sample, we summarize means and standard deviations of the traditional ($-\epsilon_{Ct}$) and the adjusted ($-\epsilon_{Ct}{}^{a}$) dual productivity growth measures within the estimation period , their difference, ($\epsilon_{Ct}{}^{a} - \epsilon_{Ct}$), and the adjustment factors $(1-\Gamma)\eta\cdot g_k$ and $(1-\epsilon_{CY})\cdot g_Y$ in the following Table 1. A postive (negative) difference between $\epsilon_{Ct}{}^{a}$ and ϵ_{Ct} implies that "true" TFP growth is reduced (increased) by the sum of the two adjustment factors. We also report the values of these measures for the reference year 1980, i.e. the year where prices in the model have been normalized.

The most important results in Table 1 can be briefly summarized as follows. First, there is substantial variation in the estimated TFP growth measures both within and between industries. Second, the average annual growth rate of the adjusted measure is smaller than that of the traditional measure in most industries, and has on average been well below one percent. Surprisingly, average TFP growth has been particularly low in industries usually classified as technologically advanced, such as chemical products, electrical engineering, precision and optical instruments, and finished metal goods. Third, the within-industry variation in the adjusted measure is considerably less than in the traditional measure in all industries. Fourth, both economies of scale and varying capacity utilization have contributed to these adjustments, where the latter effect may either reinforce or weaken the adjustment arising from scale economies.

For the reference year 1980, which precedes the cyclical downturn in the early eighties, we observe both negative and postive adjustments of the traditional TFP growth measure. The latter shows substantial inter-industry variation ranging from -5.62 (musical instruments, toys etc.) to +2.54 (precision and optical instruments) in that year. For these two industries the adjustment in TFP growth is substantial, the traditional measure being increased by 4.19 and reduced by 3.23 percentage points, respectively. Overall, the inter-industry variation in "true" TFP growth is very much reduced, where for the reference year the combined effect of scale economies and the growth rate in output has been quantitatively much more important than the effect emanating from adjustments of the capital stock.

The relative importance of scale economies and varying capacity utilization for the adjustment of the traditional TFP growth measure is more readily apparent from Table 2 where the mean values and standard deviations of $(1-\Gamma)\cdot\eta$ and $(1-\epsilon_{CY})$ as well as their components Γ and η are given for each industry within the estimation period. In addition, the estimated values for the reference year with the corresponding t-statistics are also reported for each measure. With the exception of the structural metal products industry, for which the precision of the estimates of η and Γ is rather poor and which will therefore be excluded from the subsequent analysis, estimation results for these measures seem within a reasonable range.

TABLE 1: Traditional ($-\epsilon_{Ct}$) and adjusted ($-\epsilon_{Ct}{}^{a}$) TFP growth measures, their difference and adjustment factors for scale economies and varying capacity utilization at the industry level.

Industry	$-\epsilon_{Ct}$			$-\epsilon_{Ct}{}^{a}$			$\epsilon_{Ct}{}^{a}-\epsilon_{Ct}$			$(1-\Gamma)\cdot\eta\cdot g_K$			$(1-\epsilon_{CY})\cdot g_Y$		
	1961-1985		1980	1961-1985		1980	1961-1985		1980	1961-1985		1980	1961-1985		1980
	μ	σ		μ	σ		μ	σ		μ	σ		μ	σ	
14 Chemical products	1.64	2.54	-3.88	0.03	0.58	0.12	1.60	2.36	-4.00	0.58	0.48	0.12	2.19	2.48	-3.89
16 Plastic products	1.54	1.85	-0.70	1.01	1.00	-1.00	0.53	1.49	0.29	1.32	0.72	0.77	1.85	1.67	1.06
17 Rubber products	1.06	1.95	0.73	0.68	1.00	0.38	0.38	1.86	0.35	0.42	0.34	0.09	0.79	1.86	0.44
18 Stones and clay	0.69	2.32	-0.88	0.89	0.58	-0.56	-0.20	2.25	-0.31	0.95	1.06	0.12	0.76	2.34	-0.19
19 Ceramic goods	1.07	2.65	2.25	0.64	1.21	0.45	0.43	1.90	1.80	-0.11	0.12	-0.03	0.32	1.90	1.78
20 Glass	1.05	1.98	1.02	1.26	1.04	0.64	-0.21	1.49	0.37	0.91	0.43	0.46	0.70	1.38	0.84
22 Non-ferrous metals	1.19	2.03	1.43	0.56	1.40	0.36	0.63	1.16	1.07	0.03	0.16	-0.08	0.66	1.10	0.99
23 Foundries	0.75	2.40	1.02	0.49	1.04	0.58	0.26	1.96	0.45	-0.13	0.21	-0.08	0.13	1.96	0.37
24 Drawing plants etc.	0.78	1.93	-0.35	0.44	0.69	-0.17	0.35	1.73	-0.18	0.19	0.25	0.05	0.53	1.70	-0.13
25 Structural metal products	1.11	1.82	0.73	-1.21	1.36	-2.92	2.32	1.54	3.65	-1.96	0.84	-2.06	0.36	1.18	1.59
26 Mechanical engineering	0.81	1.48	-1.25	0.47	0.79	-0.80	0.33	1.02	-0.45	0.11	0.06	0.08	0.44	1.01	-0.37
31 Electrical engineering	1.84	2.11	1.18	0.00	1.83	-0.69	1.84	0.77	1.87	-1.12	0.31	-0.95	0.72	0.75	0.91
32 Precision and optical instruments	1.26	1.83	2.54	-0.47	1.49	-0.70	1.72	1.45	3.23	-0.49	0.23	-0.75	1.23	1.51	2.48
33 Finished metal goods	0.85	1.59	-0.03	0.09	0.91	-0.25	0.76	1.13	0.22	-0.33	0.12	-0.31	0.43	1.13	-0.09
34 Musical instruments, toys etc.	0.30	2.50	-5.62	0.43	1.15	-1.44	-0.12	1.82	-4.19	0.38	0.20	0.33	0.25	1.82	-3.86
37 Paper manufacturing	1.10	2.90	1.52	0.73	1.07	0.91	0.37	2.56	0.61	0.56	0.54	0.14	0.93	2.46	0.75
38 Paper processing	0.58	1.79	1.76	1.24	1.00	1.48	-0.67	1.23	0.27	1.12	0.59	0.61	0.46	1.15	0.88
39 Printing and duplicating	1.20	2.16	-1.13	1.48	1.41	-0.20	-0.28	1.32	-0.93	0.92	0.57	0.52	0.64	1.30	-0.41
41 Textiles	1.22	1.27	0.19	1.32	0.70	0.40	-0.11	1.02	-0.21	0.18	0.28	-0.05	0.07	1.04	-0.26
42 Clothing	0.90	0.90	0.22	0.80	0.73	0.24	0.09	0.37	-0.03	-0.09	0.09	-0.06	0.00	0.32	-0.08

TABLE 2: Splitting up of the adjustment factors for TFP growth into the structural parameters describing the production technology at the industry level.

Industry	$(1-\Gamma)\cdot\eta$			$(1-\epsilon_{CY})$			Γ			η		
	1961-1985		1980[1]	1961-1985		1980[1]	1961-1985		1980[2]	1961-1985		1980[2]
	μ	σ		μ	σ		μ	σ		μ	σ	
14 Chemical products	0.12	0.04	0.08 (3.5)	0.37	0.02	0.35 (28.5)	0.85	0.05	0.89 (3.8)	0.75	0.03	0.73 (11.4)
16 Plastic products	0.13	0.01	0.12 (3.4)	0.20	0.02	0.18 (6.1)	0.86	0.01	0.87 (3.7)	0.93	0.02	0.94 (1.7)
17 Rubber products	0.08	0.01	0.07 (3.7)	0.25	0.03	0.27 (14.3)	0.90	0.01	0.91 (3.9)	0.83	0.04	0.80 (9.1)
18 Stones and clay	0.18	0.04	0.13 (4.0)	0.33	0.01	0.32 (14.0)	0.79	0.04	0.84 (4.5)	0.86	0.03	0.82 (6.8)
19 Ceramic goods	-0.04	0.02	-0.05 (1.0)	0.30	0.01	0.30 (7.7)	1.06	0.04	1.08 (0.9)	0.66	0.02	0.65 (9.1)
20 Glass	0.17	0.03	0.19 (4.3)	0.23	0.05	0.24 (10.5)	0.82	0.03	0.80 (4.9)	0.94	0.02	0.94 (1.6)
22 Non-ferrous metals	-0.02	0.05	-0.07 (1.7)	0.19	0.04	0.21 (6.6)	1.03	0.07	1.10 (1.6)	0.79	0.08	0.72 (9.3)
23 Foundries	-0.12	0.09	-0.22 (5.9)	0.22	0.03	0.22 (9.6)	1.22	0.17	1.38 (4.6)	0.66	0.11	0.57 (13.4)
24 Drawing plants etc.	0.11	0.03	0.07 (1.7)	0.24	0.02	0.24 (13.6)	0.87	0.03	0.91 (1.9)	0.87	0.05	0.84 (4.1)
25 Structural metal products	-0.50	0.15	-0.63 (4.2)	0.15	0.03	0.14 (4.5)	2.95	1.45	3.75 (1.3)	0.35	0.16	0.23 (6.1)
26 Mechanical engineering	0.03	0.01	0.03 (0.6)	0.17	0.05	0.22 (7.4)	0.96	0.01	0.96 (0.6)	0.86	0.04	0.82 (4.0)
31 Electrical engineering	-0.19	0.05	-0.24 (2.4)	0.13	0.02	0.15 (3.1)	1.29	0.10	1.38 (1.9)	0.68	0.07	0.61 (4.7)
32 Precision and optical instruments	-0.12	0.07	-0.19 (3.2)	0.26	0.01	0.24 (10.1)	1.20	0.13	1.33 (2.5)	0.63	0.07	0.57 (8.0
33 Finished metal goods	-0.09	0.04	-0.13 (3.0)	0.18	0.02	0.18 (7.1)	1.12	0.07	1.19 (2.6)	0.74	0.05	0.69 (7.6)
34 Musical instruments, toys etc.	0.08	0.01	0.08 (1.6)	0.25	0.03	0.25 (8.7)	0.90	0.01	0.90 (1.7)	0.83	0.02	0.83 (5.1)
37 Paper manufacturing	0.14	0.05	0.08 (2.2)	0.28	0.05	0.30 (9.1)	0.84	0.05	0.90 (2.4)	0.86	0.08	0.78 (4.5)
38 Paper processing	0.19	0.03	0.21 (7.9)	0.18	0.06	0.22 (8.6)	0.81	0.04	0.78 (8.7)	1.01	0.03	0.99 (0.5)
39 Printing and duplicating	0.19	0.04	0.15 (0.9)	0.24	0.05	0.28 (4.1)	0.80	0.02	0.83 (1.0)	0.94	0.08	0.87 (1.1)
41 Textiles	0.09	0.02	0.07 (2.4)	0.21	0.07	0.28 (14.4)	0.90	0.02	0.91 (2.5)	0.88	0.08	0.79 (9.1)
42 Clothing	-0.05	0.03	-0.09 (1.7)	0.06	0.02	0.09 (2.6)	1.06	0.04	1.10 (1.7)	0.88	0.05	0.83 (6.5)

1) Absolute t-values for the hypothesis that the term is equal to zero are in parantheses.

2) Absolute t-values for the hypothesis that the parameter is equal to one are in parantheses.

The most important results contained in Table 2 are the following. First, η is smaller than one in the great majority of industries (c.f. the estimates for the reference year), which implies increasing economies of size. Evidence for the prevalence of relatively large scale economies in manufacturing accompanied by prices well above marginal costs has recently also been found by Morrison (1989) and Hall (1989). For West-German manufacturing a similiar picture is emerging from the present study. Our results with respect to the price equation (not reported here, but see Flaig and Steiner (1990) for a detailed description) show that estimated industry markups are significantly larger than one with no or only a slightly positive time trend in most industries. These results fit quite well into the picture since for industries characterized by increasing economies of scale a markup above one is clearly necessary to sustain an industry equilibrium. Second, we observe both excess capacity ($\Gamma < 1$) and over-utilization of the existing capital stock where disequilibrium in the capital stock seems a permanent rather than a cyclical phenomenon in most industries, with excess capacity prevailing. Third, for the reference year the estimates for $(1-\epsilon_{CY})$ are positive and statistically different from zero in all industries implying that for a positive growth rate in output and a given capital stock, "true" TFP is unequivocally overestimated by the traditional measure.

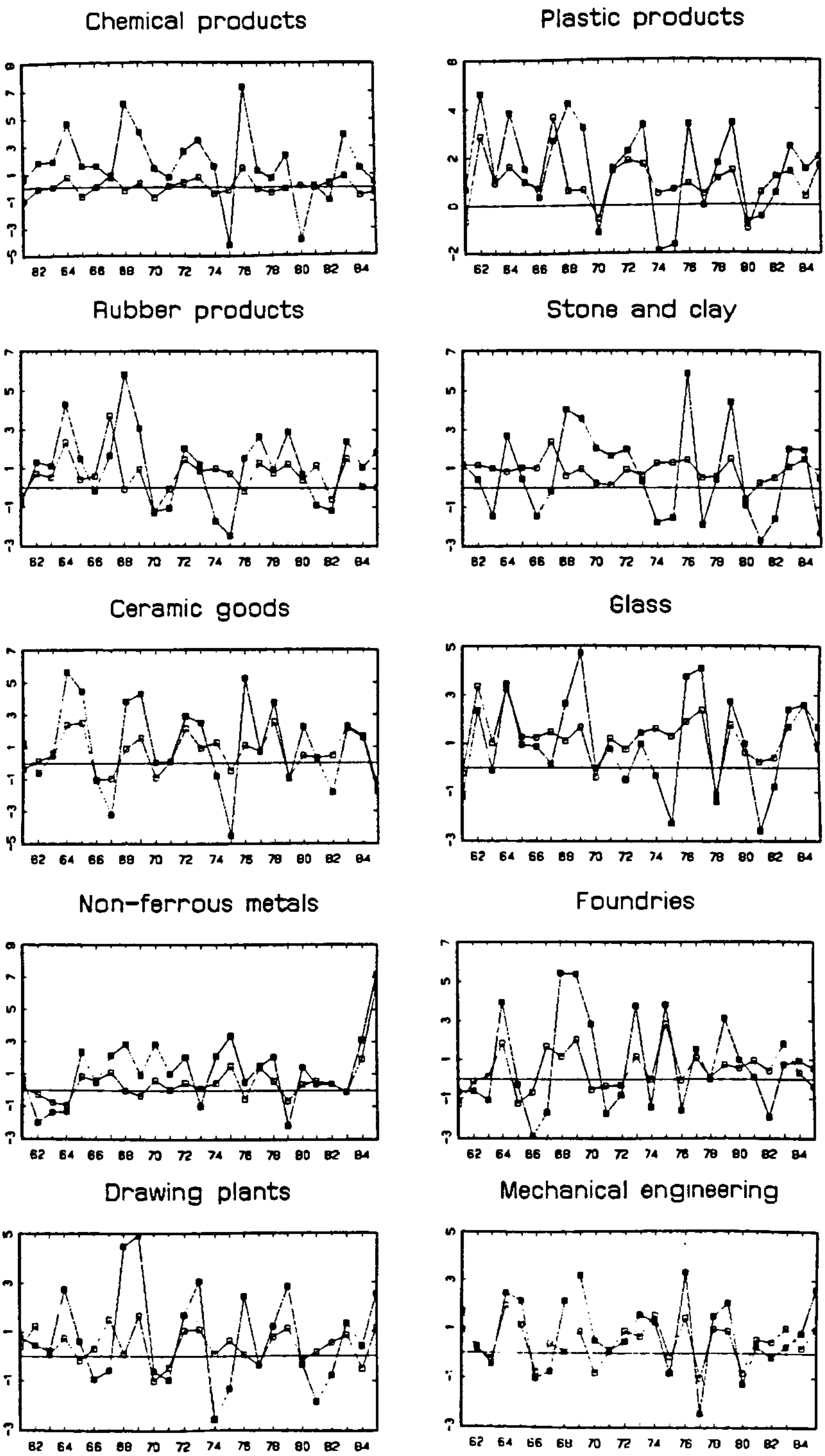
We have already briefly commented on the relative importance of cyclical fluctuations in production for the two TFP growth measures. A more impressive picture of the long-term development and cyclical behavior of TFP growth is provided by the following Figure 1 which shows, for each industry remaining in the sample, estimates of the traditional and the adjusted measures within the estimation period.

These plots reveal, among other things, the following important stylized facts about productivity behavior at the industry level. (The very strong increase in both productivity measures for the non-ferrous metals industry at the end of the observation period seems quite unexplainable. This industry is therefore excluded from the subsequent analysis.) First, neither the traditional nor the adjusted measure shows a clear negative long-term trend in TFP growth as it is frequently asserted in the literature. Second, there is no indication for a structural break following the first oil price shock in the adjusted measure. Third, as a rule, the adjusted series are much smoother than those based on the traditional measure, i.e. cyclical fluctuations practically disappear after adjustment for scale economies and varying capacity utilization. In particular, the prominent spikes in the traditional measure around the first oil price shock and, to a lesser extent, in the early eighties are virtually absent in the adjusted measure.

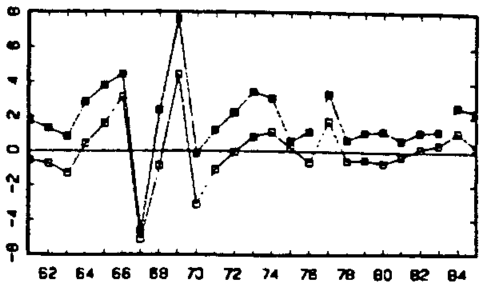
The general impression from these plots seems squarely at odds with conventional wisdom on the behavior of TFP growth, i.e. the alleged decline in TFP growth and the procyclical correlation with output growth (see the papers cited in the Introduction for the former, and especially Hall 1987 for the latter issue). Therefore, we have tested somewhat more formally our conjecture that there has in fact been no decline in "true" TFP growth at the industry level and whether our adjusted measure is indeed acyclical. To this end, we have run simple OLS regressions of the adjusted measure on a constant and tested the validity of this specification against, alternatively, (i) a model including a linear time trend, (ii) a model with a dummy variable to account for the alleged structural break in TFP growth after 1974, and (iii) a model with a constant and the contemporaneous growth rate of industry output as regressors.

The first two columns of Table 3 contain the industry-specific constants, which are, of course, equivalent to the industry means of the adjusted TFP growth measure in Table 1, and their absolute t-values obtained from these regressions. The latter statistics reveal that in four industries TFP growth has not been significantly different from zero within the estimation period.

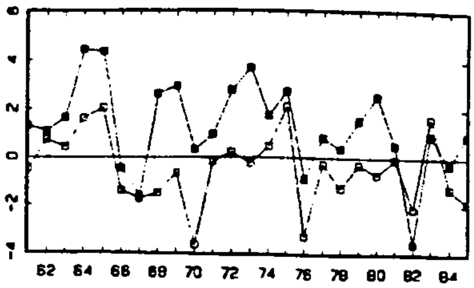
FIGURE 1: Time series behavior of traditional ($-\epsilon_{Ct}$, □) and adjusted ($-\epsilon^{a}_{Ct}$, ■) TFP growth measures.



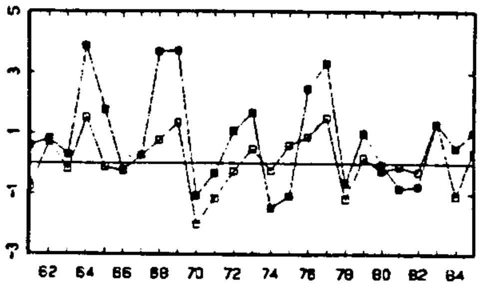
Electrical engineering



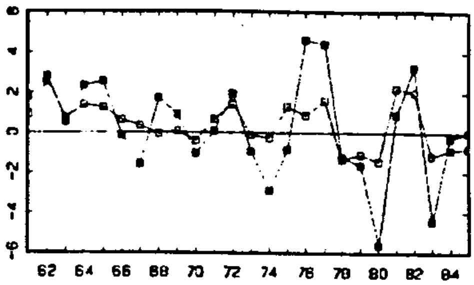
Precision/opt. instruments



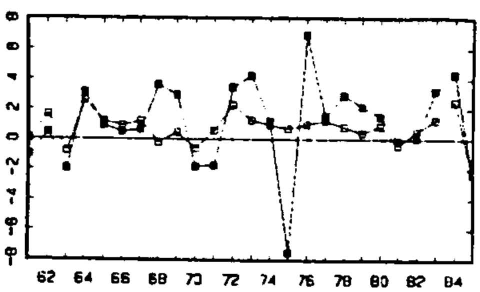
Finished metal goods



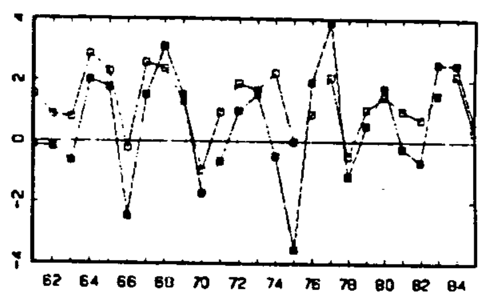
Musical instruments



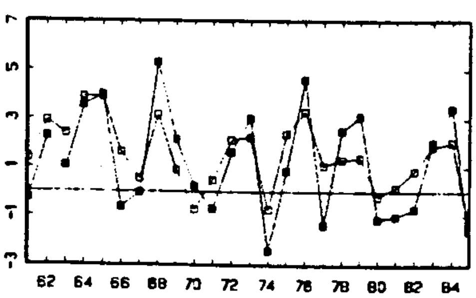
Paper manufacturing



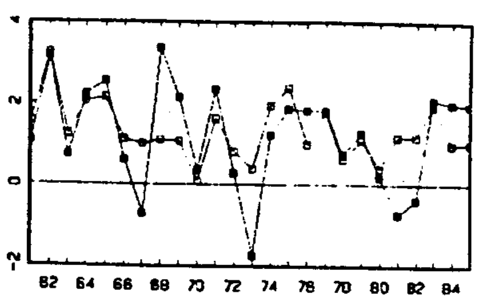
Paper processing



Printing and duplicating



Textiles



Clothing

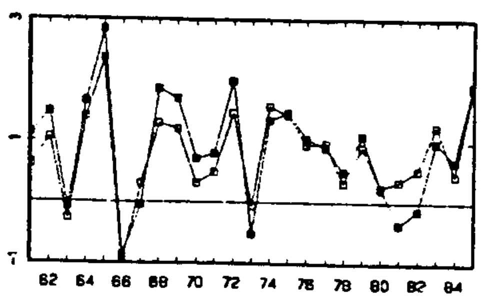


TABLE 3: Testing for constant adjusted TFP growth at the industry level; OLS regressions.

Industry	Constant[1)]		Trend	Test[2)] for Struct. Break	Cyclical Effect	Residual tests[3)] DW	LM	ARCH
14 Chemical Products	0.03	(0.27)	0.55	-0.66	0.82	2.19	3.11	2.33
16 Plastic products	1.01	(5.03)	-0.66	-1.06	0.58	2.27	0.21	1.75
17 Rubber products	0.68	(3.40)	-0.50	0.23	-0.61	2.39	0.67	1.15
18 Stones and clay	0.89	(7.72)	-1.19	1.14	0.53	1.88	0.03	0.97
19 Ceramic products	0.64	(2.65)	0.17	-0.02	2.37	1.99	2.72	0.69
20 Glass	1.26	(6.08)	-0.68	0.55	1.33	2.45	0.66	0.72
23 Foundries	0.49	(2.33)	1.06	0.22	1.08	2.10	0.45	0.23
24 Drawing plants etc.	0.44	(3.16)	-0.31	-0.45	0.74	2.59	2.56	2.15
26 Mechanical engineering	0.47	(3.00)	0.06	0.47	1.70	2.64	1.79	0.68
31 Electrical engineering	0.00	(0.01)	0.49	0.17	1.23	2.47	5.42	3.43
32 Precision and optical instruments	-0.47	(1.57)	-1.02	1.07	-0.88	2.03	0.05	1.48
33 Finished metal goods	0.09	(0.48)	-0.12	0.87	1.42	2.26	0.23	4.32
34 Musical instruments, toys etc.	0.43	(1.85)	-2.15	0.79	2.23	1.46	1.52	10.65
37 Paper manufacturing	0.73	(3.41)	-0.60	0.18	0.53	2.16	1.04	4.41
38 Paper processing	1.24	(6.25)	-0.75	-0.19	2.12	2.20	2.88	0.60
39 Printing and duplicating	1.48	(5.24)	-2.28	0.51	2.24	1.46	1.09	1.03
41 Textiles	1.32	(9.39)	-1.57	2.64	0.94	1.88	0.18	1.70
42 Clothing	0.80	(5.47)	0.37	0.66	2.11	2.43	3.10	3.63

1) Absolute t-values for the hypothesis that the industry-specific constant is zero are in parantheses.

2) t-values for the hypothesis that the coefficient of, respectively, the linear time trend, the dummy variable taking on a value of one after 1974, and the annual growth rate of industry output is zero.

3) DW is the Durbin-Watson test stastistic. The Lagrange Multiplier (LM) test statistic for autocorrelation up to second order is distributed as F(2,20), the critical value at the 5 percent level is 3.49. The ARCH test statistic for heteroscedasticity with two lagged values of the squared OLS residuals is distributed as $chi^2(2)$, the critical value at the 5 percent level is 5.99.

The t-values arrayed in the next three columns of Table 3 show the following interesting results. First, with the possible exception of two industries (printing and duplicating, and musical instruments, toys etc.) the hypothesis that adjusted TFP growth is untrended cannot be rejected. Second, the hypothesis of a structural break in TFP growth following the first oil price shock is firmly rejected by the results in the fourth column of Table 3, where the only exception is the textiles industry with higher rather than lower TFP growth after 1974, however. Finally, the results in the fifth column of Table 3 indicate that for the great majority of industries the hypothesis that adjusted TFP growth is acyclical clearly is compatible with the data.

In view of the first two of these results, the question quite naturally springs to mind why, then, other researchers have invariably reported results to the contrary, rare exceptions being Griliches (1988) and Morrison (1989) for U.S. manufacturing. Besides the fact that most evidence for the alleged universal productivity slowdown is based on rather restrictive assumptions about the production technology and/or on simply averaging traditional measures over relatively short time periods with hardly any formal testing for the significance of reported differences, the most likely explanation may well be aggregation bias in estimation results based on studies usually carried out at the level of the whole business sector or even the national economy.

The third result mentioned above, too, seems rather remarkable indeed, as "[a]ll measures agree that productivity accelerates in booms and stalls or even regresses in slumps" (Hall 1987, p. 421). It is also in conflict with the results for the U.S. by Hall (1987, 1989) whose adjustments of the Solow-residual for imperfect competition and economies of scale seem to leave, as a rule, his alternative TFP growth measures procyclical. In this context, it should be noted that in our study the traditional measure does in fact show a very strong and statistically highly significant positive contemporaneous correlation with industry output. However, this correlation is mainly due to the constant economies of scale assumption and, with the exception of a few industries, disappears in the adjusted measure. Therefore, all measures of TFP growth based on this assumption seem rather unreliable. Although Hall (1989) does account for economies of scale, his result of the procyclical behavior of the adjusted measure may well be due to his rather fragile estimation procedure which leads to obviously implausible estimates of economies of scale and industry markups (c.f. his Tables 2 and 3).

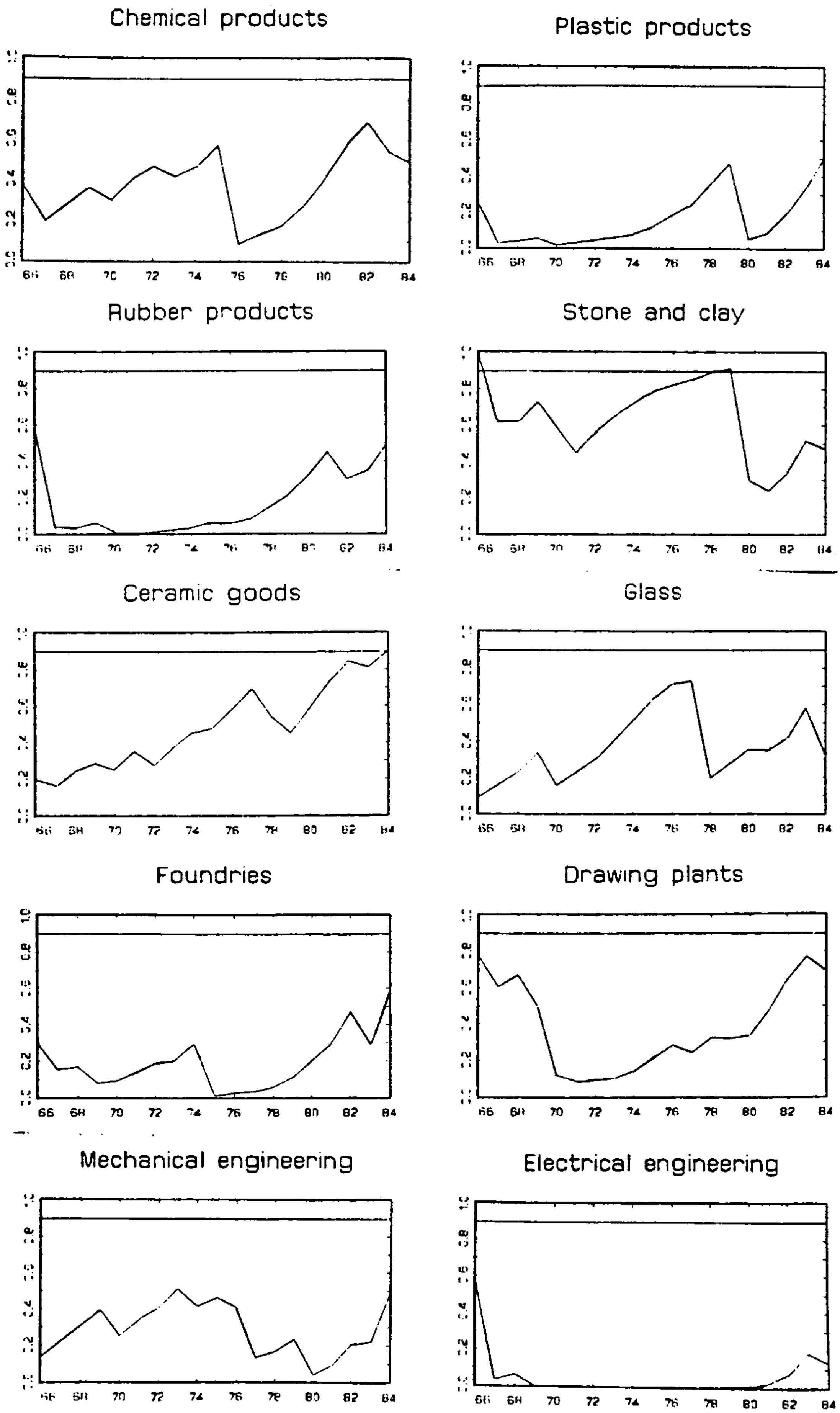
The hypothesis that a major portion of fluctuations in output is caused by shifts in technology as measured by the adjusted Solow-residual plays a major role in real business-cycle models, at least in the version that stresses productivity shocks as driving forces of output fluctuations (see e.g. Plosser 1989; for critical remarks see Mankiw 1989). Hall (1987) and Shapiro

(1987), after adjusting the Solow-residual for the impact of imperfect competition, suggest that there is indeed some evidence supporting this hypothesis for the U.S. economy, although their conclusion critically depends on the validity of rather restrictive assumptions. In any case, as there is no contemporaneous correlation between the adjusted TFP growth measure and the growth rate in output in the great majority of the industries listed in Table 3, this hypothesis seems to be clearly rejected for West-German manufacturing. However, it should be noted that this result only refers to productivity shocks within a particular industry and is based on simple correlations without accounting for possible dynamic effects.

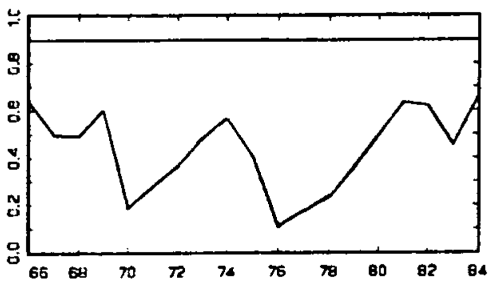
In the mentioned version of real business-cycle theory, it is usually assumed that the log of the level of productivity follows a random walk with drift (Prescott 1986; Plosser 1989), which, inter alia, implies that shocks to productivity are permanent. Therefore, it seems of some interest whether our adjusted TFP growth measure exhibits this time series property. Thus, we have tested the stochastic part of a time series model of adjusted TFP growth including an industry-specific constant and an error term. The results of some standard tests based on the OLS residuals from this regressions are contained in the remaining columns of Table 3.

Furthermore, we have tested the validity of this particularly simple specification using 'recursive residuals', i.e. a model's standardized one-step prediction errors, which contain all information necessary (and available) for model evaluation (see Harvey 1981, pp. 182; Pagan 1989). There is a variety of possible tests which differ only in the presentation of the information contained in the one-step prediction errors. Because of their intuitive appeal in the present context, we have calculated 'fixed point' Chow tests which test a selected point within the estimation period against all other points for structural stability. In Figure 2 these test statistics are plotted against the last period and compared to the critical 10 percent significance level, where observations prior to 1966 were used to initialize the estimation procedure.

FIGURE 2: Sequential fixed point Chow-tests against last period for structural stability of the model: $(-\epsilon_{Ct}{}^{a})_{it}$ = constant + u_{it}, with u_{it} white noise

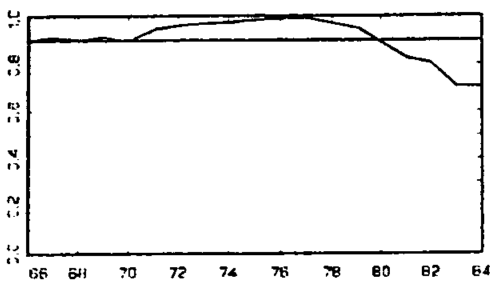


Precision/opt. instruments

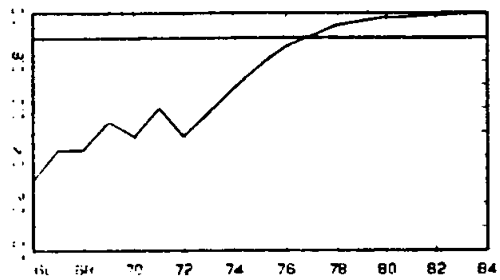


Finished metal goods

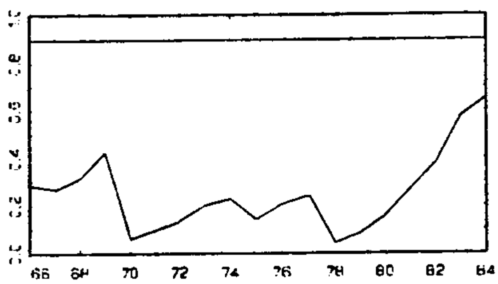
Musical instruments



Paper manufacturing

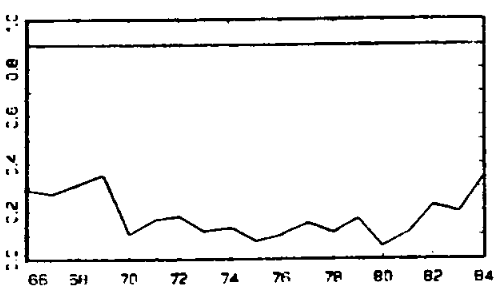


Paper processing

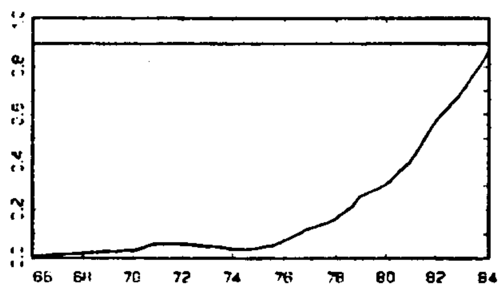


Printing and duplicating

Textiles



Clothing



Briefly, the results from these various tests are the following. With the exception of two industries (electrical engineering, musical instruments, toys etc.), there is no evidence for autocorrelation or heteroscedasticity in the OLS residuals. Furthermore, except for a few industries (stone and clay, musical instruments, paper manufacturing, clothing), the plots in Figure 2 do not indicate structural instability of this simple model, and, overall, are quite compatible with the results in Table 3.

V. Conclusions

On the basis of an econometric model of production we have estimated traditional and adjusted measures of total factor productivity growth for West-German manufacturing two-digit industries. The estimates of these measures revealed substantial variation at the two-digit industry level both within and between industries, which indicates the danger of severe aggregation bias in highly aggregated analyses of TFP growth. Most importantly, it has been shown that ignoring scale economies and assuming full immediate adjustment of all factors of production will introduce quantitatively important errors in the measurement of TFP growth. Adjusting the dual of the traditional measure of TFP growth, the Solow-residual, for scale economies and varying capacity utilization both lowers the average value of TFP growth and substantially reduces its cyclical variability, where the former factor plays the crucial role in these adjustments. Contrary to conventional wisdom, at the industry level there has been neither a long-term productivity slowdown nor a structural break in TFP growth within the estimation period. Furthermore, there is little evidence for the popular hypothesis of the procyclical behavior of TFP growth after it has been adjusted for economies of scale and varying capacity utilization. This also implies the rejection of the hypothesis that a major portion of fluctuations in output is caused by exogeneous shifts in technology as measured by the adjusted Solow-residual, which is an essential part of a prominent version of the real business-cycle model. Finally, a fair amount of statistical testing has revealed that, in the great majority of industries, TFP growth can be successfully modelled by an industry-specific constant and a stochastic term, the nature of which implies that the (log-)level of TFP follows a random walk with drift. Therefore, exogeneous shocks to productivity will have persistent effects, i.e. there is no tendency for productivity to return to the initial growth path. An explanation of productivity growth thus needs to identify the sources of these shocks, which has been well beyond the scope of the present paper.

Appendix

Data

The data refer to the manufacturing sector of the West-German economy over the period 1960 to 1985. Data for nominal gross output, nominal intermediate inputs and real value added have been taken from the yearly disaggregated national income accounts (Source: Statistisches Bundesamt (StaBu), Fachserie 18). Real gross output series have been obtained as follows: After correcting the producer price index for domestic and foreign sales at the industry level (Source: StaBu, Fachserie 17 and Fachserie M) for the change in the tax system in 1968 (when the sales tax was replaced by the value added tax), we obtained weights for the respective bundle of goods in each of our industries from the disaggregated input-output table for 1982 (StaBu, Fachserie 18, Reihe 2, Table 4.2). Then, price indices for industry gross output were calculated as a weighted sum of the domestic producer price index. An implicit price index for intermediate inputs for each industry was derived by dividing nominal intermediate inputs by the difference between real gross output and real value added. Yearly total hours at the industry level are average yearly hours actually worked per employee (Source: Institut für Arbeitsmarkt- und Berufsforschung Nurenberg, Kohler and Reyher 1988) multiplied by the number of employees in the respective industry. The capital stock and the user costs of capital which are fully compatible with the disaggregated national income accounts have kindly been made available by the IFO Institute Munich (see Gerstenberger et al. 1989). All variables have been normalized at the year 1980.

Because of data problems six industries had to be excluded from the sample. For these industries there are either no consistent price indices (mineral oil refining, shipbuilding, aircraft and spacecraft, tobacco) or data is not available over the whole estimation period (office machinery and data processing equipment, leather and leather goods).

TABLE A1: Estimated elasticities of the input equations with respect to output and the wage rate

Industry	ϵ_{LY} 1961-1985 μ	ϵ_{LY} 1961-1985 σ	ϵ_{LY} 1980[1)]		ϵ_{LW} 1961-1985 μ	ϵ_{LW} 1961-1985 σ	ϵ_{LW} 1980[1)]		ϵ_{MY} 1961-1985 μ	ϵ_{MY} 1961-1985 σ	ϵ_{MY} 1980[1)]		ϵ_{MW} 1961-1985 μ	ϵ_{MW} 1961-1985 σ	ϵ_{MW} 1980[1)]	
14 Chemical products	0.30	0.07	0.24	(3.8)	-0.20	0.05	-0.24	(5.0)	0.94	0.02	0.96	(41.4)	0.07	0.01	0.08	(5.0)
16 Plastic products	0.54	0.05	0.53	(4.7)	-0.21	0.05	-0.26	(3.3)	1.07	0.03	1.10	(30.5)	0.10	0.02	0.11	(3.3)
17 Rubber products	0.51	0.06	0.45	(6.4)	-0.08	0.01	-0.10	(1.9)	1.08	0.01	1.09	(41.0)	0.04	0.01	0.05	(1.9)
18 Stones and clay	1.03	0.07	0.92	(3.6)	-1.09	0.26	-1.37	(4.2)	0.82	0.06	0.88	(8.7)	0.50	0.07	0.58	(3.9)
19 Ceramic goods	0.73	0.06	0.68	(10.7)	-0.31	0.05	-0.36	(10.2)	1.02	0.06	1.06	(16.2)	0.36	0.04	0.39	(10.2)
20 Glass	0.67	0.11	0.84	(10.4)	-0.18	0.04	-0.21	(3.0)	1.11	0.11	0.99	(25.3)	0.10	0.01	0.12	(3.0)
21 Iron and steel	0.08	0.25	-0.01	(0.1)	-0.12	0.03	-0.16	(1.0)	1.17	0.09	1.08	(23.6)	0.05	0.01	0.06	(1.0)
22 Non-ferrous metals	0.31	0.22	0.11	(0.6)	-0.12	0.04	-0.16	(4.2)	1.08	0.02	1.06	(30.2)	0.02	0.01	0.03	(4.1)
23 Foundries	0.71	0.10	0.86	(8.1)	0.00	0.00	0.00	(0.1)	1.13	0.09	1.02	(16.2)	0.00	0.00	0.00	(0.1)
24 Drawing plants etc.	0.47	0.04	0.50	(4.4)	-0.13	0.01	-0.15	(1.6)	1.12	0.04	1.08	(26.0)	0.06	0.01	0.07	(1.6)
25 Structural metal products	0.46	0.21	0.80	(6.9)	-0.25	0.06	-0.33	(2.1)	1.22	0.16	1.01	(24.6)	0.13	0.02	0.15	(2.1)
26 Mechanical engineering	0.63	0.06	0.57	(7.1)	-0.25	0.03	-0.27	(3.7)	1.13	0.04	1.10	(26.3)	0.14	0.02	0.16	(3.8)
28 Road vehicles [2)]	0.82	0.04	0.83	(6.7)	-0.69	0.11	-0.84	(9.1)	1.03	0.04	0.99	(17.3)	0.28	0.05	0.33	(9.9)
31 Electrical engineering	0.66	0.13	0.79	(7.6)	-0.19	0.04	-0.22	(4.8)	1.14	0.08	1.07	(19.7)	0.11	0.03	0.14	(4.9)
32 Precision and optical instruments	0.60	0.15	0.78	(10.0)	0.02	0.00	0.02	(0.3)	1.00	0.10	0.89	(15.5)	-0.01	0.00	-0.02	(0.3)
33 Finished metal goods	0.55	0.02	0.54	(5.7)	-0.06	0.01	-0.07	(0.5)	1.16	0.03	1.18	(27.1)	0.03	0.01	0.04	(0.5)
34 Musical instruments, toys etc.	0.62	0.11	0.60	(9.6)	-0.27	0.02	-0.30	(5.8)	0.99	0.05	1.00	(21.9)	0.16	0.01	0.16	(5.4)
35 Wood working [2)]	0.14	0.20	-0.01	(0.1)	-0.29	0.05	-0.35	(3.7)	0.96	0.11	0.87	(20.3)	0.08	0.02	0.10	(3.6)
36 Wood products	0.38	0.20	0.68	(5.7)	-0.01	0.00	-0.02	(0.2)	1.26	0.14	1.12	(22.8)	0.01	0.00	0.01	(0.2)
37 Paper manufacturing	0.72	0.29	0.96	(6.8)	-0.10	0.03	-0.12	(2.7)	1.02	0.13	0.91	(25.9)	0.03	0.01	0.04	(2.7)
38 Paper processing	0.61	0.05	0.59	(5.7)	-0.24	0.04	-0.28	(6.2)	1.08	0.04	1.05	(35.7)	0.10	0.01	0.11	(6.1)
39 Printing and duplicating	0.77	0.01	0.77	(4.4)	-0.27	0.05	-0.33	(4.6)	1.05	0.09	0.98	(9.7)	0.22	0.03	0.24	(4.5)
41 Textiles	0.52	0.18	0.31	(3.7)	-0.05	0.01	-0.06	(1.0)	1.18	0.01	1.18	(47.9)	0.02	0.00	0.02	(1.0)
42 Clothing	0.87	0.07	0.78	(8.2)	-0.38	0.06	-0.44	(7.2)	1.08	0.03	1.10	(36.0)	0.16	0.03	0.19	(7.3)
43 Food and beverages	-0.34	0.40	-0.82	(3.5)	0.49	0.06	0.56	(4.2)	1.38	0.01	1.39	(22.8)	-0.09	0.01	-0.10	(4.3)

1) absolute t-values in parentheses

2) The convexity condition with respect to the capital stock is violated.

TABLE A2: Summary statistics for the variable cost function, the input equations and the price equation

Industry	G		L/Y		M/Y		P	
	DW	$\bar{R}^2$	DW	$\bar{R}^2$	DW	$\bar{R}^2$	DW	$\bar{R}^2$
14 Chemical products	1.717	1.000	1.680	0.999	1.903	0.751	2.158	0.990
16 Plastic products	1.362	1.000	1.208	0.998	1.340	0.860	1.414	0.997
17 Rubber products	1.557	1.000	1.452	0.994	1.713	0.930	0.955	0.997
18 Stones and clay 1)	0.947	1.000	1.235	0.996	0.900	0.749	0.604	0.998
19 Ceramic goods	1.756	0.999	1.616	0.997	1.458	0.940	1.969	0.999
20 Glass	1.090	0.999	1.536	0.999	1.442	0.955	0.929	0.998
21 Iron and steel 1)	1.503	0.999	0.737	0.988	1.127	0.602	1.305	0.987
22 Non-ferrous metals	1.038	0.997	1.061	0.999	1.003	0.355	1.972	0.989
23 Foundries	1.757	1.000	1.032	0.993	0.966	0.863	1.232	0.997
24 Drawing plants etc.	2.187	1.000	1.263	0.993	1.735	0.982	1.301	0.997
25 Structural metal products	0.884	0.999	1.000	0.992	1.746	0.934	1.098	0.998
26 Mechanical engineering	1.664	1.000	1.788	0.998	1.584	0.974	1.415	0.999
28 Road vehicles	1.055	1.000	1.026	0.995	0.725	0.846	0.802	0.997
31 Electrical engineering	1.318	1.000	2.316	0.997	1.381	0.889	1.521	0.993
32 Precision and optical instruments	1.703	0.999	1.337	0.999	0.950	0.905	1.017	0.994
33 Finished metal goods	1.376	1.000	1.009	0.997	1.400	0.927	1.407	0.999
34 Musical instruments, toys etc.	1.197	0.999	1.523	0.996	1.326	0.832	1.711	0.999
35 Wood working	1.258	0.997	1.467	0.999	1.065	0.569	1.094	0.994
36 Wood products 1)	0.767	0.999	0.773	0.999	1.533	0.963	1.075	0.997
37 Paper manufacturing 1)	1.776	0.999	0.764	0.992	1.792	0.879	1.472	0.995
38 Paper processing	1.560	1.000	1.552	0.994	1.468	0.968	1.757	0.997
39 Printing and duplicating	1.218	0.999	1.264	0.996	1.474	0.951	1.437	0.997
41 Textiles	0.990	0.999	1.475	0.999	1.264	0.945	1.213	0.994
42 Clothing	1.209	0.999	1.647	0.998	1.364	0.980	1.877	0.999
43 Food and beverages 1)	0.636	1.000	1.060	0.997	0.756	0.897	1.774	0.996

1) DW statistic indicates serious autocorrelation.

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