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Industry Structure and Productivity Growth: Panel Data Evidence for Germany from 1971~~1971~~2000

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Working Papers

Industry Structure and Productivity Growth: Panel Data Evidence for Germany from 1971–2000

Thomas Fuchs

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Abstract

The paper presents a detailed industry-level productivity analysis (52 industries) for the effects of industry structure on TFP growth for Germany from 1971 until 2000. The analysis builds on a theory by Acemoglu et al. (2003) relating industry structure and productivity growth of an industry. The analysis reveals positive effects of vertically disintegrated industries with respect to TFP growth during a convergence period. After the convergence period, there remains only a positive effect for industries which use a higher share of imported intermediate inputs, especially in manufacturing industries, providing evidence for beneficial effects of higher levels of international cooperation on TFP growth.

The database of the analysis is the recently collected productivity database for Germany. The Ifo Productivity Database, which is unique due to its high data quality, offers industry- and asset-specific capital data and also for the first time data on domestic and international intermediates input over such a long period. The database allows to allocate productivity growth according to the gross output growth accounting method following Jorgenson and Stiroh (2000).

JEL Code: F15, L 60, L 80, O11, O14.

Keywords: Growth accounting, productivity, sectoral analysis, internationalization, globalization, international outsourcing, panel data.

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1. Introduction

The effects of outsourcing have been in the focus of several economic and political debates all over the developed world for the last years. The discussion accompanies job relocations from the developed world to developing countries which have accelerated during the 1990s. But outsourcing does not only relocate production activities from one country to another and induces pressure on the labor market for low-skilled workers (cf. Feenstra and Hanson, 1999). It also changes considerably the organizational structure of the production process an industry (industry structure henceforth) and its degree of international integration due to the substitution of domestic suppliers by foreign ones. Its therefore eminently important to analyze the effects of the change in the industry structure and the degree of international integration on the productivity growth of an economy since a higher level of vertical integration of an economy could constitute a change in the production technology or process of an economy and affect the production possibility frontier of an economy.

A recent article by Acemoglu, Aghion and Zilibotti (AAZ) (2003) provides a theoretical intuition for the effects of different industry structures,¹ i.e. the share of intermediate inputs over gross output, on productivity growth. They argue in their article that the organizational form of a production unit, i.e. outsourcing vs. vertical integration of the production, influences the productivity level and the convergence path to the world technological frontier. This study intends to test the AAZ hypothesis empirically on the industry-level by analyzing the effects of industry structure on (total factor) productivity growth of an industry.

The focus on the effects of outsourcing on the productivity of industries and hence the international competitiveness of those industries is an important complementary perspective for the public debate and can help to draw a more accurate picture of the effects of outsourcing on the economy as a whole and not only on the labor market. The public discussion on outsourcing focuses mainly on this issue which is an important field of research but should not be the only one. The labor market focus of the public debate is aligned by a focus of the economic literature on the effects of outsourcing on labor market outcomes. Feenstra and Hanson (1999) and Hijzen et al. (2003) have analyzed among others the impact of outsourcing activities on wages and the wage distribution, with a common consensus that

¹ The authors analyze in their article the effects of vertical integration vs. non-integrating for firms and generalize it for whole economies to illustrate the convergence path of economies. In principal the reader can also think of an industry as a production unit with a production function for which the intuition for the effects of industry structure would also hold.

outsourcing of activities lowered the wages of low-skilled workers, while the effect on high skilled workers is in tendency positive.

Recently the focus has shifted towards outsourcing and the productivity of an economy (Acemoglu et al., 2003). Especially in Germany there is a growing awareness of a change of the production structure towards a “Bazaar economy” (Sinn, 2005), assembling intermediate inputs produced in low costs countries to the final product which calls for an analysis on the productivity influence of this development. On the aggregate level, several efforts have been undertaken to analyze the effects of outsourcing both from a theoretical (Grossman and Helpman, 2002) and empirical point of view (Alcalà and Ciccone, 2004) and illustrated the opportunities and risks of this development.

On a lower level, inspired by the seminal work of Griliches and Siegel (1992), several attempts have been undertaken to quantify the outsourcing effects on productivity growth. Görg et al. (2004) analyzed the effects of increased outsourcing activities on the firm-level for a panel of Irish firms, finding a positive effect of outsourcing of intermediate goods which is especially relevant and significant for firms which export a high share of their final goods to other countries, but no clear effect for the outsourcing of intermediate services. This finding is reinforced by Görzig and Stephan (2002) and Görg et al. (2004) for England and Germany on establishment-level data that also show positive effects of outsourcing on productivity in terms of profitability and returns.

But on the industry-level less emphasis has been dedicated to quantify the effects of outsourcing and a changing organizational structure on the productivity growth. Foster et al. (1998) and Jorgenson and Stiroh (2000) analyze each the productivity growth on industry- or plant-level but do not concentrate on the effects of outsourcing on productivity growth although this could have potential effects following the AAZ hypothesis. It is therefore the goal of this analysis to deliver more empirical evidence on the AAZ hypothesis on the industry-level, to analyze the effects of international integration of industries on productivity growth and to contribute to productivity research by providing evidence on the effects of industry structure and international integration on TFP growth.

The basis of the empirical analysis of the paper is the recently collected Ifo Productivity Database which is a uniquely rich dataset for growth accounting analyses of Germany on the industry-level and covers the period from 1970 until 2000. The database is also, according to the author’s knowledge, one of the few datasets which allows a growth accounting analysis on the industry-level using the gross output concept which is the preferred concept on the industry level (Jorgenson and Stiroh, 2000, Sichel, 2001, Jorgenson et al., 1987). A unique

feature of the database is its differentiation of intermediate inputs into domestic and international intermediate inputs which offer the unique opportunity to study the effects of international outsourcing on the industry-level. This issue is of special relevance for Germany due to the fact that its location in the heart of Europe and the relatively high openness of the German economy provide a rare opportunity to analyze the effects of international outsourcing on the productivity potential of an economy. Especially the fall of the iron curtain and the market opening of the Eastern European economies can be seen as a unique opportunity to study the effect of internationalization of production networks on the industry-level and deserve to be analyzed.

For this purpose, the study is structured as follows. In section 2, the article is related to the economic literature on outsourcing and productivity and surveys the available evidence. Section 3 presents the theoretical underpinning and intuition for the effects of outsourcing while section 4 introduces the implied growth accounting framework and the database which is used for the TFP calculations. Section 5 introduces the econometric estimation approach of the paper and presents the results of the econometric section. Section 6 summarizes the results of the paper and proposes future fields of research for productivity analysis related to outsourcing activities of economies on the industry level.

2. Related literature

The analysis is related to three separate streams of the economics literature on outsourcing and productivity and contributes to the existing literature by adding evidence on the effects of industry structure and international integration on productivity growth.

The first stream of economic literature which is related to the research topic of the study is the well researched field of productivity analysis on the industry-level. A disadvantage of the available evidence on the industry-level is the relatively small number of growth accounting studies which use the gross output concept for industry analyses. Jorgenson and Stiroh (2000) provide an encompassing study of productivity growth on the industry-level using the gross output concept for the US. Their analysis highlights the importance of intermediate inputs to explain productivity growth of industries and especially the contribution of the ICT industry as main contributor to the productivity growth of the US economy. Another related contribution on the industry-level was undertaken by Oulton and O'Mahony (1994) who analyze the productivity growth of industries for the British economy. Van ark et al. (2002) analyze for a sample of developed countries the development of productivity growth over time. While this analysis is of great worth from an international comparative perspective and

provides rich evidence on the sources of differential productivity paths between Europe and the United States, the use of the value-added growth accounting methodology limits the applicability of the results for within country analyses. The neglecting of intermediate inputs in the production functions does not allow to analyze the effects of a changing intermediate input mix and industry structure and is therefore less well suited to decompose the aggregate productivity growth according to industry contributions since the Domar (1961) aggregation is not used to aggregate the productivity growth of industries.

The second stream of the literature which is related to the research is the rich field of economic literature which analyses the effects of trade and outsourcing on labor market outcomes. Feenstra and Hanson (1999) estimate the effect of outsourcing on the relative wages of production and non-production workers for the US from 1979 to 1990. Their analysis highlights the effects of outsourcing as an explanation for the widening wage gap of production and non-production workers. A similar study for Great Britain has been undertaken by Hijzen (2003) finding similar effects of international outsourcing for the wage dispersion in the UK. Egger and Egger (2005a,b) analyze in a series of papers empirically and theoretically the effects of outsourcing on the labor market and the industry structure of an economy. In Egger and Egger (2005a), the authors analyze the effects of outsourcing on productivity of low-skilled workers finding a negative impact of outsourcing activities for this group in the EU. A specific analysis of the Austrian economy of Egger and Egger (2005b) shows the significance of industry spillovers for estimating effects of outsourcing on the labor market. Their article suggests that indirect spill-over effects influence the employment situation considerably and reveals also a positive effect on the employment situation of skilled compared to unskilled workers. In an additional theoretical model, Egger and Egger (2005c) analyze the effects of outsourcing and trade on welfare and the structure of production networks of economies.

The third stream of related economic literature are econometric analyses on the determinants of TFP growth. Flaig and Steiner (1993) analyze the determinants of TFP growth for a sample of West German manufacturing industries and reject the hypothesis of a structural break or slowdown for productivity growth in the period from 1961 to 1985. Recently Basu et al. (2003) analyzed the effect of ICT investment on productivity growth using a sample of British industries for the 1980s and 1990s. Basu et al. (2003) use a dynamic panel data approach and suggest that ICT investment has a long-term influence similar to a General Purpose Technology. They conclude that ICT investment has an influence on productivity growth which fully realizes its potential over a longer time period. Several

papers on productivity growth on plant-level like Görg et al. (2004) analyze the effects of outsourcing on plant productivity using econometric panel data techniques which are similar to the econometric approach employed below. These studies find positive effects of outsourcing of intermediate inputs on plant productivity and are one of the motivations for the conduction of a productivity analysis of outsourcing on the industry-level as a next step in productivity research.

3. Theoretical Underpinning

While the effects of outsourcing on wages and the wage distribution are quite intuitive, it is less clear why outsourcing should also affect the productivity of an economy. The basic idea for outsourcing effects is that vertically disintegrated industries are better suited to converge to the world technological frontier and hence have a higher level of productivity. To illustrate this intuition, this section presents two complementary theories of Acemoglu et al. (2003, 2004) and Linbeck and Snower (2000) which analyze the potential effects of globalization and/or technological shocks in production on productivity growth.

Outsourcing vs. vertical integration- A simple model of economic development

In the recent economic literature, a research project of Acemoglu, Aghion and Zilibotti deals with the effects of institutional settings on productivity growth. Different frameworks create different incentives for agents and can either encourage or hinder the economic development of a country. The authors analyze the effects of several institutional settings like financing and selectivity of an economy on the long-term growth path and the convergence of an economy to the world technological frontier. Their model explains under which circumstances economies converge to the technological frontier and under which circumstances an economy is caught in a convergence trap with a lower level of productivity in the long-run.

An article of this research project deals with the organization of firms and the effects of organizational choices on the long term growth of an economy which can be used to derive a theoretical intuition for the effects of outsourcing on productivity growth. Acemoglu et al. (2003) show that an economy which decides to stay vertically integrated experiences a lower steady-state productivity growth and steady-state productivity level compared to the world technological frontier. The reason for firm owners to abstain from outsourcing and choosing an inefficient integrated production organizational form is owed to a hold-up problem which arises due to the fact that firm owners have to share rents with suppliers in the case of

outsourcing. Building on that article, the following section develops a simple model of industry structure and productivity (growth) and modifies the model of Acemoglu et al. (2003) in a few points. Since the decision process of the organizational form of an industry is not in the focus of interest in this paper, organizational decisions are taken as exogenous and the organizational forms of “vertical integration” and “outsourcing” and their influence on the productivity level of an industry are compared.

Industry structure and productivity growth

The production function $y_t(i)$ of a sector i in period t is a function of the labor $L_t(i)$ used for production, the scale investment $s_t(i)$ in industry i in period t , the state of technology $A_t(i)$ of industry i in period t and the input of intermediate goods $x_t(i)$.

$$y_t(i) = \frac{1}{\alpha} L_t(i)^{1-\alpha} \cdot (s_t(i) \cdot A_t(i))^{1-\alpha} \cdot x_t(i)^\alpha . \quad (3.1)$$

The model assumes that each industry is either vertically integrated with $x_t(i)=0$ or out sources its production with $x_t(i)=1$.² The industries face with regard to their organizational form a trade off of realizing either the potentials of an improved innovative potential by disintegrating the production process and being caught in a hold-up scenario (due to the fact that the firm owner has to share production rents with the supplier whose scale and productivity decisions are ex post non-verifiable by a third party) or staying vertically integrated and being less innovative. In addition to the basic model by Acemoglu et al. (2003), this setting assumes that outsourcing is not always the most efficient form of production and that industries which are vertically integrated invest more effort T in their ability to adapt technologies from the world technological frontier and put less emphasis on innovation activities for their own production technology.

More specifically, following Acemoglu et al. (2003), the model assumes that the technological state $A_t(i)$ of an industry i in period t is:

$$A_t(i) = \eta_t(i) \bar{A}_{t-1} + \gamma_t(i) A_{t-1} \quad (3.2)$$

with the imitation parameter $\eta_t(i)$ for the technology adaptation of the world technological frontier as

$$\eta_t(i, T(i)) = \underline{\eta} + z((1 - T_t(i))) \quad (3.3)$$

and the innovation parameter $\gamma_t(i)$ of an industry’s own technology as

$$\gamma_t(i, T(i)) = \underline{\gamma} + x(T_t(i)) . \quad (3.4)$$

² The organization form can depend on various circumstance like competition intensity, fixed investment costs and many others which influence the decision making process. A detailed analysis on the influence of several factors on the organizational decision can be found in Acemoglu et al. (2003).

The technological state of an industry depends on the inflow of technology (adaptation) from the world technological frontier and the innovation activity of the own production technology. Both the imitation of the existing technology at the world technological frontier \bar{A}_{t-1} and the innovation of an industry's existing technology A_{t-1} have a lower threshold parameter for imitation $\underline{\eta}$ and innovation $\underline{\gamma}$ of an industry. Additionally to the lower threshold parameters each industry spends an effort T (which depends on the organizational form of an industry) either on adapting the world technology or on innovative activities of the current state of the industry's own technology. For simplicity, the model assumes that an industry either allocates all effort to adaptation activities (with $z(T=0)=\lambda$) or innovation activities (with $x(T=1)=\mu$).

By dividing (3.2) through $\bar{A}_t(i)$, we can derive the following convergence paths for vertically integrated industries and outsourcing-dependent industries to the world technological frontier.

The convergence path for a vertically integrated industry relative to the world technological frontier is

$$a_{t+1}^{vi} = \frac{1}{1+g} (\underline{\eta} + \lambda + \underline{\gamma} \cdot a_t^{vi}), \quad (3.5)$$

which implies for the existence for a non-convergence trap of the imitating industries that

$$1+g > (\underline{\eta} + \lambda + \underline{\gamma}) \quad (3.6)$$

3.6 implies that in the long-run an industry which imitates only innovations of the world technological frontier reaches a lower steady state equilibrium compared to the long-run equilibrium of the world technological frontier.³

For industries which specialize on innovation activities and out source therefore parts of the production process, the level of the own production technology relative to the world technological frontier is

$$a_{t+1}^{ni} = \frac{1}{1+g} (\underline{\eta} + (\underline{\gamma} + \beta) a_t^{ni}) \quad (3.7)$$

which implies the growth rate of the world technological frontier as

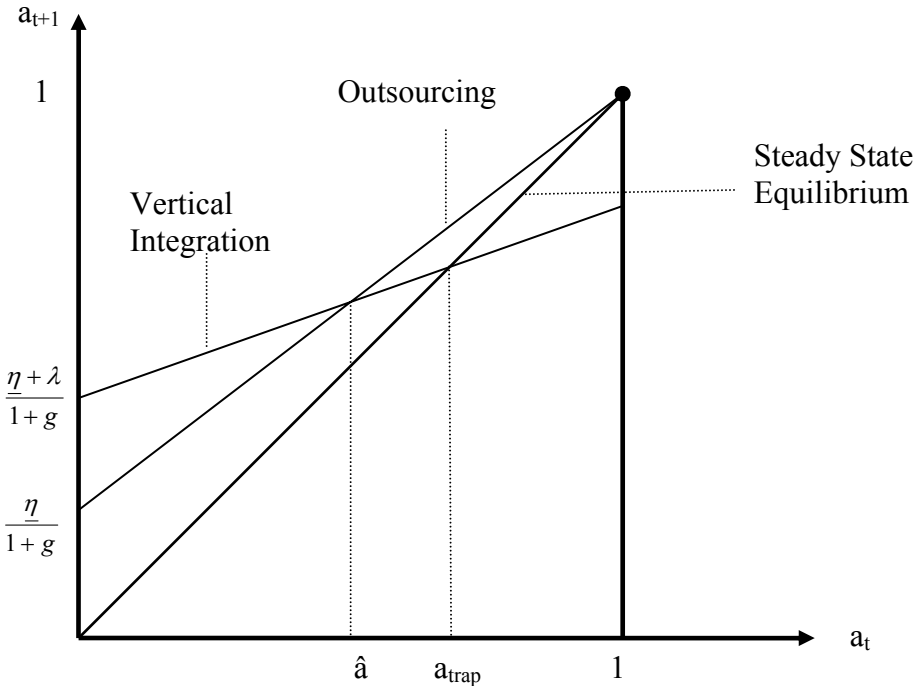
$$1+g = (\underline{\eta} + \underline{\gamma} + \beta). \quad (3.8)$$

³ The growth rate for industries which are caught in a convergence trap equals in steady state the growth rate of the world technological frontier but is smaller in absolute terms. The growth gap of the integrated industries to the world technological frontier depends in this case on the relative productivity level of an industry compared to the world technological frontier.

The growth rate of the world technological frontier is in the long-run equal to the growth rate of the most advanced country which can be derived from equation (3.2) using (3.5), (3.7) and (3.8).

Using (3.5) and (3.7), the convergence paths and the convergence trap of the vertically integrated industry are illustrated in Figure 1.

Figure 1: Convergence of vertically integrated and non-integrated industries



The vertically integrated industry begins the convergence to the long-run steady state equilibrium with a jump start compared to the outsourcing industry. The intuition for that development is that spending resources on innovation of existing technology is less promising compared to the adaptation of the world technology in early stages of technological development. The own technological level is too low compared to the technological level at the world technological frontier so that the outsourcing strategy leads to a lower technological level compared to the vertical integration strategy. With the technological development of an industry, the own technological level compared to the technological frontier grows and the innovation of the own technology becomes more profitable in terms of the technological level. The growth rate of outsourcing industries is, as illustrated in Figure 1, higher during the convergence process than the growth rate of vertically integrating industries assuming that for

all industries the growth rate of the world technological frontier is equal for all industries.⁴ This theoretical prediction for the effects of industry structure will be tested in the following empirical analysis while the second prediction of the model, a lower technological level of vertically integrated industries relative to the world technological frontier will not be tested in the subsequent analysis.

Outsourcing and productivity – benefits of holistic organization

A second complementary theoretical argument for an effect of outsourcing activities on an international level on productivity growth is incorporated in the organizational literature. Lindbeck and Snower (2000) deliver in their article an explanation of the positive effects of outsourcing on productivity by arguing in favor of a holistic rather than a tayloristic organization. The factors favoring a holistic organization include changes in production technology, information technology, in human capital and in worker preferences and occurred during the last decades. The shift of the economic environment on firm level in favor of a holistic organization of tasks could also principally occur on the industry level and lead to productivity advantages for those industries which pro-actively reorganize their production process according to the changes mentioned above (cf. Jarillos, 1993, and the success of the Toyota manufacturing which led a whole industry reorganize the existing production process towards a more holistic organization). Industries which actively reorganize the production process and decrease their share of value added of the gross output should be able to realize the merits of a holistic organization and experience therefore a higher productivity growth while they outsource a part of their share of the value chain. This conjecture will be tested during the subsequent analysis, estimating the effect of the industry structure on productivity growth.

A more drastic reorganization of the organizational structure of an industry is also likely to occur with the establishment of new supplier links (which are likely to go along with a higher share of international intermediates inputs since a globalized economy relies more on international cooperation and specialization of economies) which is the reason why the estimation approach controls also for the intermediate input mix with regard to the country of origin of the intermediate inputs. A higher share of international intermediate inputs of all inputs could therefore be accompanied by a higher productivity growth not only because of a more drastic organizational change towards a holistic organization but also because of

⁴ Acemoglu et al. (2003) show that the steady state growth rate of outsourcing and vertically integrating industries are equal and that they differ with respect to their relative technological level compared to the world technological frontier.

specialization advantages of industries within an international production network of industries (economies). Both effects point in the same direction, are closely linked and cannot be separated in this kind of analysis. The analysis aims therefore mainly to analyze the effect of international cooperation of industries but does not identify one single reason for the effects of international cooperation on TFP growth.

As the reorganization of the production process takes some time and is likely not to be completed and fully effective in the year the outsourcing occurs, it seems to be plausible to assume that the effects of outsourcing on industry productivity occur possibly with a time lag and a longer period, which is considered in the following econometric analysis.

Summarizing the conjectures of the theoretical section, it can be concluded that the outsourcing activities of parts of the value chain of industries should positively affect the productivity growth of industries suggesting positive productivity effects of a development of, e.g. the German economy, towards a “Bazaar economy” (Sinn, 2005).

4. Data and TFP calculation

Productivity analyses are always only as good as the data which is employed and the method which is used to calculate the productivity of an industry. The following section presents the data which is used for the productivity analysis and introduces the computation method for the TFP calculations which are used in the subsequent econometric analysis.

Ifo Productivity Database

The basic database used in this paper is the Ifo Productivity Database which offers detailed information on the productivity development of the German economy.⁵ According to the author’s knowledge, the Ifo Productivity Database is the only database which allows a detailed industry-level growth accounting analysis using the gross output concept for Germany. An advantage of the database is the long time period it covers (1971-2000) and the detailed information it provides on the two digit industry-level according to the NACE classification.⁶ A unique feature of the database and one of the most important strengths of it is the inclusion of intermediate inputs as domestic and international intermediate inputs. The distinction of intermediate inputs according to the country of origin of intermediate inputs allows to compute the input contribution of intermediate inputs for domestic and international

⁵ A detailed description of the database is given in the appendix and in more detail in Fuchs and Kuhlmann (2005).

⁶ Before 1990, the database uses a different industry classification according to the Wz 79 Classification of the German Statistical Office.

outsourcing activities and offers the possibility to analyze the importance of international outsourcing for industries measured as imported share of consumed intermediates. Additionally to this feature the Ifo Productivity Database offers industry-level capital stocks distinguished according to investment assets which is for Germany a unique feature and quite rare in the world.⁷ The database provides also data on labor inputs and the gross output of each industry. Using the detailed information of the database, we get with the above specified growth accounting formula the TFP growth rates of each industry and the industry level contributions of each input sector for the 1971-2000 time period.

Growth Accounting Framework

For the following empirical analysis of the effects of various input factors on the TFP growth rates, the paper relies on the growth accounting framework as described in Jorgenson and Stiroh (2000). The gross output concept, which is employed in this analysis, was shown to be preferable for industry-level productivity analyses since it includes also intermediate inputs in the production function and is less plagued by biases introduced by an exclusion of this important production factor (Jorgenson et al. 1987, Sichel 2001) due to the fact that it does not account for disembodied technological change.

The basic growth accounting equation can be regarded as a general specification of the production function of the AAZ model (3.1). The only extension of (3.1) is that the formulated production function allows for an influence of industry structure and intermediate input mix on the productivity level A_{it} of an industry resulting in the following production function:

$$Q_{it} = A_{it} \cdot K_{it}^{v_{Kit}} \cdot L_{it}^{v_{Lit}} \cdot INT_{it}^{v_{Int}} \cdot M_{it}^{v_{Mit}} \quad (4.1)$$

with Q_{it} as gross output in industry i during period t , L_{it} as labor inputs in industry i in period t , K_{it} as capital stock in industry i at period t , and INT_{it} and M_{it} as national and international intermediate inputs of industry i in period t .

Logarithmising both sides of (4.1) and first differencing the expressions, the basic growth accounting equation of the gross output concept can be written as:

$$\Delta \ln Y_{it} = v_{Lit}^{-L} \Delta \ln L_{it} + v_{Cit}^{-C} \Delta \ln C_{it} + v_{Mit}^{-M} \Delta \ln M_{it} + v_{Int}^{-I} \Delta \ln I_{it} + \Delta TFP_{y_i}, \quad (4.2)$$

⁷ According to the authors, this feature offer only databases for the US and UK and is not published by the German Statistical Office for the German Economy.

The residual of the equation is often referred to as the Solow residual or total factor productivity TFP_{y_i} . TFP_{y_i} is gross output total factor productivity and can be written as a function of the output less the input contributions:

$$\Delta TFP_{y_i} = \Delta \ln Y_{it} - \bar{v}_{it}^{-L} \Delta \ln L_{it} - \bar{v}_{it}^{-C} \Delta \ln C_{it} - \bar{v}_{it}^{-M} \Delta \ln M_{it} - \bar{v}_{it}^{-I} \Delta \ln I_{it}. \quad (4.3)$$

with \bar{v}_{it} representing the input shares of each industry i (calculated as cost shares) in period t which fulfill under constant returns of scales and perfect competition the following condition: $\bar{v}_{it}^{-L} + \bar{v}_{it}^{-K} + \bar{v}_{it}^{-C} + \bar{v}_{it}^{-I} = 1$.⁸

To get unbiased calculations of the TFP growth of industries it is a necessary condition that these two conditions hold which is a strong assumption given the fact that various studies deny that the conditions hold in reality (cf. Flaig and Steiner, 1993 who show for a sample of German manufacturing industries from 1965-1986 that the constant returns to scale assumption is violated in the analyzed sample). It is therefore necessary that in the following econometric analysis of the determinants of TFP growth a strategy is used which controls for possible violations of the constant returns to scale assumption and the perfect competition assumption.

5. Econometric analysis

The emphasis of the estimation in this study lies on the impact of industry structure and the intermediate input mix as a measure of international integration on TFP growth. As mentioned above, the underlying production function allows for an influence of industry structure and intermediate input mix on the TFP growth assuming the following relationship between A_{it} , INTSHARE_{it} (the ratio of the value of consumed intermediates for production over the value of gross output and can be seen as an indicator of the degree of vertical integration of an industry i), INTCHANGE_{it} (the change in intermediates consumption over gross output in industry i from period $t-1$ to t), IMPSHARE_{it} (the ratio of imported intermediates over total intermediate input of an industry i in period t) and IMPCHANGE (the change of IMPSHARE from period $t-1$ to t in industry i):

$$A_{i,t} = e^{\beta_1 \cdot \text{INTSHARE}_{i,t} + \beta_2 \cdot \text{INTCHANGE}_{i,t} + \beta_3 \cdot \text{MPTSHARE}_{i,t} + \beta_4 \cdot \text{IMPCHANGE}_{i,t}}. \quad (5.1)$$

This particular specification of the productivity function $A_{i,t}$ allows for an influence of intermediate inputs on TFP growth if the contribution of the input factor changes

⁸ The costs shares of labor and capital are calculated using the labor services and capital services flows of each industry as proposed by Jorgenson and Stiroh (2000).

disproportionately compared to the other input factors. Equal changes in the input contributions of all factors which do not change the production technology but only the amount of inputs used in this process are assumed to be irrelevant for the production technology $A_{i,t}$ in this scenario.

The remaining part of this section develops the econometric approach to estimate the determinants of productivity growth and discusses econometric issues related to the estimations and presents thereafter the results of the estimation series.

Estimation approach

Empirical estimations of the determinants of TFP growth are accompanied by several empirical issues which need to be considered in the estimation strategy of the determinants of TFP growth. The two most severe problems are possible measurement errors in the explanatory and independent variables and possible violations of the assumptions underlying the growth accounting framework, i.e. the perfect competition assumption and the constant returns to scale assumption which are below discussed for their relevance.

Econometrical issues

A major task for any empirical estimation of the relationship of TFP growth is how measurement errors in any of the input contributions could influence the TFP growth contributions. In Appendix C, the TFP regressions which are used in this setting are derived using simple matrix algebra, showing that the TFP regressions are basically restricted productivity growth regressions which assume constant returns to scale for all input factors.⁹ This means that TFP growth regressions are not more or less plagued by mismeasurement of exogenous or dependent variables than ordinary output growth regressions using output growth as dependent variable. But the remaining issue is still in how far measurement errors could bias the estimates of the TFP growth regressions. If measurement errors are not systematically correlated with the exogenous variables, the TFP growth estimates are still consistent but suffer from inflated standard errors which impose with regard to the inference of the coefficients a tendency to over reject coefficient estimates in statistical tests. In contrast to no systematically correlated measurement errors, systematically correlated measurement errors result in a bias of the coefficients of unknown form which is more severe than the inference problematic. The critical question for this issue is therefore to what extent the data suffers from systematically correlated measurement errors. The basis of the data used in this

⁹ The TFP growth regressions which are undertaken in section 5 are identical to output growth regressions with no constant returns to scale. One reason why the author choose TFP regressions is the fact that this concept is widely used for productivity analyses and allows comparing the numbers for Germany with other countries.

analysis is taken or derived from official data published by the German Statistical Office (StBA) and it seems unlikely that official data suffers systematically from a measurement error of unknown form over a time period of 30 years. A second argument for no systematically correlated measurement errors is the fact that the econometric analysis uses growth rates instead of levels as dependent and explanatory variables. Time persistent measurement errors in the levels of the explanatory variables will not show up in first differences so that this problem seems to be less relevant for the following econometric analysis.¹⁰

Another issue for the econometric analysis are violations of the constant returns to scale assumption and the perfect competition assumption of the growth accounting framework. The estimation approach controls for violations of the constant returns to scale assumption by allowing every input contribution to have a different effect on output and not restricting the sum of all value shares to one.¹¹ The violation of the perfect competition assumption cannot be controlled for by the data used by the inclusion of indicators for the competition intensity in an industry since these are not available in the used dataset. The strategy to deal with that problem is instead a fixed effects estimation approach. The fixed effects control for industry-specific effects and can hence account for systematic industry differences in the competition intensity and their effects on TFP growth. Possibly time-varying changes in the competition level are assumed to influence all industries in a similar way and are controlled for by including a common time trend in the estimation.

Estimating the effects of industry structure on TFP growth

The estimation strategy described above leads finally to specification (1) which is an OLS estimation equation of the following form:

$$\Delta TFP_{y_{it}} = \beta_{0i} + \beta_1 \cdot INTSHARE_{it} + \beta_2 \cdot INTCHANGE + \beta_3 \cdot IMPSHARE_{it} + \beta_4 \cdot IMPCHANGE_{it} + \beta_5 \cdot X_{it} + \beta_6 \cdot IDUMMY + \beta_7 \cdot TIME + \varepsilon_{it} \quad (5.1)$$

This estimation equation resembles a two-step estimation approach due to the fact that it uses the Solow Residual of equation (4.3) as independent variable, but is nevertheless

¹⁰ There is still the possibility that the first difference of the variables are plagued by measurement errors which are systematically correlated the dependent variable over time. But I can hardly imagine any measurement error which is persistent over time and shows up in first differences.

¹¹ This procedure leads finally to an estimation approach which is equal to an estimation approach of the output growth $\Delta \ln Y_{it}$ of an industry in a one step estimation, allowing for non-constant returns to scale of the input contributions to output growth. The TFP growth regressions in this study are therefore regressions on TFP growth which account already for economies of scale and differ therefore from the Solow residual which assumes constant returns to scale.

equivalent to a one-step estimation procedure of output growth with non-constant returns to scale as shown in Appendix C.¹²

The variables in the estimation equation are ΔTFP_{yit} as the TFP growth rate of industry i in period t , $INTSHARE_{it}$ as the ratio of the value of consumed intermediates for production over the value of gross output and can be seen as an indicator of the degree of vertical integration of an industry, $INTCHANGE_{it}$ as the change in intermediates consumption over gross output in industry i from period $t-1$ to t , $IMPSHARE_{it}$ as the ratio of imported intermediates over total intermediate input of an industry i in period t and $IMPCHANGE$ as the change of $IMPSHARE$ from period $t-1$ to t in industry i . To control for non-constant returns to scale in the production function, the input contributions are added as a matrix of control variables X_{it} for each industry i in period t . Furthermore, the estimation equation controls also for a time trend ($TIME$) and industry-specific effects ($IDUMMY$) and assumes that the error term ε_{it} is a white noise error term and distributed with $(0;\delta)$.

Specification (2) is a static fixed effects panel data model and estimated according to the following estimation equation:

$$\begin{aligned} \Delta TFP_{y_{it}} - \overline{\Delta TFP}_{y_i} = & \beta_1 \cdot (INTSHARE_{it} - \overline{INTSHARE}_i) + \beta_2 \cdot (INTCHANGE_{it} - \overline{INTCHANGE}_i) \\ & + \beta_3 \cdot (IMPSHARE_{it} - \overline{IMPSHARE}_i) + \beta_4 \cdot (IMPCHANGE_{it} - \overline{IMPCHANGE}_i) \\ & + \beta_5 \cdot (X_{it} - \overline{X}_i) + \beta_7 \cdot TIME + (\varepsilon_{it} - \overline{\varepsilon}_i). \end{aligned} \quad (5.2)$$

The fixed effects model which is in most regressions specifications preferable to the random effects model (and hence also the between effects estimator)¹³ delivers the within effects estimator and utilizes the time-varying component of changes of the explanatory variables. The estimates of this model can therefore be seen as the short-run effects of changes in the industry structure and are the relevant estimators for the data given the relative short time-period utilized in this sample (Mundlak, 1978).

But this estimator is still sensitive to dynamic misspecifications and heteroskedasticity of the error term, which is the reason why in the next step auto-correlated panel techniques for first order serial correlation, panel-specific correlation and panel specific heteroskedasticity following Prais and Winsten (1954) are employed for the estimation of the effects of the TFP regression

¹² The estimated coefficients of industry structure variables and intermediate input mix variables are equal, only the coefficients of the input contributions differ in the regressions with $\beta_{TFP} = \beta_{Output} - 1$. This is the case due to the fact that the TFP growth or Solow-residual is computed as the difference between output growth and the input contributions to output growth.

¹³ The Hausman test which is reported in the tables evidences that.

Specification (3) allows for dynamic effects of shocks of the error term and utilizes an AR(1) panel estimator, assuming that the error term can be serially correlated of first order $\varepsilon_{it} = \rho\varepsilon_{it-1} + u_{it}$ with u_{it} as an independently identically distributed (iid) white noise error term.

Specification (4) accounts for panel-specific correlation and heteroskedasticity in a Prais and Winsten estimation, relaxing the iid assumption of the error term of the AR(1) panel estimator and allowing for panel specific heterogeneity with a variance-covariance matrix of the following form:

$$\Omega = \Sigma_{m \times m} \otimes I_{T_i \times T_i}, \text{ with } \hat{\Sigma}_{ij} = \frac{\varepsilon_i \varepsilon_j'}{T_{ij}}.$$

But still, static panel estimators suffer from an estimation bias if the impact of industry structure and intermediate input mix have a dynamic impact which is realized over a time period. To account for the dynamic nature of the influences of the explanatory variables over time, the impact of industry structure and intermediate input mix on TFP growth are estimated in a dynamic model in specifications (5)-(7):

$$\begin{aligned} \Delta TFP_{y_{it}} = & c_i + \beta_0 \Delta TFP_{y_{it-1}} + \beta_1 \cdot INTSHARE_{it} + \beta_2 \cdot INTCHANGE_{it} + \beta_3 \cdot IMPSHARE_{it} \\ & + \beta_4 \cdot IMPCHANGE_{it} + \beta_5 \cdot X_{it} + \beta_6 \cdot IDUMMY + \beta_7 \cdot TIME + \varepsilon_{it} \end{aligned} \quad (5.4)$$

The dynamic panel data model cannot be consistently estimated with an OLS estimator or a fixed effects estimator due to the fact that the lagged dependent variable is correlated with the error term $\varepsilon_{i,t}$. A solution to this problem was proposed by Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998) who have shown that (5.4) can be consistently and efficiently estimated using first differences which leads to the following estimation equation

$$\begin{aligned} \Delta TFP_{y_{it}} - \Delta TFP_{y_{it-1}} = & \beta_0 \cdot (\Delta TFP_{y_{it-1}} - \Delta TFP_{y_{it-2}}) + \beta_1 \cdot (INTSHARE_{it} - INTSHARE_{it-1}) \\ & + \beta_2 \cdot (INTCHANGE_{it} - INTCHANGE_{it-1}) + \beta_3 \cdot (IMPSHARE_{it} - IMPSHARE_{it-1}) \\ & + \beta_4 \cdot (IMPCHANGE_{it} - IMPCHANGE_{it-1}) + \beta_5 \cdot (X_{it} - X_{it-1}) + \varepsilon_{it} - \varepsilon_{it-1}, \end{aligned} \quad (5.5)$$

using the lagged first differences of the independent and dependent variables, as well as the lagged levels, as instruments in a system GMM approach.

The dynamic system GMM estimator proposed by Blundell and Bond (1998) requires for its consistency a lack of second correlation, which is reported in the tables below and a valid Sargan over identification test. The advantage of the Blundell-Bond over the Arellano-Bond estimator results from the fact that it uses the lagged levels and first differences of the explanatory variables and dependent variables in a system approach rather than just instrumenting the explanatory variables by their lagged levels and differences. This procedure

results in a system GMM approach for the estimation of the effects and was shown to be more efficient and less plagued by biases, also with respect to small samples, which is the reason why it is used in this application.

Results

This section presents the results of the above described estimation equations beginning with the results for the West German economy and the time period from 1971 to 1990 and is followed by the results for Unified Germany for the time period from 1991 to 2000.¹⁴ The results of the all industries sample are reported first and then compared in a sensitivity analysis to the results for selected sub samples of industries.

Industry structure and TFP growth

The OLS regression of the effect of industry structure on TFP growth in table 1a illustrates that in the period from 1971 until 1990, the industry structure was of great importance for the productivity growth potential of an economy. The estimated effect of the industry structure, as measured as percentage of intermediate input consumption of gross output of an industry, is 0.08 and statistically highly significant for the OLS regression. After controlling for industry-specific effects in a fixed effects panel estimation, which utilizes the time-varying components of the industry data, the effect prevails statistically highly significant in a similar magnitude compared to the OLS regressions ranging around 0.05 for the estimated effect of industry structure INTSHARE on TFP growth, providing evidence for beneficial effects of a vertically disintegrated industry structure on TFP growth for 1971-1990 period. The beneficial effects of vertical disintegration are also evidenced in the dynamic system GMM estimation which controls for a dynamic impact of INTSHARE on TFP growth. The effects of TFP growth in this specification were found to be statistically significant at the one percent level and with an estimated value of 0.04 in both specifications. This result suggests that industries which have a one standard deviation higher share of intermediates input over gross output experienced during the 1971-1990 period a 0.6 percentage points higher TFP growth which is twice the average annual industry TFP growth rate for the 1971-1990 period.

For the period from 1991 until 2000, the effect of industry structure on TFP growth is during most specifications statistically insignificant. This result is an indication for the conjecture that the German economy could have already reached a steady state equilibrium for the majority of its industries. The reason why there is no longer an effect of industry structure on productivity growth is that even industries, which decided not to vertically

¹⁴ The division of the sample into two time periods is owed to a change in industry classification and the German reunification in 1990 which make it impossible to obtain a 30 year time period from 1971-2000.

disintegrate and are potentially caught in a convergence trap, would experience in steady state the same growth rate compared to vertically disintegrating industries and stay relative to the world technological frontier in a stable position.¹⁵

A second interesting issue concerning the industry structure is what influence do changes in industry structure exert on TFP growth. Of special importance is hereby whether vertically disintegrating industries experience positive short run effects of outsourcing or whether potentially detrimental effects like e.g. adjustment costs outweigh the beneficial potential of outsourcing. For the 1971-1990 period, the OLS estimation delivers a statistically significant estimated effect of INTCHANGE of 0.16 and an estimated effect. The static panel analyses confirm that the magnitude of the estimated effect of INTCHANGE varies around 0.16 and that the effect is statistically significant at the one percent level. The dynamic system GMM regression estimates the effect of INTCHANGE for the 1971-1990 period somewhat smaller with 0.145 which would correspond to an increase of TFP growth by 0.003 for a one standard deviation increase of INTCHANGE illustrating once more the positive potential of vertical disintegration during this period.

For the 1991-2000 period, the effects of changes of industry structure INTCHANGE on TFP growth are for all estimations positive but fail to be statistically significant at the ten percent level in all regressions. It seems therefore to be the case that changes in the industry structure did not play an important role as determinants of productivity growth in this period which indicates that either the adjustments costs of changes of industry structure are offsetting the benefits or that the changes in industry structure are non-systematic changes and not related to a convergence process and have therefore no impact on TFP growth.

Intermediate input mix and TFP growth

Another point of interest with regard to the use of intermediate inputs and their influence on TFP growth is the effect of the intermediate inputs mix of domestic and imported intermediates. As argued in section 4, it is possible that international outsourcing activities can have a positive effect on TFP growth if they promote holistic production networks in a more favorable way than national outsourcing activities.

The econometric analysis of the intermediate input mix IMPSHARE on TFP growth for the 1971-1990 period delivers mixed results for different estimation approaches with varying results both in magnitude and sign of the estimated effects. While the OLS estimation delivers a very small insignificant effect, the static panel analyses show in general a pattern of

¹⁵ Cf Acemoglu et al (2003).

statistically significant negative effects of a higher share of imported intermediates input on TFP growth. But this negative effect of IMPSHARE is not supported in the dynamic system GMM approach which controls for dynamic influences of the explanatory variable. Concluding it can be said that the results of the estimation series delivers for the effects of IMPSHARE a mixed picture suggesting in tendency statistically insignificant effects and hence an irrelevance of the intermediate input mix on TFP growth of industries ion the 1971-1990 period.

But the picture totally changes if we take the changes of the intermediate input mix IMPCHANGE into consideration. The estimated effect of the OLS regression of the intermediate input mix changes show a highly statistically significant effect of about 0.20. This result is reinforced by the results of the estimated effects of the static panel regression series which are of similar magnitude during the specifications and statistically significant at the one percent level. Only the dynamic system GMM estimations fail to deliver statistically significant effects, even at the ten percent level, but deliver results of the effects of IMPCHANGE which are of the same magnitude as the estimated OLS and static panel effects and differ only by more imprecise estimations of the coefficient estimates and larger standard errors. It can be therefore concluded that the estimates of IMPCHANGE are in tendency an evidence of the positive effects of a higher share of intermediated inputs on TFP growth, which is in favor of the holistic organization hypothesis mentioned in section 4. The substitution of domestic intermediate inputs by imported intermediate inputs seems in the analyzed sample not to depend on the level of the ratio of intermediate inputs rather on the changes of the intermediate input mix. This could be interpreted as evidence that the hypothesis that international outsourcing increases the TFP growth rate is true if the intermediate input mix is changed which could be caused by organizational changes of an industry. In contrast to the industry structure, the analysis shows no permanent significant effect of a change in the intermediate input mix once a higher share of imported intermediates inputs is realized which suggest that the changes of the intermediate input structure are only effective for the time period of the change.

For the 1991-2000 period, the estimated effects of intermediate input mix on TFP growth are mixed with a positive effect of the level of the share of the intermediate input mix IMPSHARE. This positive effect of IMPSHARE is statistically significant at the five percent significance level for the static panel analyses with an estimated effect of 0.25. But the statistically significant positive effect vanishes as soon as the Prais-Winston regression result and the results of the dynamic system GMM are taken into account which calls for a

discussion which results are reliable and which ones are not reliable. With regard to the OLS estimation, it is plausible to rely on the estimated effects of the static panel data analyses which utilize the time-varying components of the data to estimate short-run effects of the intermediate inputs share. But still the static panel analysis could suffer from a dynamic misspecification (of the error term) for which the Prais-Winstone estimation of the static panel data gives some evidence. It is therefore reasonable to rely with regard to the interpretation of the estimated effects on the dynamic system GMM estimation which accounts for the possibly dynamic influence of IMPSHARE and uses a system GMM approach to correct for potential estimation biases caused by endogenous variables. Summarizing the results for the 1991-2000 period, the study does not find any significant effects IMPCHANGE on TFP growth suggesting that for the analyzed periods changes of the intermediate input mix had no effect on the TFP growth potential of an industry while the level of IMPSHARE had in tendency positive effects which fail to be statistically significant in all specifications.

Sensitivity analyses of TFP growth

This section is intended to complement the previous sections by providing further evidence on the effects of industry structure and intermediate input mix and TFP growth for different industries.

Manufacturing industries

For the sub sample of manufacturing industries, the estimation series delivers for the estimated effects of industry structure on TFP growth results which are comparable with the results of the all industries sample used during the previous regressions for 1971-1990. The effects of vertically disintegrating industries seem therefore to be relevant for manufacturing industries both with respect to the level of industry structure INTSHARE and changes of industry structure INTCHANGE and confirm the conjectured positive effects of industry structure on TFP growth for manufacturing industries. The effects of an increase of changes of industry structure are hereby only partial effects which should, for a comprehensive interpretation of the effects of changes of industry structure on TFP growth, take also the estimated effects of a higher share of intermediate inputs over gross output INTSHARE into account. The indirect effect of increases in INTCHANGE by one standard deviation over a time period of ten years would result in an increase of 0.8 percentage points of TFP growth in the subsequent years, illustrating the permanent potential of changes in industry structure after an adjustment period.

The effects of changes of the intermediate input mix IMPCHANGE on TFP growth are for the manufacturing sub sample 2.5 times bigger than the estimated effect of the all industry

sample suggesting a positive, statistically highly significant effect of 0.5 on TFP growth for changes in the intermediate input mix of industries. This result is not surprising when we consider the fact that the beneficial effects of holistic organizations shall be mainly relevant for manufacturing industries which produce goods rather than services and have therefore the opportunity to vertically disintegrate a larger part of their production chain compared to service industries whose share of value-added of the gross output of an industry is on average higher. The estimated positive effect of vertical disintegration of 0.5 corresponds to a 1.05 percentage points increase of TFP growth for a one standard deviation increase in the IMPCHANGE, implying a huge potential for productivity increases for an industry, especially for TFP growth calculations using the gross output concept. This one standard deviation increase over a time period of ten years corresponds to an increase of the share of intermediate inputs of gross output of 21 percentage points corresponding to an increase of IMPSHARE by approximately 1.7 standard deviations which illustrates how drastic the supplier linkages must change to realize the potential of efficiency gains of international outsourcing.

For the 1991-2000 time period of the manufacturing sub sample, the estimated effects industry structure on TFP growth are statistically insignificant suggesting that for the 1991-2000 period changes in industry structure were irrelevant for the TFP growth path of an industry. This result could be interpreted as evidence for the suspicion that the German manufacturing industries had converged until 1990 to their long-run steady state equilibrium so that the industry structure and changes in the industry structure do no longer affect the productivity growth of an industry.

But unlike industry structure, the estimation results of the effects of intermediate input mix on TFP growth for 1991-2000 show a positive, statistically significant effect of IMPSHARE on TFP growth for the dynamic panel analysis and in tendency positive but insignificant effects for the static panel estimations. The estimated effect of IMPSHARE of the dynamic system GMM approach ranges around 0.035 (and is statistically significant at the 5 percent level) corresponding to an increase of 0.5 percentage points of TFP growth for a one standard deviation increase of the share of imported intermediate inputs of all intermediate inputs. This shows that for the 1990s the productivity growth potential depended on the level of the intermediate input mix rather than on changes of the intermediate input mix indicating that this period was beneficial to those firms which had in the previous period undertaken efforts to change their intermediate import mix. Changes of the intermediate input mix of industries offer according to the results no direct gains for TFP growth potential but only indirect gains

through a higher share of intermediate inputs in the subsequent years, implying implicitly that other factors, like e.g. adjustment costs offset the potential benefits of changes of the intermediate input mix in the short run.

Service industries

The services industries sub sample for the 1971-1990 period delivers mixed results for the estimated effects of industry structure and intermediate input mix. The estimated effects of intermediate input mix for services industries are in tendency statistically insignificant for the panel analyses but consistently negative for IMPCHANGE providing weak evidence for negative effects of international outsourcing activities in the service sector. The estimated effects for IMPCHANGE fail to be statistically significant in the dynamic system GMM estimation, so that the estimated effects of the static panel estimations should be interpreted with caution especially when we consider the result that the dynamic system GMM estimation suggests a dynamic misspecification of the static panel model with a statistically significant lagged dependent variable.

The results of industry structure on TFP growth are in contrast to the intermediate input mix less mixed and provide evidence for a statistically significant, positive effect of changes in industry structure towards a vertically disintegrated industry for the 1971-1990 period for services industries. The estimated effects of the static panel analyses and the dynamic system GMM estimation range around 0.18 indicating that a one standard deviation increase of INTCHANGE results in an increase of 0.3 percentage points of TFP growth for these industries. This illustrates that vertical disintegration of industries was also for services industries during the 1971-1990 period a potential source of a higher TFP growth rate and that the positive effects of vertical disintegration was not limited to the manufacturing industries.

For the 1991-2000 period, the results deliver no clear trends for industry structure and intermediate input mix on TFP growth suggesting that the convergence of German services industries has already taken place until 1990 and confirming the results of the 1971-1990 period for service industries with respect to the irrelevance of intermediate input mix on TFP growth.

Conclusions

This paper attempts, to the author's knowledge for the first time, an analysis of the effects of industry structure and intermediate input mix on TFP growth on the industry level. The analysis reveals the positive potential of vertical disintegration of industries for both

manufacturing and services industries. The results suggest that during a convergence period vertically disintegrated industries possess a comparative advantage over vertically integrated industries in terms of the productivity growth potential. After the completion of the convergence to the technological frontier, the industry structure plays a minor role for productivity growth confirming the theoretically derived conjectures by Acemoglu et al. (2003) with respect to industry structure and productivity growth of industries.

Another interesting result of the study is the relevance of the intermediate input mix for the productivity potential of an economy. While during the convergence period, the changes in the intermediate input mix affected the productivity potential of an economy, the situation changed after the completion of the convergence process of an industry. In this period the share of imported intermediates of all intermediate inputs mattered for the productivity growth of an industry, especially in the manufacturing sector, implying permanent and substantial effects of international cooperation.

It can be concluded therefore that economies should try to promote international cooperations of industries (and hence also firms) to realize the productivity potential of a higher degree of globalization. Interestingly the higher level of specialization seems only permanently possible on the international level. In contrast to domestic outsourcing activities, international outsourcing activities lead to a higher productivity potential even after the completion of the convergence process to the world technological frontier which can either be explained by specialization advantages in an international production framework of industries, differing factor costs in foreign countries or the opportunity to revolutionary change the production process and organization of inter-industry networks which is only hardly possible on the national level since the persistency of existing supplier linkages allows mainly for evolutionary changes and innovations of the organizational form of an industry which can be especially detrimental in an economic environment which experiences a comparative advantage change from a tayloristic to a holistic organization of the production process.

References

- Acemoglu, Daron, Aghion, Phillippe, and Fabrizio Zilibotti (2003). „Vertical Integration and Distance to Frontier“, *Journal of the European Economic Association* 1(2-3), pp. 630-638.
- Acemoglu, Daron, Aghion, Phillippe, and Fabrizio Zilibotti (2004). „Distance to Frontier, Selection, and Economic Growth“, *Journal of the European Economic Association*, 2004, forthcoming.
- Alcalá, Francisco and Antonio Ciccone (2004). “Trade and Productivity”. *Quarterly Journal of Economics*, 119(2), pp. 613-646.
- Basu, Susanto, Fernald, John G., Oulton, Nicholas, and Sylaja Srinivasan (2003). "The Case of the Missing Productivity Growth: Or, Does Information Technology Explain why Productivity Accelerated in the US but not the UK?," NBER Working Papers 10010.
- Domar, E.D. (1961). “On the measurement of technological change”, *Economic Journal*, LXXI, pp. 709–29.
- Egger, Hartmut, and Petter Egger (2003). “Outsourcing and Skill-specific Employment in a Small Economy: Austria and the Fall of the Iron Curtain”, *Oxford Economic Papers* 55(4), 2003, pp. 625-643.
- Egger, Hartmut, and Petter Egger (2005). “International Outsourcing and the Productivity of Low-skilled Labor in the EU”, *Economic Inquiry*, 2005, forthcoming.
- Egger, Hartmut, and Petter Egger (2005). “Labor Market Effects of Outsourcing Under Industrial Interdependence”, *International Review of Economics and Finance*, 2005, forthcoming.
- Egger, Hartmut, and Petter Egger (2005). "Outsourcing and Trade in a Spatial World," CESifo Working Paper 1349.
- Feenstra, Robert C., and Gordon H. Hanson (1999). "The Impact Of Outsourcing And High-Technology Capital On Wages: Estimates For The United States, 1979-1990," *The Quarterly Journal of Economics*, 114(3), pp. 907-940.
- Flaig, Gebhardt, and Viktor Steiner (1993). „Searching for the productivity slowdown: some surprising Findings from West German Manufacturing”, *Review of Economics and Statistics*, 75, pp. 57-65

- Foster, Lucia, Haltiwanger, John, and C. J. Krizan (1998). "Aggregate Productivity Growth: Lessons from Microeconomic Evidence", NBER Working Paper 6803.
- Görg, Holger, Hanley Aoife, and Eric Strobl (2004). „Outsourcing, foreign ownership, exporting and productivity: An empirical investigation with plant level data”, University of Nottingham Working Paper.
- Görg Holger and S. Grimma (2004). "Outsourcing, foreign ownership and productivity: Evidence from UK establishment level data", *Review of International Economics*, 12(5), pp. 817-832.
- Görzig, Bernd, and Andreas Stephan (2002). "Outsourcing and firm-level performance", Discussion Paper No. 309, DIW Berlin.
- Grossman, Gene M., and Elhanan Helpman (2002). "Integration Versus Outsourcing In Industry Equilibrium," *The Quarterly Journal of Economics*, 117(1), pp. 85-120.
- Hijzen, Alexander, Görg, Holger and Robert C. Hine (2003). "International Fragmentation and Relative Wages in the UK", IZA Discussion Papers 717,
- Jarillo, Carlos (1993). "Strategic Networks: Creating the Borderless Organization", Butterworth-Heinemann.
- Jorgenson, Dale, Gollop, Frank, and Brabara M. Fraumeni (1987). "Productivity and U.S. Economic Growth" Cambridge, MA: Harvard University Press.
- Jorgenson, Dale and Kevin J. Stiroh (2000). "Raising the Speed Limit: US Economic Growth in the Information Age", OECD Economic Department Eorkin Paper ECO/WKP (2004) 34.
- Lindbeck, Assar, and Dennis J. Snower (2000). "Multitask Learning and the Reorganization of Work: From Tayloristic to Holistic Organization," *Journal of Labor Economics*, 18(3), pp. 353-76.
- Mundlak, Yair (1978). "On the Pooling of Time-Series and Cross-Section Data", *Econometrica* 46, pp. 69-85.
- Prais, S., and C. Winsten (1954). "Trend Estimators and Serial Correlation". Discussion Paper 383, Coewlls Foundation.

- Oulton, Nicholas, and Megan O'Mahony, (1994). "Productivity and Growth", Cambridge University Press, Cambridge.
- Sichel, D.E. (2001), "Productivity in the communications sector: an overview", Paper presented to Workshop on Communications Output And Productivity at the Brookings Institute, 23 February, <http://www.brook.edu/es/research/projects/productivity/workshops/20010223/20010223.html>.
- Siegel, Daniel and Griliches, Zvi (1992). "Purchased services, outsourcing, computers, and productivity in manufacturing", in Griliches, Z. (ed.): Output Measurement in the Service Sector, University of Chicago Press, Chicago, p. 429-458.
- Sinn, Hans-Werner (2005). „Die Basarökonomie“, Ifo Schnelldienst, 06/2005.
- Van Ark, Bart Inklaar, Robert and Robert H. McGuckin (2002), " "Changing Gear": Productivity, ICT and Services: Europe and the United States", Research Memorandum GD-60, Groningen Growth and Development Centre, December (downloadable from <http://www.eco.rug.nl/ggdc/pub/>).

Appendix A

Table 1a: INDUSTRY STRUCTURE AND TFP GROWTH, 1971-1990, West Germany

	I		II		III		IV		V		VI		VII	
	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E
L.DTFP														
IMP SHARE	-0.011	0.02	-0.032*	0.017	-0.035*	0.019	-0.016**	0.006	0.014	0.085	-0.049	0.082	0.014	0.08
IMP CHANGE	0.201***	0.062	0.208***	0.062	0.223***	0.063	0.178***	0.058			-0.002	0.008	-0.007	0.007
INT SHARE	0.077***	0.023	0.059***	0.021	0.084***	0.023	0.048***	0.009	0.041***	0.015	0.21	0.187	0.218	0.171
INT CHANGE	0.164***	0.044	0.169***	0.044	0.166***	0.044	0.148***	0.041	0.145*	0.079			0.042***	0.014
CONSTANT	0.771*	0.428	-0.015	0.012	-0.027**	0.012	-0.016***	0.005	-0.017*	0.009	0.005*	0.003	0.148**	0.071
DCAPITAL	0.097	0.501	0.052	0.501	-0.063	0.545	0.188	0.309	0.231	0.407	-0.361	0.456	-0.017*	0.009
DDOMESTIC	0.021	0.032	0.013	0.032	0.032	0.032	0.038	0.028	-0.043	0.06	0.012	0.094	0.011	0.089
DIMPORTS	-0.504***	0.043	-0.505***	0.043	-0.514***	0.044	-0.483***	0.039	-0.415***	0.148	-0.486**	0.182	-0.498***	0.171
DLHOURS	0.015	0.081	0.002	0.081	0.013	0.085	0.017	0.067	0.054	0.144	-0.018	0.152	0.016	0.139
DLQUALITY	0.356	1.151	0.247	1.151	0.111	1.156	1.689*	0.884	3.338**	1.655	2.029	1.343	3.295*	1.678
Controls for														
Time trend	<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	
Industry dummies	<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	
AR(1)	<input type="checkbox"/>		<input type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	
Observations	950		950		900		950		950		950		950	
R-squared	0.24		0.20		0.22		2031 [†]		0.71		0.69		0.66	
					0.00 ⁺				1.00 [‡]		1.00 [‡]		1.00 [‡]	

Notes: Dependent variable: TFP growth rates. Coef.: Coefficient estimate. - S. E.: standard error. Significance level: *** 1 percent. ** 5 percent. * 10 percent. - IMP SHARE: share of imported intermediates of all intermediates - IMP CHANGE: change of IMP SHARE from t-1 to t - INT SHARE: share of intermediate inputs of gross output. - INT CHANGE: change of INT SHARE from t-1 to t. - DCAPITAL: share weighted contribution of capital input to output growth. - DDOMESTIC: share weighted contribution of domestic intermediate inputs to output growth. - DIMPORTS: share weighted contribution of international intermediate inputs to output growth. - DLHOURS: share weighted contribution of labour hours worked to output growth - DLQUALITY: share weighted contribution of labour quality to output growth. - I: OLS regression; II, III: Fixed Effects Panel regression; IV: Prais-Winsten-Panel regression; V-VII: Blundell-Bond dynamic system GMM regression. †: Log Likelihood value. ‡: p-value of the Sargan test. +: p-value of the Hausmann-test.

Table 1b: INDUSTRY STRUCTURE AND TFP GROWTH, 1991-2000, Unified Germany

	I		II		III		IV		V		VI		VII	
	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E
L.DTFP	0.155***	0.045	0.146***	0.045	0.251**	0.099	0.013	0.01	-0.074	0.059	-0.055	0.06	-0.053	0.061
IMP SHARE	0.015	0.072	0.017	0.072	0.089	0.086	-0.057	0.059	0.026	0.017	0.026	0.017	0.018	0.016
IMP CHANGE	-0.019	0.018	-0.018	0.018	-0.019	0.021	-0.023**	0.011	-0.025	0.023	-0.021	0.066	-0.017	0.066
INT SHARE	0.013	0.013	0.012	0.013	0.01	0.014	0.016	0.01	0.018	0.018	0.005	0.005	0.013	0.014
INT CHANGE	1.81	1.664	-0.011	0.014	-0.023	0.02	0.016**	0.007	0.022*	0.011	0.005	0.005	0.014*	0.007
CONSTANT	-0.574	0.678	-0.43	0.664	-1.17	0.802	-0.13	0.3	-0.11	0.28	-0.23	0.322	-0.153	0.311
DCAPITAL	-0.047	0.048	-0.048	0.048	-0.028	0.053	-0.016	0.039	-0.014	0.052	-0.009	0.059	-0.012	0.058
DDOMESTIC	-0.250***	0.09	-0.257***	0.09	-0.412***	0.106	-0.137**	0.068	-0.190***	0.04	-0.234***	0.078	-0.218***	0.077
DIMPORTS	-0.301*	0.179	-0.358**	0.171	-0.548**	0.224	0.15	0.108	0.185	0.191	0.253	0.205	0.207	0.202
DLHOURS	-1.859	1.424	-1.8	1.424	-1.504	1.426	-2.468**	1.214	-1.887*	1.075	-1.841*	1.047	-1.856*	1.061
DLQUALITY														
Controls for	<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	
Time trend	<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	
Industry dummies	<input type="checkbox"/>		<input type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	
AR(1)	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	
Observations	416		416		364		416		416		416		416	
R-squared	0.12		0.07		0.10		0.00 ⁺		1.48		1.48		1.52	

Notes: Dependent variable: TFP growth rates. Coef.: Coefficient estimate. – S. E.: standard error. Significance level: *** 1 percent. – ** 5 percent. – * 10 percent. – IMP SHARE: share of imported intermediates of all intermediates – IMP CHANGE: change of IMP SHARE from t-1 to t – INT SHARE: share of intermediate inputs of gross output. – INT CHANGE: change of INT SHARE from t-1 to t. – DCAPITAL: share weighted contribution of capital input to output growth. – DDOMESTIC: share weighted contribution of domestic intermediate inputs to output growth. – DIMPORTS: share weighted contribution of international intermediate inputs to output growth. – DLHOURS: share weighted contribution of labour hours worked to output growth. – DLQUALITY: share weighted contribution of labour quality to output growth. – I: OLS regression; II, III: Fixed Effects Panel regression; IV: Prais-Winsten-Panel regression; V-VII: Blundell-Bond dynamic system GMM regression. †: Log Likelihood value. ‡: p-value of the Sargan test. ††: p-value of the Hausmann-test.

Table 2a: INDUSTRY STRUCTURE AND TFP GROWTH, 1971-1990, West Germany, Manufacturing Sub-sample

	I		II		III		IV		V		VI		VII	
	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E
L.DTFP	0.005	0.035	-0.042	0.032	-0.033	0.036	-0.01	0.008	-0.034	0.106	-0.113	0.098	-0.038	0.096
IMP SHARE	0.530***	0.081	0.538***	0.082	0.566***	0.083	0.503***	0.075			-0.012	0.008	-0.004	0.006
IMP CHANGE	0.124***	0.032	0.093***	0.031	0.134***	0.035	0.041***	0.012			0.553***	0.135	0.537***	0.128
INT SHARE	0.211***	0.055	0.219***	0.056	0.261***	0.056	0.226***	0.052	0.043***	0.012			0.039***	0.012
INT CHANGE	1.372***	0.495	-0.035*	0.019	-0.058***	0.02	-0.018**	0.008	0.172	0.107			0.149*	0.082
CONSTANT	-1.454	1.12	1.515	1.128	-2.737**	1.269	0.534	0.785	-0.023**	0.009	0.004	0.005	-0.021**	0.01
DCAPITAL	0.225***	0.042	0.210***	0.042	0.241***	0.043	0.206***	0.039	1.466	1.208	0.861	1.324	1.115	1.201
DDOMESTIC	-0.727***	0.048	-0.724***	0.048	-0.749***	0.049	-0.700***	0.045	0.043	0.042	0.224***	0.058	0.207***	0.052
DIMPORTS	0.09	0.093	0.056	0.093	0.078	0.096	0.113	0.083	-0.551***	0.076	-0.758***	0.032	-0.748***	0.029
DLHOURS	4.407**	1.87	4.142**	1.881	3.960**	1.872	5.002***	1.442	0.153	0.212	0.111	0.2	0.087	0.195
DLQUALITY									6.236***	1.684	4.429**	1.761	6.048***	1.69
Controls for														
Time trend	<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	
Industry dummies	<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	
AR(1)	<input type="checkbox"/>		<input type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	
Observations	551		551		522		551		551		551		551	
R-squared	0.44		0.39		0.43		1209 [†]		-0.14	1.00 [‡]	-1.47	1.00 [‡]	-1.29	1.00 [‡]

Notes: Dependent variable: TFP growth rates. Coef.: Coefficient estimate. – S. E.: standard error. Significance level: *** 1 percent. – ** 5 percent. – * 10 percent. – IMP SHARE: share of imported intermediates of all intermediates – IMP CHANGE: change of IMP SHARE from t-1 to t – INT SHARE: share of intermediate inputs of gross output. – INT CHANGE: change of INT SHARE from t-1 to t. – DCAPITAL: share weighted contribution of capital input to output growth. – DDOMESTIC: share weighted contribution of domestic intermediate inputs to output growth. – DIMPORTS: share weighted contribution of international intermediate inputs to output growth. – DLHOURS: share weighted contribution of labour hours worked to output growth. – DLQUALITY: share weighted contribution of labour quality to output growth. – I: OLS regression; II, III: Fixed Effects Panel regression; IV: Prais-Winsten-Panel regression; V-VII: Blundell-Bond dynamic system GMM regression. [†]: Log Likelihood value. [‡]: p-value of the Sargan test. [§]: p-value of the Hausmann-test.

Table 2b: INDUSTRY STRUCTURE AND TFP GROWTH, 1991-2000, Unified Germany, Manufacturing Sub-sample

	I		II		III		IV		V		VI		VII	
	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E
L.DTFP	0.179***	0.054	0.180***	0.05	0.035**	0.1017	0.015	0.012	-0.271*	0.132	-0.272*	0.134	-0.274*	0.133
IMP SHARE	0.103	0.078	0.102	0.075	0.038	0.071	-0.008	0.06			0.038**	0.017	0.035*	0.018
IMP CHANGE	-0.022	0.022	-0.022	0.022	-0.006	0.016	-0.007	0.014			-0.001	0.048	-0.003	0.047
INT SHARE	0.008	0.016	0.008	0.016	0.000	0.014	0.004	0.012	-0.019	0.014			-0.01	0.013
INT CHANGE	-0.14	2.602	-0.034*	0.019	-0.028	0.032	0.006	0.01	0.008	0.009			0.003	0.009
CONSTANT	1.634	1.518	1.617	1.418	0.405	0.449	-0.045	0.493	0.362	0.274	-0.001	0.006	0.005	0.01
DCAPITAL	-0.017	0.045	-0.017	0.045	-0.023	0.042	-0.035	0.035	-0.038	0.052	0.668*	0.337	0.662*	0.345
DDOMESTIC	-0.353***	0.089	-0.353***	0.088	-0.246***	0.115	-0.137**	0.061	-0.163***	0.04	-0.212***	0.056	-0.211***	0.056
DIMPORTS	-0.18	0.211	-0.179	0.204	-0.025	0.140	-0.037	0.119	0.049	0.154	0.032	0.143	0.036	0.139
DLHOURS	1.579	2.799	1.577	2.79	1.238	2.719	-0.336	2.328	-0.295	2.345	-0.251	2.336	-0.284	2.351
DLQUALITY														
Controls for	<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	
Time trend	<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	
Industry dummies	<input type="checkbox"/>		<input type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	
AR(1)	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	
Observations	192		192		168		192		192		192		192	
R-squared	0.20		0.16		0.16		0.34 ⁺		0.81		0.75		1.00 [‡]	

Notes: Dependent variable: TFP growth rates. Coef.: Coefficient estimate. – S. E.: standard error. Significance level: *** 1 percent. – ** 5 percent. – * 10 percent. – IMP SHARE: share of imported intermediates of all intermediates – IMP CHANGE: change of IMP SHARE from t-1 to t – INT SHARE: share of intermediate inputs of gross output. – INT CHANGE: change of INT SHARE from t-1 to t. – DCAPITAL: share weighted contribution of capital input to output growth. – DDOMESTIC: share weighted contribution of domestic intermediate inputs to output growth. – DIMPORTS: share weighted contribution of international intermediate inputs to output growth. – DLHOURS: share weighted contribution of labour hours worked to output growth. – DLQUALITY: share weighted contribution of labour quality to output growth. – I: OLS regression; II: Fixed Effects Panel regression; III: Random Effects Panel regression; IV: Prais-Winsten-Panel regression; V-VII: Blundell-Bond dynamic system GMM regression. †: Log Likelihood value. ‡: p-value of the Sargan test. †: p-value of the Hausmann-test.

Table 3a: INDUSTRY STRUCTURE AND TFP GROWTH, 1971-1990, West Germany, Services Sub-sample

	I		II		III		IV		V		VI		VII	
	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E
L.DTFP	-0.086***	0.031	-0.070***	0.023	-0.074**	0.029	-0.023	0.016	0.161**	0.073	0.088	0.06	0.169**	0.075
IMP SHARE	-0.118	0.115	-0.129	0.114	-0.134	0.113	-0.169	0.114			-0.014	0.015	-0.009	0.015
IMP CHANGE	0.02	0.034	0.036	0.029	0.089**	0.035	-0.004	0.017			-0.117	0.193	-0.133	0.192
INT SHARE	0.069	0.077	0.059	0.076	0.059	0.073	0.118*	0.071	-0.018	0.016			-0.017	0.017
INT CHANGE	-0.633	0.798	0.014	0.011	-0.003	0.011	0.016**	0.007	0.182*	0.092	0.010**	0.003	0.187*	0.093
CONSTANT	-0.73	0.614	-0.652	0.606	-0.96	0.771	-0.144	0.481	0.016**	0.007	0.137	0.431	0.016**	0.007
DCAPITAL	-0.314***	0.049	-0.309***	0.048	-0.292***	0.048	-0.315***	0.045	-0.051	0.313	-0.302***	0.092	-0.315***	0.092
DDOMESTIC	0.092	0.172	0.097	0.171	0.1	0.174	0.138	0.166	-0.062	0.168	0.102	0.237	0.103	0.22
DIMPORTS	-0.361**	0.16	-0.367**	0.16	-0.499***	0.175	-0.316***	0.119	-0.343*	0.179	-0.293*	0.163	-0.340*	0.18
DLHOURS	-2.338*	1.223	-2.210*	1.212	-2.163*	1.107	-0.936	0.923	-0.353	0.714	0.413	0.774	-0.1	0.901
DLQUALITY														
Controls for	<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	
Time trend	<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	
Industry dummies	<input type="checkbox"/>		<input type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	
AR(1)	<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	
Observations	266		266		252		266		266		266		266	
R-squared	0.27		0.25		0.28		0.29 [†]		-0.43		-0.70		-0.56	
					0.00 ⁺				1.00 [‡]		1.00 [‡]		1.00 [‡]	

Notes: Dependent variable: TFP growth rates. Coef.: Coefficient estimate. - S. E.: standard error. Significance level: *** 1 percent. ** 5 percent. * 10 percent. -IMPSHARE: share of imported intermediates of all intermediates - IMPCHANGE: change of IMPSHARE from t-1 to t - INTSHARE: share of intermediate inputs of gross output. - INTCHANGE: change of INTSHARE from t-1 to t. - DCAPITAL: share weighted contribution of capital input to output growth. - DDOMESTIC: share weighted contribution of domestic intermediate inputs to output growth - DIMPORTS: share weighted contribution of international intermediate inputs to output growth - DLHOURS: share weighted contribution of labour hours worked to output growth - DLQUALITY: share weighted contribution of labour quality to output growth. - I: OLS regression; II: Fixed Effects Panel regression; IV: Prais-Winsten-Panel regression; V-VII: Blundell-Bond dynamic system GMM regression. [†]: Log Likelihood value. [‡]: p-value of the Hausmann-test.

Table 3b: INDUSTRY STRUCTURE AND TFP GROWTH, 1991-2000, Unified Germany, Services Sub-sample

	I		II		III		IV		V		VI		VII	
	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E	Coef.	S. E
L.DTFP														
IMP SHARE	-0.002	0.069	-0.005	0.069	0.174	0.138	0.007	0.019	0.196*	0.103	0.194*	0.106	0.198*	0.107
IMP CHANGE	-0.092	0.109	-0.13	0.106	-0.049	0.106	-0.14	0.09	0.006	0.021	0.006	0.021	0.006	0.022
INT SHARE	-0.02	0.022	-0.02	0.022	-0.026	0.025	-0.002	0.014	-0.091	0.128	-0.091	0.128	-0.092	0.126
INT CHANGE	0	0.016	-0.001	0.016	0	0.017	-0.004	0.012	-0.004	0.012	-0.004	0.012	0	0.013
CONSTANT	2.534	1.951	0.031*	0.018	0.008	0.023	0.019**	0.009	-0.004	0.015	0.015***	0.004	-0.006	0.015
DCAPITAL	-0.681	0.635	-0.573	0.631	-0.508	0.67	-0.764**	0.324	-0.534*	0.271	-0.573	0.348	-0.564	0.343
DDOMESTIC	-0.272**	0.123	-0.310**	0.119	-0.201	0.131	-0.240***	0.08	-0.259**	0.097	-0.279**	0.111	-0.279**	0.11
DIMPORTS	0.193	0.189	0.143	0.186	-0.068	0.265	-0.032	0.177	0.021	0.192	0.058	0.26	0.057	0.256
DLHOURS	-0.744***	0.255	-0.819***	0.249	-1.130***	0.262	-0.157	0.161	-0.231	0.143	-0.18	0.113	-0.188	0.118
DLQUALITY	-2.429*	1.25	-2.309*	1.249	-2.025*	1.17	-3.166***	1.151	-2.558**	1.108	-2.532**	0.996	-2.515**	1.015
Controls for														
Time trend	<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	
Industry dummies	<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	
AR(1)	<input type="checkbox"/>		<input type="checkbox"/>		<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>		<input type="checkbox"/>	
Observations	192		192		168		192		192		192		192	
R-squared	0.21		0.18		0.24		0.437		0.76		0.87		0.85	
					0.01 ⁺				1.00 [‡]		1.00 [‡]		1.00 [‡]	

Notes: Dependent variable: TFP growth rates. Coef.: Coefficient estimate. – S. E.: standard error. Significance level: *** 1 percent. – ** 5 percent. – * 10 percent. – IMP SHARE: share of imported intermediates of all intermediates – IMP CHANGE: change of IMP SHARE from t-1 to t – INT SHARE: share of intermediate inputs of gross output. – INT CHANGE: change of INT SHARE from t-1 to t. – DCAPITAL: share weighted contribution of capital input to output growth. – DDOMESTIC: share weighted contribution of domestic intermediate inputs to output growth. – DIMPORTS: share weighted contribution of international intermediate inputs to output growth. – DLHOURS: share weighted contribution of labour hours worked to output growth. – DLQUALITY: share weighted contribution of labour quality to output growth. – I: OLS regression; II, III: Fixed Effects Panel regression; IV: Prais-Winsten-Panel regression; V-VII: Blundell-Bond dynamic system GMM regression. [†]: Log Likelihood value. [‡]: p-value of the Sargan test. [‡]: p-value of the Hausmann-test.

Appendix B

Variables and data sources of the Ifo Productivity Database

Capital stocks and capital service flows

The capital stocks and investment data used for the capital services flows calculations are taken from the Ifo Investorenrechnung Database. The Ifo Investorenrechnung Database provides industry- and asset-specific capital stocks data for 1970 until 1990 for West Germany. From 1991 onwards, the Ifo Productivity Database computes industry- and asset-specific capital stocks according to the perpetual inventory method:

$$S_{i,j,t} = S_{i,j,t-1}(1 - \delta_{i,j}) + I_{i,j,t} \quad (6).$$

$S_{i,j,t}$ is hereby the capital stock in industry i of the investment asset j in period t . $I_{i,j,t}$ is the corresponding investment in industry i of investment asset j in period t and $\delta_{i,j}$ is the industry and asset specific depreciation rate which is unique to our knowledge. Both the investment data and the depreciation rates are taken from the Ifo Investorenrechnung Database which bases these data on the official series taken from the German statistical office and computes hence the industry- and asset-specific distribution as explained in Appendix A1.¹⁶

For the capital services calculations, the Ifo Productivity Database parallels the method in Jorgenson and Stiroh (2001). Capital services $K_{i,j,t}$ of asset j in industry i during period t are assumed to be proportional to the average capital stock used in one sector with $q_{i,j}$ denoting a constant of proportionality. The capital services are therefore a function of the capital stock at the end of the current period and beginning of the current period.

$$K_{i,j,t} = q_{i,j} \frac{(S_{i,j,t} + S_{i,j,t-1})}{2} \quad (7).$$

In the next step, we compute the costs of capital based on an arbitrage condition for capital services. It is assumed that an investor is indifferent whether he invests his money at the capital market and earns a nominal interest r_t for his investment or whether he invests in an asset j in industry i in period t and earns a rental fee $c_{i,j,t}$ less the depreciation $\delta_{i,j}$ of the asset.

$$(1 + r_t)P_{i,j,t-1} = c_{i,j,t} + (1 - \delta_{i,j})P_{i,j,t} \quad (8)$$

¹⁶ The Ifo Investorenrechnung bases in contrast to the German Statistical Office the classification of assets on an economic usage based concept.

Rearranging the arbitrage condition yields the familiar cost of capital equation:

$$c_{i,j,t} = (r_t - \pi_{i,j,t})P_{i,j,t} + \delta_{i,j}P_{i,j,t} \quad (9)$$

where the industry and asset-specific capital gains $\pi_{i,j,t}$ in period t are given by the percentage change of the asset prices in industry i during period t:

$$\pi_{i,j,t} = (P_{i,j,t} - P_{i,j,t-1}) / P_{i,j,t-1} \quad (10)$$

The cost of capital equation in its final form states that the costs of capital of asset j in industry i in period t equals the difference between the nominal interest rate and the capital gains of the asset weighted by the industry- and asset-specific price deflator plus the asset and industry-specific depreciation of the asset weighted by the industry- and asset-specific price deflator. The major advantage of the use of industry- and asset specific price deflators and depreciation rates is that this method needs less rigid assumptions for the calculation of the costs of capital. The cost of capital data which is computed using this method are therefore closer to reality compared to only asset-specific price deflators and depreciation rates which are usually taken for growth accounting exercises (Jorgenson and Stiroh 2000). The use of this method was only possible for our purposes due to availability of the Ifo Investorenrechnung Database which is according to our knowledge the only database which offers such high quality data on industry-level for Germany.

Additionally to changes in the capital stock, our database includes also changes in the composition of the capital quality as a determinant of output growth. The capital quality component shall account for a shift of the capital stock composition over time towards higher quality assets with high rental prices and high marginal products and for non-steady state movements of the capital stock towards a steady state.

For this purpose, we have first to calculate the value shares of capital income of asset j in industry i in period t. The value share of capital services $v_{i,j,t}$ for asset j in industry i in period t is based on the rental price formula and is a two year average of the current and the prior period of the share weighted capital income of asset j in industry i:

$$v_{i,j,t} = \frac{1}{2} \cdot \left(\frac{c_{i,j,t} K_{i,j,t}}{\sum_i c_{i,j,t} K_{i,j,t}} + \frac{c_{i,j,t-1} K_{i,j,t-1}}{\sum_i c_{i,j,t-1} K_{i,j,t-1}} \right),$$

similarly we calculate the investment price based weights $w_{i,j,t}$ for the sectoral and asset specific capital stocks as two year averages of the current and prior period and share weighted value shares of the capital stocks of asset j in industry i:

$$w_{i,j,t} = \frac{1}{2} \cdot \left(\frac{p_{i,j,t} S_{i,j,t}}{\sum_i p_{i,j,t} S_{i,j,t}} + \frac{p_{i,j,t-1} S_{i,j,t-1}}{\sum_i p_{i,j,t-1} S_{i,j,t-1}} \right).$$

These two derivations are used in the next step to construct an index of capital quality $q_{K,i,t}$ which is assumed to equal the difference between the growth of capital services and the capital stock for industry i in period t :

$$\Delta \ln q_{K,i,t} = \Delta \ln K_{i,t} - \Delta \ln \left(\frac{S_{i,t} + S_{i,t-1}}{2} \right) = \sum_j (v_{i,j,t} - w_{i,j,t}) \Delta \ln \left(\frac{S_{i,j,t} + S_{i,j,t-1}}{2} \right).$$

For aggregate growth accounting, we construct also the price indices of aggregate capital services c_t and the value shares of the capital stock $p_{S,t}$ as:

$$c_t = \frac{\sum_i \sum_j c_{i,j,t} K_{i,j,t}}{K_t} \quad \text{and}$$

$$p_{S,t} = \frac{\sum_i \sum_j p_{i,j,t} S_{i,j,t}}{S_t}.$$

Labor input and labor services flows

The labor input calculation parallel the method of the capital input calculations.

The flow of labor input is assumed to equal the flow of hours worked for worker category j in industry i in period t :

$$L_{i,j,t} = q_{L,i,j} \cdot H_{j,i,t}.$$

The growth of the labor input in industry i is the share-weighted growth of labor input by each worker category:

$$\Delta \ln L_{i,t} = \sum_j v_{i,j,t} \Delta \ln L_{i,j,t}$$

and respectively for the aggregate economy:

$$\Delta \ln L_t = \sum_i \sum_j v_{i,j,t} \Delta \ln L_{i,j,t}$$

where the weights are value shares of labor income of worker category j in industry i in period t :

$$v_{i,j,t} = \frac{1}{2} \cdot \left(\frac{w_{i,j,t} L_{i,j,t}}{\sum_i w_{i,j,t} L_{i,j,t}} + \frac{w_{i,j,t-1} L_{i,j,t-1}}{\sum_i w_{i,j,t-1} L_{i,j,t-1}} \right).$$

The labor quality index is defined as the difference between the share-weighted growth of labor hours and the unweighted growth of labor hours yielding to the following formulas for a labor quality index on the industry level:

$$\Delta \ln q_{L,i,t} = \sum_j v_{j,t} \Delta \ln H_{j,t} - \Delta \ln H_{j,t}$$

and on the aggregate level:

$$\Delta \ln q_{L,t} = \sum_i \sum_j v_{i,j,t} \Delta \ln H_{i,j,t} - \Delta \ln H_{i,j,t} .$$

Real gross output and real gross input calculations

For the sectoral growth accounting exercises using the gross output concept, it is necessary to estimate real gross output and real intermediate inputs data since these are not provided by the statistical office for 56 industries. In order to obtain data on the industry real gross output and gross input, the Ifo Productivity database uses input-output-tables for the German economy ranging from 1970 to 2000 and estimates the quantities in 1991 prices (respectively in 1995 prices for the period from 1991-2000). The estimation procedure is basically the following method. For 60 output goods and services, we have taken the price deflators from the German Statistical Office and estimated the intermediate inputs in 1991 prices. To ensure consistency of our data with the German Statistical Office, we scaled in the next step our estimates to match the data by the German Statistical Office on the lowest available sectoral level. Unfortunately the German Statistical Office does not provide such disaggregated data as we wish, so that the within industry distribution of intermediate inputs are assumed to equal the value-shares of our estimates

$$\bar{v}_{i,j,t} = \frac{v_{i,j,t}}{\sum_i v_{i,j,t}} \cdot \bar{v}_{j,t} .$$

To illustrate the method, let's assume that the German Statistical Office provides data for an aggregate sector j , but not for the specific industries i 's of which j consists. The quantity of sector j in total intermediate input consumption as computed using the Input-Output-tables is given by $v_{j,t}$ and for the industries i belonging to j by $v_{i,j,t}$. For our purposes, we scale the quantity of all industries i of sector j $v_{i,j,t}$ to equal the quantity provided by the German Statistical Office $\bar{v}_{j,t}$. The distribution of the quantities within sector j is obtained by the computation of the quantity of the intermediates consumption of industry i of sector over the quantity of intermediate consumption by all industries i 's belonging to sector j . This method delivers results which are consistent with the data released by the German Statistical Office,

but allows for differing developments within sectors. Due to the fact that Input-Output-tables are not published regularly, we employ the following method to impute the quantities of intermediate consumption of industry i of sector j :

$\bar{v}_{j,t}$ is once more provided by the German Statistical Office. To impute the missing values $\bar{v}_{i,j,t}$, we assume that the $v_{i,j,t}$ and also $v_{j,t}$ follows a linear function with $v_{i,j,t-k}$ and $v_{j,t-k}$ as computed values using the latest available Input-Output-tables before t and $v_{i,j,t+m}$ and $v_{j,t+m}$ as computed values using the closest years after t .

$$\bar{v}_{i,j,t} = \left(\frac{v_{i,j,t-k}}{\sum_i v_{i,j,t-k}} + k \cdot \left(\frac{v_{i,j,t+m}}{\sum_i v_{i,j,t+m}} - \frac{v_{i,j,t-k}}{\sum_i v_{i,j,t-k}} \right) \right) \cdot \bar{v}_{j,t}$$

For more detailed analysis of the importance the Ifo productivity Database provides numbers on domestic and international intermediate inputs, which are computed using the Input-Output-tables. The share of intermediate imports for each industry is computed after the price deflation of the intermediate inputs. This share is multiplied with data on real gross input, after the scaling of the Input-Output-data to the official statistics provided by the German Statistical Office on real intermediate input quantities.

The imputation of this share of missing values due to a lack of available data of the Input-Output-tables for the year is the same as described above.

The real gross output of an sector is computed as the sum of intermediates input and value-added, as provided by the German Statistical Office.

Data sources

For the period 1971-1990 the Ifo Productivity Database uses data for West Germany, for 1991-2000 we use data for unified Germany.

Capital stocks and capital service flows

Capital stocks and capital services flows are derived from the Ifo Investorenrechnung Database (as described in chapter 3.1) and displayed in table 1.

Table A1: Data sources of capital inputs

Variable	Industry-level/ Aggregate	Period	Source
Capital Stocks, industry- and asset-specific	I	1960-2000	Ifo Investorenrechnung Database
Investment data, industry- and asset-specific	I	1960-2000	Ifo Investorenrechnung Database
Depreciation rates, industry- and asset-specific	I	1960-2000	Ifo Investorenrechnung Database
Price deflators, industry- and asset-specific	I	1960-2000	Ifo Investorenrechnung Database
All aggregate measures are the sum of the above industry specific data	A	1960-2000	Ifo Investorenrechnung Database

Extrapolation of missing values

The capital stocks for 1991-2000 are capital stocks computed for Unified Germany. In accordance to the method employed by the German Statistical Office, we assume that the Eastern German capital stocks is totally devalued after the reunification.

Capital stocks and capital services flows for communication technologies and software are not available for the years 1971-1990 due to changes in the systematics. To cope with this problem we extrapolate the missing data (on the total economy level) using the following procedure. First we calculate the ratio of the respective asset type to the aggregate for every year where these data are available (1991-2000). Using the 10-year average and the trend-growth of this ratio we extrapolate earlier values of it beginning in 1990 going backwards. Then we multiply this approximated ratio with the respective aggregate value (which is available) for every year in 1971-1990.

In order to test, whether this method is appropriate, we use this technique to extrapolate values, which are available, namely computer hardware (business equipment). In this case of hardware capital stocks the correlation between the extrapolated and the real data is remarkably high with a coefficient of 99.59%.

Labor Input

In our estimates of aggregate labor input (L) we again resort to data of O'Mahony and van Ark (2003) CD-ROM (Groningen Growth and Development Centre, Industry Growth Accounting Database: Labor quality). According to Jorgenson (2000) we derive changes in labor input by: $\Delta \ln L = \Delta \ln LQ + \Delta \ln H$, where $\Delta \ln LQ$ equals labor quality (which is growth in skill-adjusted labor input minus growth in total hours worked) and H is hours worked as described in the respective subsection. Given that the series of labor quality covers only the period 1980-2000, we extrapolate earlier values by using those of the 1980ies. These values feature a relatively constant or non-volatile growth and thereby we assume for 1970-1979 a growth in labor quality equal to the average of the later period (which is 0.46% every year). All further sources in the context of labor inputs are depicted in table 2.

Table A2: Data sources of labor inputs

Variable	Industry-level/ Aggregate	Period	Source
Gross wage sum	I	1991-2000	GSO, DESTATIS 7728XXX
	A		GSO, DESTATIS 7614001
Employees and Self-employed workers	I	1991-2000	GSO, DESTATIS 7729XXX
	A		GSO, DESTATIS 7607004
Employees	I	1991-2000	GSO, DESTATIS 7730XXX
	A		GSO, DESTATIS 7616001
Hours worked	I	1991-2000	GSO, DESTATIS 7518XXX
	A		GSO, DESTATIS 7702012
Labor quality	I	1980-2000	GGDC, www.ggdc.net, based on unpublished data received from German Statistical Office, originally from the German Employment Statistics and Wage and Salary Statistics.
Gross wage sum	I	1971-1990	GSO, Fachserie 18, 2279XXX
	A		GSO, DESTATIS 7861085
Employees and Self-employed workers	I	1971-1990	GSO, Fachserie 18, 917XXX
	A		GSO, DESTATIS 7862085
Employees	I	1971-1990	GSO, Fachserie 18, 917XXX
	A		GSO, DESTATIS 7863085
Hours worked	I	1971-1990	GSO, time-series service, 4037XXX

	A		See Footnote ¹⁷
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3.2.1 Value Shares

The capital's and labor's average shares of nominal income (v_t^K and v_t^L) are derived from the respective capital services flows (csf) and the total wage sum. The csf originate from the Ifo Productivity Database, for the calculation of the total wage sum we deflated (nominal) gross wage sum (see table 2 and 3) and multiplied this series with the ratio of all wage earners (employees and self-employed workers) to employees. Specific capital shares (communication, hardware, software) are the ratio of the respective csf to total csf multiplied by total capital share v_t^K .

Output, value added GDP

All Output measures that we use at the industry and aggregate level are displayed in table 3.

Table A3: Data sources of output and input data

Variable	Industry-level/ Aggregate	Period	Source
Gross Output, in 1991 prices	I	1971-1990	GSO, Fachserie 18, 863, own calculations using Input-Output tables, various issues
Gross Output, in current prices	I	1971-1990	GSO, Fachserie 18, 1486
GDP, in current prices	A	1971-1990	GSO, DESTATIS 7841005
GDP, in 1995 prices	A	1971-1990	GSO, DESTATIS 7841024
GDP deflator	A	1971-1990	Ratio of nominal to real GDP
Intermediate Inputs, in 1991 prices	I	1971-1990	GSO, Fachserie 18, 863, own calculations using Input-Output tables, various issues
Intermediate Inputs, in current prices	I	1971-1990	GSO, Fachserie 18, 1487XXX
Value-Added, in 1991 prices	I	1971-1990	GSO, Fachserie 18, 1496XXX
Value-Added, in current prices	I	1971-1990	GSO, Fachserie 18, 1495XXX
Price deflators for investment assets	I	1971-1990	Own calculations using the gross output deflator at lowest available level for periods prior to 1976 or

¹⁷ For 1970-1990 Hours worked at the aggregate level is a constructed time series, where annual hours per worker are multiplied with the total number of employees. The basis of the former data is O'Mahony and van Ark (2003) CD-ROM (GGDC, Total Economy Database: Hours), the one of the latter is the German Statistical Office (DESTATIS 7862085).

			service industries, or data of investment assets GSO, DESTATIS 7849XXX, 7846XXX for 1976 and later.
Gross Output, in 1991 prices	I	1991-2000	GSO, DESTATIS 7713XXX
Gross Output, in current prices	I	1991-2000	GSO, DESTATIS 7716XXX
GDP, in current prices	A	1991-2000	GSO, DESTATIS 7601001
GDP, in 1995 prices	A	1991-2000	GSO, DESTATIS 7601002
GDP deflator	A	1991-2000	Ratio of nominal to real GDP
Intermediate Inputs, in 1991 prices	I	1991-2000	GSO, DESTATIS 7715XXX
Intermediate Inputs, in current prices	I	1991-2000	GSO, DESTATIS 7716XXX
Value-Added, in 1991 prices	I	1991-2000	GSO, DESTATIS 7712XXX
Value-Added, in current prices	I	1991-2000	GSO, DESTATIS 7711XXX
Price deflators for investment assets	I	1991-2000	Own calculations using the gross output deflator at lowest available level for service industries, or data of investment assets GSO, time-series service 1428XXX

Appendix C

Appendix C derives the a TFP regression as a function of an output regression and shows that TFP regressions are restricted output regressions with basically the same coefficients on the TFP contributions. The following section compares the consistency of the estimator of the TFP regression with ordinary output regressions and shows that the derived TFP estimator is a consistent and efficient estimator of the output function.

The (OLS)-estimator¹⁸ of the output of the production function is

$$Y = X\beta + e. \quad (\text{C.1})$$

and the identity of the growth accounting equation is

$$Y = X + TFP \quad (\text{C.2})$$

which leads to a stochastic expression for the total factor productivity with

$$TFP = X\beta - X + e$$

Y is the industry gross output growth and X is a matrix containing the input contributions to output. β is the coefficient vector for the effectiveness of input contributions to gross output and e is a stochastic error term. If all the assumptions of the growth accounting methodology are fulfilled, we would expect that the coefficient vector for all inputs is equal to one and that the constant terms equals the exogenous rate of technological progress measured by TFP . The interest of the study lies on the estimation of determinants of TFP growth and it is therefore of interest to compare the TFP estimator with the output estimator with regard to consistency and efficiency.

Consistency of TFP regression

(6.1) as:

$$Y = X\beta + TFP.$$

Solving for TFP :

$$TFP = X\beta - X + e$$

and regressing X on TFP leads to the following estimation equation:

$$TFP = X\beta^* + u.$$

¹⁸ The OLS estimator offers a convenient way to discuss the estimation approach while being still very simple. The problems discussed for OLS can be extended for panel estimators without any loss of the conclusions but for the sake of simplicity why we do not include the discussion for all estimation procedures used in the estimation series.

$$\hat{\beta}^* = E[(X'X)^{-1} X'(TFP)] = E[(X'X)^{-1} X'(X\beta - X + e)]$$

$$\hat{\beta}^* = E[(X'X)^{-1} X'(X\beta) - (X'X)^{-1} X'(X) + (X'X)^{-1} X'e]$$

$$\hat{\beta}^* = \beta - I + (X'X)^{-1} X'E(e)$$

$$\hat{\beta}^* = \beta - I$$

Efficiency of TFP regressions

The variance of the β estimator is

$$Var(\beta) = s^2 (X'X)^{-1}$$

The variance of the TFP estimator $\hat{\beta}^*$ is:

$$Var(\hat{\beta}^*) = Var[(X'X)^{-1} X'(X\beta - X + e)] = Var[(X'X)^{-1} X'e]$$

$$Var(\hat{\beta}^*) = Var(\beta)$$

The derivation of Appendix C showed that efficiency and consistency of TFP regressions are identical to ordinary output growth regression with TFP regression coefficient estimates as:

$$\hat{\beta}^* = \beta - I .$$

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