THE IFO INDUSTRY GROWTH ACCOUNTING DATABASE

OLIVER ROEHN
THEO S. EICHER
THOMAS STROBEL

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Abstract

In this paper we present a new database that allows deep industry-level growth accounting from 1991–2003. The database allows for the first complete analysis of the German industry performance drivers based on the contributions of 12 asset types in 52 different industries. The industry sources of productivity and output growth are crucial to the understanding of the transformation of the German economy from manufacturing to information technology and service industries. The database enables researchers to develop an adequate picture of the sources of growth using standard growth accounting techniques. We formally document the new data series and its origins, with special focus on the capital stock and capital service data.

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Oliver Roehn
Ifo Institute for Economic Research
at the University of Munich
Poschingerstr. 5
81679 Munich
Germany
roehn@ifo.de

Theo S. Eicher
Department of Economics
University of Washington
301 Savery Hall, Box 353330
Seattle WA 98195-3330
USA
te@u.washington.edu

Thomas Strobel
Ifo Institute for Economic Research
at the University of Munich
Poschingerstr. 5
81679 Munich
Germany
strobel@ifo.de

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1. Introduction

Growth accounting exercises are popular and often employed in productivity analyses to understand the underlying dynamics that determine the economic fortunes of countries. The need to illuminate the transition of industrialized nations from pure manufacturing to information and service based economies has emphasized the importance of growth accounting exercises as a means to identify structural shifts early and comprehensively. Key to such analyses is industry level investment data that distinguishes between all relevant assets types. In the US and other OECD countries, growth accounting exercises allow researchers to identify the effects of information and communication technology (ICT) investment on aggregate output and productivity. In Germany, however, no such data exists at the 52 industry level.

In this paper we present the *Ifo Industry Growth Accounting Database* that provides consistent investment and capital stock data for 12 investment assets in 52 industries from 1991 onward.[1] The 12 assets are comprised of 3 ICT assets (Computer and Office Equipment; Communication Equipment; Software) and 8 additional equipment assets (Metal Products; Machinery; Electrical Generation and Distribution; Instruments, Optics and Watches; Furniture, Music and Sports Equipment; Other Machines and Equipment; Automobiles; Other Vehicles) as well as investments in Buildings and Structures. The 52 industries roughly correspond to the 2-digit industry-level NACE classification.

The *Ifo Industry Growth Accounting Database* is derived from the *Ifo Investorenrechnung*, which provides industry investment data based on investments in 100 different subassets. This detailed level of information allows us to allocate investments by asset type to each industry, using the Ifo investment flow matrix. We then use Jorgenson, Ho and Stiroh's (2005) growth accounting concepts to construct capital stock and capital service estimates for assets and industries.

The *Ifo Industry Growth Accounting Database* has three unique features. First, it provides information on an unprecedented number of German capital stocks and capital services at the industry level. Second, industry-level assets include three different types of ICT assets (Computer and Office Equipment; Communication Equipment; Software), which are of particular interest to understand the productivity performance of industries in the past decade. It is the first time that this level of ICT disaggregation is available at the German 52 industry level. Third, the detailed disaggregation of the different asset types and marginal productivities (measured as user costs) allows researchers to construct the most accurate

[1] The database is available at http://faculty.washington.edu/te/growthaccounting/

measures of ICT and non-ICT capital services. To allow for complete German growth accounting, the database complements our original capital data with German Statistical Office (GSO) data on labor hours, labor quality, and value-added. Preliminary productivity analysis based on the database indicates a structural weakness in German ICT investment as well as a widespread collapse in TFP growth post-2000 (see Eicher and Roehn, 2007).

A similar productivity database exists at the Groningen Growth and Development Centre. Differences between the *Ifo Industry Growth Accounting Database* and the *Groningen Industry Growth Accounting Database* are fourfold. First, Groningen reports on 26 industries, while the *Ifo Industry Growth Accounting Database* contains 52 industries. Second, the *Ifo Industry Growth Accounting Database* includes Office Equipment in ICT assets, since Office Equipment and Computers cannot be separated at the German industry-level. A third difference arises in the asset class entitled Buildings and Structures. The *Ifo Industry Growth Accounting Database* includes Residential and Non-Residential Buildings and Structures while Groningen includes only Non-Residential Buildings and Structures.

Finally, and perhaps most importantly, since German Software investments are not reported by the GSO, the Groningen database assumes that a fixed fraction of Intangible Assets is Software. Groningen then generates German industry-level Software investment by using a ratio of Software to IT-equipment investment that was obtained from an average of French, Dutch and US data. In contrast, the *Ifo Industry Growth Accounting Database* obtains data on Software investment shares in total Intangible Assets, and industry-level Software investment from an extensive (Ifo internal) survey based study by Herrmann and Mueller (1997) and from extensive industry level Ifo investment surveys in 1995, 1998, 1999, 2000.

The paper is structured as followed: Section 2 gives a brief overview of the underlying growth accounting methodology in the *Ifo Industry Growth Accounting Database*. Section 3 details the exact composition of the data in the Database. It describes the methodology used to obtain the input estimates and provides extensive information on all sources. Specifically, Section 3.1 focuses on the derivation of the capital input and Section 3.2 on the details of the labor inputs. Section 4 presents some results, while Section 5 concludes.

2. Growth Accounting Framework

The growth accounting framework allows us to decompose economic growth into the contributions from accumulated input factors and the residual: total factor productivity (TFP). The residual captures disembodied technological progress as well as all other productivity enhancing factors that are not explicitly measured. The framework is used to disentangle the sources of growth into the growth effects that can be attributed to factor accumulation and to productivity increases. Prominent applications of the growth accounting framework are the *productivity slowdown* beginning in the early seventies (e.g. Jorgenson and Yip, 2001), the examination of the growth miracle of the East Asian countries (e.g. World Bank, 1993) and analyses of the information and communication technology (ICT) revolution (e.g. Jorgenson and Stiroh, 2000, and Oliner and Sichel, 2000).

The breakdown of sectoral output growth into input factors, capital and labor, especially into ICT and non-ICT capital allows us to determine the underlying sources of aggregate output growth as well as of gains in productivity in times of rapid technological progress. In this section we introduce the growth accounting methodology and the data requirements to apply these techniques. The following chapters detail the sources and preliminary results of the *Ifo Industry Growth Accounting Database*.

The growth accounting framework employed in the *Ifo Industry Growth Accounting Database* is based on Jorgenson and Griliches (1967) and Jorgenson, Gollop and Fraumeni (1987). The database provides all data necessary for German industry level growth accounting exercises, that is, it includes data on output and input factors as well as data on all input shares. Detailed investment data is available on the industry-asset level, which allows us to dissect aggregate equipment assets into sectoral ICT and non-ICT assets. The database reports total factor productivity as well as labor productivity, and we focus on value-added as the relevant measure of industry output. The database does not report gross output since we lack appropriate deflators for intermediate inputs at the industry level. Jorgenson, Ho and Stiroh (2005) demonstrate that value-added TFP measures can be converted into gross output TFP measures using the share of nominal value added in nominal gross output.

Decomposing industry-level value-added growth into its input factors and TFP contributions requires detailed information on capital services and quality adjusted labor. Jorgenson, Ho and Stiroh (2005) commence with

$$\Delta \ln VA_{i,t} = \bar{\upsilon}_{K,i,t}\ \Delta \ln K_{i,t} + \bar{\upsilon}_{L,i,t}\ \Delta \ln L_{i,t} + \Delta \ln TFP_{i,t} \qquad (1)$$

where $K_{i,t}$ and $L_{i,t}$ denote capital services and quality adjusted labor of industry *i* and period *t*, respectively. When information on value-added, capital services and labor quality is at hand, total factor productivity growth, $\Delta \ln TFP_{i,t}$, can be derived as the residual. The two-period average nominal input shares of capital and labor are $\bar{\upsilon}_{K,i,t}$ and $\bar{\upsilon}_{L,i,t}$, respectively. They are given by

$$\bar{\upsilon}_{h,i,t} = 0.5\left(\upsilon_{h,i,t} + \upsilon_{h,i,t-1}\right), \text{ with } h = K, L. \quad (2)$$

Where the input shares $\upsilon_{h,i,t}$ are defined as

$$\upsilon_{K,i,t} = \frac{P_{K,i,t}\ K_{i,t}}{P_{VA,i,t}\ VA_{i,t}}, \quad (3)$$

$$\upsilon_{L,i,t} = \frac{P_{L,i,t}\ L_{i,t}}{P_{VA,i,t}\ VA_{i,t}}, \quad (4)$$

and $P_{K,i,t}$, $P_{L,i,t}$ and $P_{VA,i,t}$ are the prices of capital, labor, and value-added, respectively. From the standard growth accounting assumption of constant returns to scale it follows that $\upsilon_{K,i,t} + \upsilon_{L,i,t} = 1$. We can now rewrite equation (1) to derive average labor productivity (ALP) growth, defined as value-added per hour worked

$$\Delta \ln ALP_{i,t} = \bar{\upsilon}_{K,i,t}\ \Delta \ln k_{i,t} + \bar{\upsilon}_{L,i,t}\ \Delta \ln q_{i,t} + \Delta \ln TFP_{i,t} \quad (5)$$

where $\Delta \ln q_{i,t}$ represents labor quality growth and $\Delta \ln k_{i,t}$ reflects capital deepening. Equation (5) relates labor productivity growth to changes in capital deepening (when workers are matched with more and better capital), labor quality, and total factor productivity growth. TFP is often thought to capture technology, but it also reflects omitted variables, deviations from the assumption of constant returns to scale, market structure, and measurement errors.

3. Data and Methods

Equation (1) shows how the growth rate of value-added can be decomposed into the weighted growth rates of the input factors – capital and labor – and a residual (TFP). In this section we discuss how each of the ingredients of equation (1) can be estimated and provide the respective data sources. Value-added is directly taken from the GSO and we therefore focus our exposition on capital and labor input measures. The methodology is well established and a summary is provided in Jorgenson, Ho and Stiroh (2005) and recent applications can be found in Bureau of Labor Statistics (2000b). For an overview, Table 6 lists the sources of each variable employed in the *Ifo Industry Growth Accounting Database*.

3.1 Capital Inputs: Capital Services and Capital Stocks

3.1.1 Estimating Capital Services

Capital services, in contrast to capital stocks, are the flows of services by which each capital asset type contributes to the production process. It is the preferred capital measure in productivity analyses. Following Jorgenson, Ho and Stiroh (2005, p. 154) we assume capital services for an individual asset type to be proportional to the capital stock,

$$K_{i,j,t} = Q_{K,i,j} \frac{1}{2}\left(S_{i,j,t-1} + S_{i,j,t}\right) \qquad (6).$$

Here the capital service flows of asset *j* are the average of the current and past current value of capital stock $S_{i,j,t}$ (measured at the end of a period). The assumed proportionality between capital stocks and capital services implies that growth rates of stocks and services for *each asset* are identical. The distinction between capital stocks and services, however, becomes crucial when aggregating over different types of assets. To construct an aggregate index of capital services, we assume with Jorgenson, Ho and Stiroh (2005, pp. 158-162) that each asset is weighted by its marginal productivity. Under the assumption of competitive markets the marginal productivity can be measured as the price of capital services $P_{K,i,j,t}$, which as we show below is equal to the user cost of capital. An overall index of capital services can then be constructed as:

$$\Delta \ln K_{i,t} = \sum_j \bar{\mu}_{i,j} \Delta \ln K_{i,j,t} \qquad (7)$$

where $\bar{\mu}_{i,j} = 0.5(\mu_{i,j,t} + \mu_{i,j,t-1})$, and $\mu_{i,j,t} = \frac{P_{K,i,j,t} K_{i,j,t}}{\sum_j P_{K,i,j,t} K_{i,j,t}}$. Equations (6) and (7) highlight the need for two important measures to derive capital service estimates on the industry level: capital stocks $S_{i,j,t}$ and the user costs of capital $P_{K,i,j,t}$ for each capital type. The rest of this section focuses on how capital stocks and user cost of capital are constructed in the *Ifo Industry Growth Accounting Database*.

3.1.2 Estimating Capital Stocks

3.1.2.1 The Perpetual Inventory Method

We use the perpetual inventory method (PIM) to derive our capital stock measures. According to the PIM, the stock of capital of asset *j* in industry *i* at the end of period *t*, $S_{i,j,t}$, evolves according to:

$$S_{i,j,t} = S_{i,j,t-1}\left(1-\delta_{i,j}\right) + I_{i,j,t} = \sum_{\tau=0}^{\infty} (1-\delta_{i,j})^{\tau} I_{i,j,t-\tau} \qquad (8)$$

where $I_{i,j,t}$ is investment in asset *j* in industry *i* at constant prices, and $\delta_{i,j}$ is the geometric depreciation rate of asset *j* in industry *i*. Equation (8) simply states that the capital stock at the end of the period is the weighted sum of past investments where the weights reflect efficiency and retirement losses of older vintages of investment. The weights are the geometric depreciation rates. Depreciation rates are based on the age-efficiency profiles or age-price profiles of investment goods. The two time profiles are usually not identical, but they are related. While the age-efficiency profile is related to economic decay that affects the productive capacities of investments, the age-price profile refers to depreciation in terms of loss in value. The crucial point lies in how the patterns of decay and depreciation evolve over time with respect of each other. Hulten and Wykoff (1981a, 1981b, 1981c) and Fraumeni (1997) identified that the geometric pattern is the best description of economic depreciation. Another advantage of geometric depreciation rates over other forms of depreciation patterns is that the age-price profile and age-efficiency profile coincide.[2]

3.1.2.2 Transforming Investment Series into Capital Stocks

Equation (8) states that the generation of capital stocks based on the PIM requires long investment series in constant prices for each asset on the industry level. How far these investment series have to date back depends on the service life of an asset. For instance, Structures and Buildings require very long investment series due to their service lives of several decades.

The GSO provides investment series for all 12 asset types for Unified Germany (1991-2004) *at the aggregate level.* The GSO further provides industry-level investments for two asset types only, namely New Equipment and Other Assets and Structures and Buildings. To obtain industry level investments for all 12 asset types in constant 2000 euro prices, we utilize the *Ifo Investorenrechnung*. The *Ifo Investorenrechnung* breaks down the 12 asset types into 100 detailed subassets, for which investment data is collected (for a detailed list of the subdivision of the 12 asset types into the 100 subassets, see Table A.1 in the Appendix). The advantage of the deep partition into 100 subassets is that it simplifies the identification of purchasing industries. Additionally, the *Ifo Investorenrechnung* obtains information about the recipient industries directly from industry organizations or from specific *Ifo Investment Survey* questions.[3] These pieces of information are then combined into an investment flow

[2] For the relationship between an age-efficiency and an age-price profile in case of geometric rates see Jorgenson, Ho and Stiroh (2005), p. 153, and OECD (2001a), p. 64.

[3] The *Ifo Investment Survey* follows the EU guidelines for harmonized business surveys and contains 70,000 German firms, 5000 of which are surveyed for each sample period. It is established as an excellent leading indicator of German investment; it is also incorporated in a number of other leading indicators, most prominently the European Commission's *Economic Indicators of the Euro Zone*.

matrix (Abnehmer-Basismatrix) that links the 100 investment assets to the 52 industries. Based on the investment flow matrix the *Ifo Investorenrechnung* then produces industry investments that are compatible with aggregate GSO investment levels by asset types and by industries. For a detailed list of the assets and industries post-1991, see Table 1. A detailed description of the derivation and sources of investments provided by the *Ifo Investorenrechnung* can be found in the Appendix.

The *Ifo Investorenrechnung* does not provide specific information on Software investment. Software is included in the broader group of Intangible Assets. However, the allocation of Intangible Assets to the industries is derived from an Ifo study that estimated the industry investment shares in total Software investment based on survey questions about industry investment in purchased and own account Software in 1995 (see Hermann and Mueller, 1997). The Hermann and Mueller survey questions were again asked in 1998, 1999 and 2000 as part of the *Ifo Investment Survey*. The results of the surveys were used to further refine the industry investment shares and were incorporated into the user structure of the investment flow matrix. Herrmann and Mueller (1997) estimated that about 75% of aggregate investment in Intangible Assets is Software investment. The *Ifo Investorenrechnung* holds that this percentage remained stable in subsequent surveys. To differentiate industry-level Software investment from investment in Intangible Assets, we therefore assume that 75% of industry investment in Intangible Assets is Software.

Establishing consistent investment series prior to 1991 is subject to three major challenges. First, the *Ifo Investorenrechnung* and the GSO, provide only investment series for West Germany prior to 1991. Second, the industry classification changed to NACE post-1991. Pre-1991 the *Ifo Investorenrechnung* uses the older GSL WZ79 classification. Third, the asset classification has changed; pre-1991 the *Ifo Investorenrechnung* provides investments for 13 assets types that coincide only roughly with the 12 assets post-1991. For a detailed list of the pre- and post-1991 industry and asset classification schemes, see Tables 2 and 3.

To overcome these difficulties the basis for capital services in the *Ifo Industry Growth Accounting Database* is estimated as initial capital stocks for 1991. To calculate the initial capital stocks in 1991 we utilized two sources of information. First, the GSO provides net capital stock estimates on the 52-industry level for Unified Germany in 1991. However, these net capital stocks are only disaggregated into two broad asset types: Equipment and Other Assets and Structures and Buildings. To further disaggregate industry Equipment and Other Assets net capital stocks into our more detailed asset types we used information of the *Ifo*

Asset Database. Based on the *Ifo Investorenrechnung* the *Ifo Asset Database* calculated net capital stocks for 13 assets types on the industry level for West Germany (1970–1991) according to the WZ79 industry classification scheme (for details see Gerstenberger et al., 1989).

To develop a comparable set of pre- and post-1991 industries, we use the GSO (1993) correspondence. The result is a set of 28 conforming industries; Table 4 displays the conversion key. This allowed us to convert industry assets by WZ79 industry classification to industry assets by the NACE classification. Next we convert pre-1991 assets into the new assets post-1991 classification (see Table 5). We use unpublished Communication Equipment investment series (1970-1991) provided by the *Ifo Investorenrechnung* to disaggregate Communication Equipment out of the broader group of Electrical Equipment investment. Information on Intangible Assets is not available prior to 1991, but the aggregate net capital stock for 1991 is provided by the GSO. The distribution of the aggregate capital stock into industries is based on the industry investment shares in 1991 as reported in the *Ifo Investorenrechnung.*

The procedure results in net capital stocks for 28 industry groups by new asset types. To distribute the capital stocks by asset to each of the sub-industries to establish a 52 industry database we use investment shares by asset in 1991. The asset capital stocks are then proportionally scaled so that the sum over all assets equals the GSO's Equipment and Other Assets net capital stock for each of the 52 industries. Finally, the capital stocks were deflated using the investment deflators detailed in the next section.

Since our method of establishing the initial capital stock levels differ from the construction of capital stock series in Groningen's *Industry Growth Accounting Database*[4], we compare our initial capital estimates of the *Ifo Industry Growth Accounting Database* with Groningen's capital stocks in 1991.[5] To be able to make comparisons, we first aggregate our 52 industries to match Groningen's 26 industries. Further, we aggregate our 12 capital asset types into two broad capital types: ICT capital and non-ICT capital. Figures 1 and 2 depict the high correlations of ICT and non-ICT initial capital stock *levels* between the *Ifo Industry Growth Accounting Database* and Groningen's capital stock levels in 1991. The correlation coefficient of the ICT and non-ICT capital stock levels are 0.97 and 0.95, respectively. This

[4] Groningen Growth and Development Centre, *Industry Growth Accounting Database*, September 2006, online at http://www.ggdc.net/, updated from O'Mahony and van Ark (2003).

[5] We thank Robert Inklaar for making the unpublished capital stock levels of the Groningen's *Industry Growth Accounting Database* available to us.

implies that the construction of the initial capital stock cannot be the source of any potentially substantial differences in the subsequent growth rates.

3.1.2.3 Deflation of Investment

Investment deflators transform recent vintages of investments into equivalent efficiency units of earlier vintages. The key feature of investment price indices that are based on constant-quality units is that they account for price declines in goods that are characterized by fast technological progress. Computers, for instance, are such goods because their increased processing speed and storage capacity enhances their quality tremendously. Using the concept of comparable prices, the actual price of computers has continuously declined. Not accounting for such quality improvements overstates actual prices and results in lower real-term growth rates of computer investments. To overcome this measurement problem, hedonic regression approaches were applied for computers. This methodology was introduced by Cole et al. (1986) and developed further by the US Bureau of Economic Analysis and the US Bureau of Labor Statistics to capture price developments in the presence of rapidly increasing technological progress.

The *Ifo Investorenrechnung* provides price indices for each asset at the industry level. These price indices match the aggregate deflator of the GSO for each asset, for details see Gerstenberger et al. (1989):

$$P_{j,t}^{GSO} I_{j,t} = \sum_i P_{i,j,t}^{Ifo} I_{i,j,t} \qquad (9).$$

For non-ICT assets (numbered assets j = 1, 2, 4, 6, 7, 8, 9, 10, 12 in Table 1) the *Ifo Industry Growth Accounting Database* employs the asset and industry specific deflators of the *Ifo Investorenrechnung*. To deflate ICT assets into constant-quality units, the *Ifo Industry Growth Accounting Database* employs the aggregate ICT-deflators for the assets Computer and Office Equipment, Communication Equipment and Software developed by Timmer, Ypma and van Ark (2003). These deflators follow the “harmonization”-method pioneered in Schreyer (2000, 2002). According to this method, price indices are based on US hedonic price indices adjusted for differences in general inflation levels between Germany and the United States. Thus, we rescale the Ifo industry-specific deflators to match the aggregate deflator of Timmer, Ypma and van Ark (2003) for all ICT-assets (j = 3, 5, 11):

$$P_{j,t}^{Groningen} I_{j,t} = \sum_i P_{i,j,t}^{Ifo-adjusted} I_{i,j,t} \text{, where } P_{i,j,t}^{Ifo-adjusted} = P_{i,j,t}^{Ifo} P_{j,t}^{Groningen} \Big/ P_{j,t}^{GSO} \qquad (10).$$

This method preserves the industry price differences and at the same time assures that the deflators reflect an internationally comparable decline in ICT-asset prices over time. Sources for Groningen ICT deflators and non-ICT deflators are listed in Table 6.

3.1.2.4 Depreciation Rates

Geometric depreciation rates are the final ingredient necessary for the calculation of PIM capital stocks. Fraumeni (1997) derived the geometric depreciation rates, δ_j, as a function of the declining-balance rate, R_j, and the asset's average service life, T_j (industry dimension suppressed):

$$\delta_j = \frac{R_j}{T_j} \qquad (11)$$

For details on the sources of used depreciation rates and input factors used to calculate depreciation rates see Table 6. For a complete list of the geometric depreciation rates applied see Table 7. We employed Ifo specific German data on average service lives on industry-assets and combined them with the declining balance rate estimates for these assets from the US Bureau of Economic Analysis (BEA) as detailed in Fraumeni (1997). According to the BEA, the declining balance rates are set to 1.65 for the equipment assets and 0.91 for Structures and Buildings. The underlying source of Ifo specific average service lives is an Ifo study conducted by Gerstenberger et al. (1989). The authors use primarily tax-lives to derive average values for economic service lives, which generally represent the minimum of the actual economic service lives. While economic service lives change over time, data on such changes does not exist. A time-dependent adjustment of service lives is not always feasible, therefore it is common in the literature to assume a reduction of the economic service lives of 25 percent, on average, over the period 1950 to 1986 (see Gerstenberger et al. 1989, pp. 53-56). To assure that our industry-specific service lives are in line with GSO asset-specific average service lives, the industry-specific service lives are scaled so that the industry average for each asset matches the average service lives for each asset of the GSO as reported in UNECE (2004).

For ICT assets we use separate depreciation rates to generate data that is internationally comparable. For Communication Equipment and Software, we utilize the geometric depreciation rates calculated by Jorgenson and Stiroh (2000). For Computers and Office Equipment we use geometric depreciation rates from Van Ark et al. (2002). For Office Equipment the depreciation rates change over time. This reflects the fact that this asset category is comprised of asset types with very different depreciation rates. For example, computers have considerably shorter service lives than photocopiers. The varying depreciation rates, therefore, account for the fact that the composition of this asset category has changed over time, largely in the direction of a higher share of faster depreciating computers. Geometric depreciation rates for Automobiles are also taken from Jorgenson and Stiroh (2000).

3.1.3 User Cost of Capital

Capital displays different productivities in different asset classes, which is reflected in its price. In general the price of capital services is captured by the rental price of capital that reflects the marginal productivity of the invested capital. Consider a firm's investment decision, choosing between buying an asset or any other investment opportunity. In equilibrium a firm must be just indifferent between the two alternatives: investing the money ($P_{I,t}$) to earn a nominal rate of return, or buying capital with the same amount of dollars, collecting a *price of capital* (*rental price* or *user cost of capital*) and then selling the depreciated asset at next period's price ($P_{I,t+1}$). This implies the following investment arbitrage equation (Jorgenson, Ho and Stiroh, 2005, p. 154):

$$(1+i_{t+1})P_{I,i,j,t} = P_{K,i,j,t+1} + (1-\delta_{i,j})P_{I,i,j,t+1} \qquad (12)$$

where nominal interest, i_{t+1}, earned on the acquisition price in period t, $P_{I,i,j,,t}$, must equal the depreciated acquisition price in period $t+1$ plus the *price of capital*, $P_{K,i,j,t+1}$. Rearranging (12) yields the familiar *price of capital equation*:

$$P_{K,i,j,t+1} = (i_{t+1} - \pi_{i,j,t+1})P_{I,i,j,t} + \delta_{i,j}P_{I,i,j,t+1} \qquad (13),$$

where $\pi_{i,j,t+1}$ is the percent change in the acquisition price of an investment good between period t and t+1. The nominal interest rate, i_{t+1}, is the long-term interest rate for Germany derived from the OECD Economic Outlook Database (for sources see Table 6). Equation (13) simply states that the price of capital services in period $t+1$ must equal the real interest, $(i_{t+1} - \pi_{i,j,t+1})$ paid on the acquisition price of capital in period t plus the depreciation on the acquisition price of capital in period $t+1$.

3.2 Labor Input

Labor input data is provided for completeness in the *Ifo Industry Growth Accounting Database*. Much of this data is not new and can be obtained from the appropriate sources. At times we need to adjust the data to achieve the appropriate level of disaggregation. However, the novelty of the database lies in its investment and capital stock data.

3.2.1 Quality Adjusted Labor

An hour of supplied labor can exhibit very different marginal productivities, depending for instance on the level of education, experience or gender of the employee. Similarly to capital services, this difference must be reflected when aggregating different kinds of labor into an overall measure of labor input. Jorgenson, Ho and Stiroh (2005) suggest as the appropriate labor input measure

$$\Delta \ln L_{i,t} = \sum_{l} \overline{\omega}_{i,l} \Delta \ln H_{i,l,t} \tag{14}$$

where $\overline{\omega}_{i,l} = 0.5(\omega_{i,l,t} + \omega_{i,l,t-1})$, and $\omega_{i,l,t} = \frac{P_{L,i,l,t} H_{i,l,t}}{\sum_{l} P_{L,i,l,t} H_{i,l,t}}$. The hours of type *l* skills in industry *i* at time *t* are given by $H_{i,l,t}$, and the price (wage rate) of an hour of type *l* in industry *i* at time *t* is given by $P_{L,i,l,t}$.

Equivalently, Jorgenson et al. (2005) show that labor input growth can also be written as:

$$\Delta \ln L_{i,t} = \Delta \ln Q^{L}_{i,t} + \Delta \ln H_{i,t} \tag{15}$$

where $\Delta \ln Q^{L}_{i,t}$ represents the growth rate of labor quality given by

$$\Delta \ln Q^{L}_{i,t} = \sum_{l} \overline{\omega}_{i,l} \Delta \ln H_{i,l,t} - \Delta \ln H_{i,t} \quad \text{and} \quad H_{i,t} = \sum_{l} H_{i,l,t}\,. \tag{16}$$

Equation (16) expresses labor quality growth as the difference between weighted and unweighted growth rates of hours worked.

Our measure of industry labor quality growth $\Delta \ln Q^{L}_{i,t}$ is obtained from the *Groningen Industry Level Growth Accounting Database* as detailed in Inklaar, O'Mahony and Timmer (2005). However, Groningen's labor quality estimates are available for 26 broad industries only. To obtain labor quality growth for our 52 industries, we assumed that labor quality growth was the same among all sub-industries within a broad Groningen industry and equal to the broad industry growth rate. Inklaar et al. (2005) provide labor quality only until 2000. We use 1980-2000 data to extrapolate labor quality to 2003 using an AR process with optimal lag length (using the AIC, Final Prediction Error, Hannan-Quinn, and the Schwarz criterion (BIC)) for each industry to match the post-2000 aggregate labor quality growth provided by Schwerdt and Turunen (2006).

Labor hours are obtained from the GSO. A problem emerges due to the fact that hours worked are available for 14 sectors only. Here we assume that *hours worked per employee* (including self-employed) in the 14 sectors resembles those of the respective disaggregated *Ifo Industry Growth Accounting Database* industries. Specifically, we compute the hours worked per employee for each of the 14 industries and multiply them by the numbers of employees in the respective disaggregated *Ifo Industry Growth Accounting Database* industries to obtain total hours worked for each of the 52 industries. For details on the sources of all labor input data, see Table 6.

3.2.2 The Labor Compensation Share

As expressed in equation (1), the growth rate of labor inputs is weighted by the labor compensation share in total industry value-added. Labor compensation for employed workers is provided by the GSO (see Table 6 for detailed source). However, the GSO publishes no data on the compensation of self-employed workers. To adjust for self-employed workers in our measure of labor compensation, we apply the simplest assumption that compensation per self-employed is equal to the compensation of employed workers.

4. Applications

For a full overview of the applications that can be generated by the database we ask the reader to consult the voluminous literature on productivity studies summarized by Jorgenson et al. (2005). Initial work by Eicher and Roehn (2007) dissects German productivity growth on the basis of the database to highlight the specific industry contributions to German TFP growth. Figures 3a)–c), for example, plot the modified Harberger (1998) diagram for the individual industry TFP growth contributions for the three periods 1991–1995, 1995–2000 and 2000–2003. The vertical axis displays the cumulative industry contributions to aggregate TFP growth, while the horizontal axis plots the cumulative industry output share in total value added (Domar-weights, Domar, 1961). Industry nominal gross output data are directly taken from the GSO. The vertical distance between two points displays the TFP contribution of an individual industry.

Focusing first on the average TFP growth at the *aggregate level* across the three periods (displayed by the horizontal line), we find that aggregate TFP growth increased from 0.35% in 1991–1995 to 0.47% in 1995–2000. However, post-2000 total factor productivity growth collapsed to about 0% in Germany. What is striking, however, is the heterogeneity of TFP growth contributions at the disaggregated industry level outlined by Figures 3a)-c). The curves are surprisingly steep, indicating a bifurcated economy with either strong productivity gains or sharp productivity losses. Even more important is that the share of industries that contribute *negatively* is increasing dramatically over the three time periods. This is especially apparent if we compare the 1995–2000 and 2000–2003 periods in Figures 3 b), c). In 1995–2000, 17 industries experienced negative TFP growth rates, featuring large contractions in Other Business Services, Motor Vehicles and the Insurance industry. In 2000–2003, in contrast, 28 industries accounting for almost 50 percent of aggregate value added showed negative TFP growth.

Comparing the first two periods in Figures 3 a), b), it is striking that Wholesale Trade and Financial Intermediation increased their TFP contributions substantially between the two periods. The same is true for Office Machinery & Computers and Communications. Of these industries only Wholesale Trade managed to increase its TFP growth contribution further post-2000 when TFP growth in Communication and Office Machinery & Computer slowed, and Financial Intermediation TFP turned negative. Contributions from the Insurance, Machinery and the Government sector steadily declined over the three periods, pointing to severe problems within these industries. These industries started with positive TFP growth but showed negative TFP growth post-2000.

5. Summary and Conclusion

In this paper we have presented a new industry-asset level database that allows industry level growth accounting from 1991–2003 for 52 industries and 12 assets. We provide the methodological underpinnings necessary to produce the capital, labor and productivity estimates and presented some first results.

The database allows for the first time the analysis of German productivity drivers on the 52-industry level. We provide researchers with access to this database to study not only the determinants of economic growth and per capita income but also the drivers of the structural changes in the German economy since 1991 from manufacturing to an ICT-based, New Economy.

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Abbreviations

AGAM	:	Association of German Automobile Manufacturers (Verband der Deutschen Automobilindustrie, VDA)
AGMEM	:	Association of German Machinery and Equipment Manufacturing (Verband des Deutschen Maschinen- und Anlagenbaus, VDMA)
FOA	:	Federal Office of Automobiles (Kraftfahrtbundesamt, KBA)
GDDC	:	Groningen Growth and Development Centre
GIER	:	German Institute for Economic Research (Deutsches Institut für Wirtschaftsforschung, DIW)
AGEEM	:	Association of German Electrical and Electronic Manufactures (Zentralverband Elektrotechnik und Elektroindustrie, e.V., ZVEI)
GSO	:	German Statistical Office (Deutsches Statistisches Bundesamt)
IS Leasing	:	*Ifo Investment Survey Leasing* (Ifo Investitionstest Leasing)
NA	:	National Accounts provided by GSO (Volkswirtschaftliche Gesamtrechung, VGR des Deutschen Statistischen Bundesamtes)

Table 1
***Ifo Industry Growth Accounting Database* Industry and Asset Classification in accordance with National Accounts (NA)**

Seq. Nr.	Industry	Seq. Nr.	Assets
1	Agriculture, Forestry, Fishing	1	Metal Products
2	Energy Mining and Quarrying	2	Machinery
3	Mining and Quarrying, ex. Energy	3	Computers and Office Equipment
4	Food and Tobacco	4	Electrical Generation and Distribution
5	Textiles	5	Communication Equipment
6	Apparel	6	Instruments, Optics and Watches
7	Leather	7	Furniture, Music and Sports Equipment
8	Wood Products	8	Other Machines and Equipment.
9	Paper, Pulp	9	Automobiles
10	Publishing, Printing	10	Other Vehicles
11	Coke, Petroleum, Nuclear Fuels	11	Intangible Assets
12	Chemicals		Equipment and Other Assets
13	Rubber, Plastic	12	Structures and Buildings
14	Non-Metallic Mineral Products		Assets
15	Basic Metals		
16	Fabricated Metal Products		
17	Machinery		
18	Office Machinery and Computers		
19	Electrical Apparatus n.e.c.		
20	Radio, TV and Comm. Equipment		
21	Instruments, Optics and Watches		
22	Motor Vehicles		
23	Other Transport Equipment		
24	Furniture and Manufacturing n.e.c.		
25	Recycling		
26	Electricity, Gas		
27	Water Supply		
28	Construction		
29	Sale and Repair of Motor Vehicles		
30	Wholesale Trade		
31	Retail Trade		
32	Hotels and Restaurants		
33	Land Transport		
34	Water Transport		
35	Air Transport		
36	Auxiliary Transport Activities		
37	Communications		
38	Financial Intermediation		
39	Insurance		
40	Auxiliaries Financial and Insurance Intermediation		
41	Real Estate		
42	Rental and Leasing Services		
43	Computer and Related Activities		
44	Research and Development		
45	Other Business Services		
46	Public Administration, Defense, Social Security		
47	Education		
48	Health and Social Work		
49	Sewage and Refuse Disposal		
50	Organizations, n.e.c		
51	Recreational, Cultural, Sports Activities		
52	Other Services		

Source: *Ifo Industry Growth Accounting Database*, *Ifo Investorenrechnung*

Table 2
Asset Type Classifications Pre- and Post-1991

Seq. Nr.	Pre-1991 Assets	Seq. Nr.	Post-1991 Assets
1	Foundry Products	1	Metal Products
2	Steel and Railed Vehicles	2	Machinery
3	Machinery	3	Computers and Office Equipment
4	Office Equipment	4	Electrical Generation and Distribution
5	Automobiles	5	Communication Equipment
6	Other Vehicles	6	Instruments, Optics and Watches
7	Electrical Products	7	Furniture, Music and Sports Equipment
8	Fine Mechanics	8	Other Machines and Equipment
9	Iron, Plate and Steel Products (IPS)	9	Automobiles
10	Musical Instruments, Toys and Sports Equipment	10	Other Vehicles
11	Wood Products	11	Intangible Assets
12	Textiles	12	Structures (Non Residential and Residential)
13	Structures (Non Residential and Residential)		

Source: *Ifo Investorenrechnung*, Gerstenberger et al. (1989)

Table 3
Pre- and Post-1991 Industry Classification

Seq. Nr.	Pre-1991 Industries	Seq. Nr.	Post-1991 Industries
1	Agriculture, Forestry, Fishing	1	Agriculture, Forestry, Fishing
2	Electricity	2	Energy Mining and Quarrying
3	Gas	3	Mining and Quarrying, ex. Energy
4	Water Supply	4	Food and Tobacco
5	Mining	5	Textiles
6	Chemicals	6	Apparel
7	Petroleum	7	Leather
8	Plastic	8	Wood Products
9	Rubber	9	Paper, Pulp
10	Quarrying	10	Publishing, Printing
11	Fine Ceramics	11	Coke, Petroleum, Nuclear Fuels
12	Glass	12	Chemicals
13	Iron-Producing Industries	13	Rubber, Plastic
14	Non-Iron Metal Products	14	Non-Metallic Mineral Products
15	Foundry	15	Basic Metals
16	Extrusion, Railed Vehicles	16	Fabricated Metal Products
17	Steel-, Light Metal-Working, Railed Vehicles	17	Machinery
18	Machinery	18	Office Machinery and Computers
19	Office Machinery and Computers	19	Electrical Apparatus n.e.c.
20	Manufacturer Leasing Office Machinery and Computers	20	Radio, TV and Comm. Equipment
21	Road Vehicle Manufacturing	21	Instruments, Optics and Watches
22	Shipbuilding	22	Motor Vehicles
23	Aerospace Manufacturing	23	Other Transport Equipment
24	Electrical Apparatus n.e.c.	24	Furniture and Manufacturing n.e.c.
25	Manufacturer Leasing Electrical Apparatus n.e.c.	25	Recycling
26	Fine Mechanics, Optics	26	Electricity, Gas
27	Iron, Plate and Metal Manufacturing	27	Water Supply
28	Music Instruments., Toys, Sports Equipment	28	Construction
29	Wood Working	29	Sale and Repair of Motor Vehicles
30	Wood Products	30	Wholesale Trade
31	Paper, Pulp	31	Retail Trade
32	Paper, Pulp Products	32	Hotels and Restaurants
33	Publishing, Printing	33	Land Transport
34	Leather	34	Water Transport
35	Textiles	35	Air Transport
36	Apparel	36	Auxiliary Transport Activities
37	Food	37	Communications
38	Construction	38	Financial Intermediation
39	Wholesale Trade	39	Insurance
40	Retail Trade	40	Auxiliaries Financial and Insurance Intermediation
41	Railways	41	Real Estate
42	Water Transport	42	Rental and Leasing Services
43	Other Transportation	43	Computer and Related Activities
44	German Federal Mail	44	Research and Development
45	Financial Intermediation	45	Other Business Services
46	Insurance	46	Public Administration, Defense, Social Security
47	Apartment Leasing	47	Education
48	Hotels and Restaurants	48	Health and Social Work
49	Education, Science, Art, Publication	49	Sewage and Refuse Disposal
50	Health, Veterinary	50	Organizations, n.e.c
51	Other Services	51	Recreational, Cultural, Sports Activities
52	Leasing Companies	52	Other Services
53	Commercial Residential Buildings		
54	Real Estate Fund, Asset Management		
55	Local Authorities, Social Securities		
56	Private Organization without Pecuniary Reward		

Source: *Ifo Investorenrechnung*, Gerstenberger et al. (1989)

Table 4
Industry Conversion Key: Pre- to Post-1991 Industry Classification

Seq. Nr.	Pre-1991 Industries	Seq. Nr.	Post-1991 Industries
1	Agriculture, Forestry, Fishing	1	Agriculture, Forestry, Fishing
5	Mining	2	Energy Mining and Quarrying
7	Petroleum	3	Mining and Quarrying, excl. Energy
10	Quarrying	11	Coke, Petroleum, Nuclear Fuels
11	Fine Ceramics	14	Non-Metallic Mineral Products
12	Glass		
37	Food	4	Food and Tobacco
35	Textiles	5	Textiles
36	Apparel	6	Apparel
34	Leather	7	Leather
28	Music Instruments, Toys, Sports Equipment	8	Wood Products
29	Wood Working	24	Furniture and Manufacturing n.e.c.
30	Wood Products		
31	Paper, Pulp	9	Paper, Pulp
32	Paper, Pulp Products		
33	Publishing, Printing	10	Publishing, Printing
6	Chemicals	12	Chemicals
9	Plastic	13	Rubber, Plastic
8	Rubber		
13	Iron-Producing Industries	15	Basic Metals
14	Non-Iron Metal Products		
15	Foundry		
16	Extrusion		
17	Steel-, Light Metal-Working, Railed Vehicles	16	Fabricated Metal Products
27	Iron, Plate and Metal Manufacturing		
18	Machinery	17	Machinery
19	Office Machinery and Computers	18	Office Machinery and Computers
24	Electrical Apparatus n.e.c.	19	Electrical Apparatus n.e.c.
26	Fine Mechanics, Optics	20	Radio, TV and Comm. Equipment
		21	Instruments, Optics and Watches
21	Road Vehicle Manufacturing	22	Motor Vehicles
22	Shipbuilding	23	Other Transport Equipment
23	Aerospace Manufacturing		
39	Wholesale Trade	25	Recycling
40	Retail Trade	29	Sale and Repair of Motor Vehicles
		30	Wholesale Trade
		31	Retail Trade
2	Electricity	26	Electricity, Gas
3	Gas		
4	Water Supply	27	Water Supply
38	Construction	28	Construction
48	Hotels and Restaurants	32	Hotels and Restaurants
41	Railways	33	Land Transport
43	Other Transportation	35	Air Transport
		36	Auxiliary Transport Activities
42	Water Transport	34	Water Transport
44	German Federal Mail	37	Communications
45	Financial Intermediation	38	Financial Intermediation
46	Insurance	39	Insurance
		40	Auxiliaries Financial and Insurance Intermediation
47	Apartment Leasing	41	Real Estate
53	Commercial Residential Buildings		
20	Manufacturer Leasing Office Machinery and Computers	42	Rental and Leasing Services
25	Manufacturer Leasing Electrical Apparatus n.e.c.		
52	Leasing Companies		
51	Other Services	43	Computer and Related Activities
54	Real Estate Fund, Asset Management	45	Other Business Services
		52	Other Services
49	Education, Science, Art, Publication	44	Research and Development
		47	Education
		51	Recreational, Cultural, Sports Activities
50	Health, Veterinary	46	Public Administration, Defense, Social Security
55	Local Authorities, Social Securities	48	Health and Social Work
56	Private Organization without Pecuniary Reward	49	Sewage and Refuse Disposal
		50	Organizations, n.e.c

Source: based on German Statistical Office (2002)

Table 5
Asset Conversion Key: Pre- to Post-1991 Asset Type Classification

Pre-1991 Assets	**Post-1991 Assets**	**Notes**
Foundry Products; Steel and Railed Vehicles; Iron, Plate and Steel Products (IPS)	Metal Products	1) Metal products sum of Foundry Products, Steel and Railed Vehicles, Iron, Plate and Steel Products (IPS) 2) For transport services: Metal Products only sum of Foundry and IPS, capital stocks in Steel are railed vehicles and thus allocated to Other Vehicles.
Machinery	Machinery	
Office Equipment	Office Equipment	
Electrical Products; Fine Mechanics	Electrical Generation and Distribution; Communication Equipment; Instruments, Optics and Watches	1) Communication Equipment capital stock broken out of Electrical Products based on 11-year-average (1980-1991) investment share in Electrical Products. 2) Sum of Electrical Products (excluding Communication) and Fine Mechanics split up into Electrical Generation and Distribution and into Instruments, Optics and Watches according to 1991 investment share.
Musical Instruments, Toys and Sports Equipment; Wood Products; Textiles	Furniture, Music and Sports Equipment	Furniture, Music and Sports Equipment sum of Musical Instruments, Toys and Sports Equipment, Wood Products, Textiles.
Automobiles	Automobiles	
Other Vehicles	Other Vehicles	
Structures (Non Residential and Residential)	Structures (Non-Residential and Residential)	
---	Other Machines and Equipment	1% of every equipment asset (excluding Automobiles and Other Vehicles) is allocated towards the new asset Other Machines and Equipment.
---	Software	Aggregate Intangible Assets net capital stock provided by GSO. Industry allocation according to investment shares in 1991. Software is 75% of Intangible Assets.

Source: *Ifo Investorenrechnung*, Gerstenberger et al. (1989), Hermann and Müller (1997), and unpublished information from the GSO.

Table 6
Key Variables and Data Sources

Variables		Asset (Seq. Nr.)	Sources
<u>Value-Added</u>	*VA*, P_{VA} *VA*		German Statistical Office (GSO), www.destatis.de, Genesis Database: - Series 81000BJ321, Federal National Accounts (NA), *Intermediate inputs, gross output, value added for Unified Germany*, WZ 2003: Industry classification of the NA, in current and 2000 prices (update November 2006)
<u>Capital Input Share:</u>	υ_K		Derived from equation (3)
- Price of Capital (User Cost of Capital)	P_K		Derived from equation (13)
- Nominal Interest Rate	i		10-year benchmark government bond yields, Germany, www.sourceoecd.org, OECD Databases/ Economic Outlook: Statistics and Projections, EO79 Annex Tables: Interest rates and exchange rates
- Sectoral Price Inflation	π		Investment deflators, see *<u>Capital Input (Capital Services)</u>*
- Acquisition Price of Capital	P_I		Investment deflators, see *<u>Capital Input (Capital Services)</u>*
- Depreciation Rate	δ		See *<u>Capital Input (Capital Services)</u>*
- Capital Services	K		See *<u>Capital Input (Capital Services)</u>*
<u>Capital Input (Capital Services):</u>	K		Derived from equation (6)
- Proportionality Factor	Q_K		Assumes proportionality between capital services and capital stocks, used in equation (6)
- Capital Stocks:	S		Derived from equation (8)
- Initial Capital Stock	S^{1991}		*Ifo Asset Database*, *Ifo Investorenrechnung*, GSO
- Geometric Depreciation Rates	δ	Computers and Office Equipment (2)	B. Van Ark, J. Melka, N. Mulder, M.P. Timmer and G. Ypma (2002), p.23
		Communication Equip. (5)	Inklaar, Robert, Mary O'Mahony and Marcel P. Timmer (2003), Table A.4
		Automobiles (9); Software (11)	Jorgenson, Dale W. and Kevin Stiroh (2000), Table B1
- Average Service Lives	T	All asset types (1-12)	Estimates of average service lives of investments, on industry-asset level, *Ifo Investorenrechnung*
		All asset types, excluding Structures and Buildings (1-11)	Estimates of means service lives of investments, United Nations Economic Commissions for Europe (UNECE), www.unece.org, Statistics/ Documents Library/ Economic Statistics, Joint Meeting on National Accounts (Geneva, 28-30 April 2004), 18/ ADD.2 Annex 2: Assets categories (ECE secretariat), p. 83
- Declining Balance Rates	R	Metal Products (1); Machinery (2); Electrical Generation and Distribution (4); Instruments, Optics and Watches (6); Furniture, Music and Sports Equipment (7); Other Machines and Equipment (8); Other Vehicles (10); Structures and Buildings (12)	Bureau of Economic Analysis (BEA), www.bea.gov, Methodology Papers/ Fixed Assets and Consumer Durable Goods, *The Measurement of Depreciation in the NIPA's*, July 1997, Table 3
- Investments	I		*Ifo Investorenrechnung*
- Investment Deflators	$P^{Groningen}$	ICT Assets (3, 5, 11)	GGDC, www.ggdc.net, Data/ Total Economy Growth Accounting Database/ Germany, Gross fixed capital formation (in constant and current prices)
	P^{Ifo}	Non-ICT Assets (1, 2, 4, 6, 7, 8, 9, 10, 12)	*Ifo Investorenrechnung*
<u>Labor Input Share:</u>	υ_L		Derived from equation (4)
- Price of Labor	P_L		GSO, www.destatis.de, Genesis Database: - Series 81000BJ323, Wages of employed workers (in current prices; update November 2006) - Series 81000BJ323, Numbers of employed workers (update November 2006) - Series 81000BJ323, Numbers of employees, i.e. employed workers including self-employed (update November 2006)
- Labor	L		See *<u>Labor Input (Labor Services)</u>*
<u>Labor Input (Labor Services):</u>	L		Derived from equation (15)
- Labor Quality	Q^L		GDDC, www.ggdc.net, Data/ Industry Growth Accounting Database/ Germany, Quality of labor
- Hours Worked for Employees	H		GSO, www.destatis.de, Genesis Database: - Series 81000BJ323, Hours worked for employees, i.e. employed workers including self-employed (update November 2006)

Table 7
Geometric Depreciation Rates by Assets

Seq. Nr.	Assets	Geometric Depreciation Rate	Time Series
1	Metal Products	0.092	1991-2003
2	Machinery (industry average)	0.130	1991-2003
3	Computers and Office Equipment	0.243 0.254 0.295	1991-1994 1995-1999 2000-2003
4	Electrical Generation and Distribution (industry average)	0.097	1991-2003
5	Communication Equipment	0.115	1991-2003
6	Instruments, Optics and Watches (industry average)	0.114	1991-2003
7	Furniture, Music and Sports Equipment (industry average)	0.099	1991-2003
8	Other Machines and Equipment (industry average)	0.130	1991-2203
9	Automobiles	0.272	1991-2003
10	Other Vehicles (industry average)	0.085	1991-2003
11	Software	0.315	1991-2003
12	Structures and Buildings (industry average)	0.012	1991-2003

Source: B. Van Ark, J. Melka, N. Mulder, M.P. Timmer and G. Ypma (2002); Inklaar, Robert, Mary O'Mahony and Marcel P. Timmer (2003); Jorgenson, Dale W. and Kevin Stiroh (2000); *Ifo Investorenrechnung*; United Nations Economic Commissions for Europe (UNECE); Bureau of Economic Analysis (BEA). For further details, see Table 6.

Figure 1
ICT Capital Stock Levels Comparison: Ifo and Groningen 1991

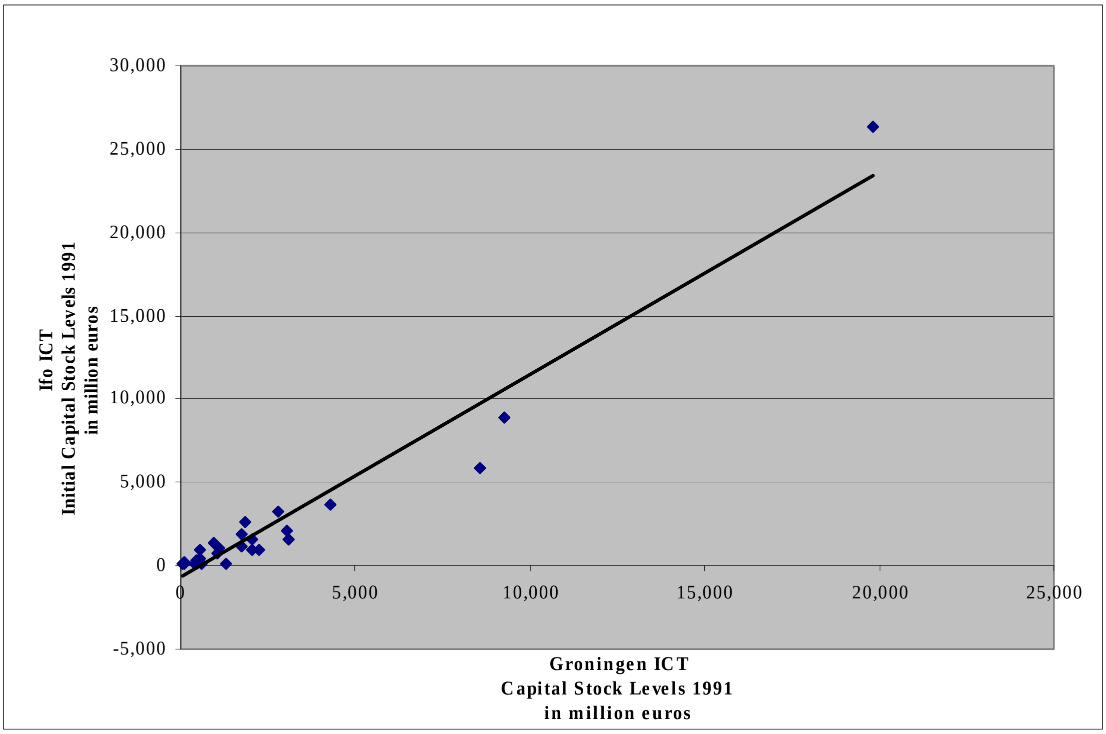


Figure 2
Non-ICT Capital Stock Levels Comparisons: Ifo and Groningen 1991

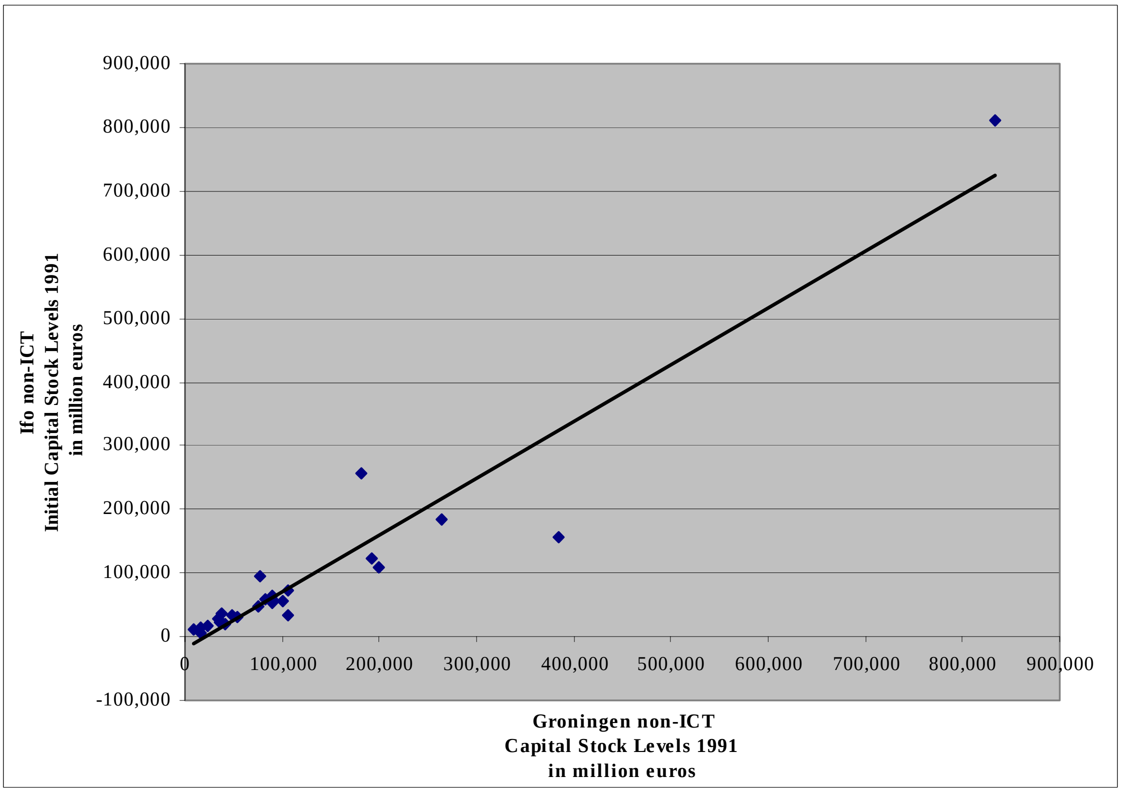
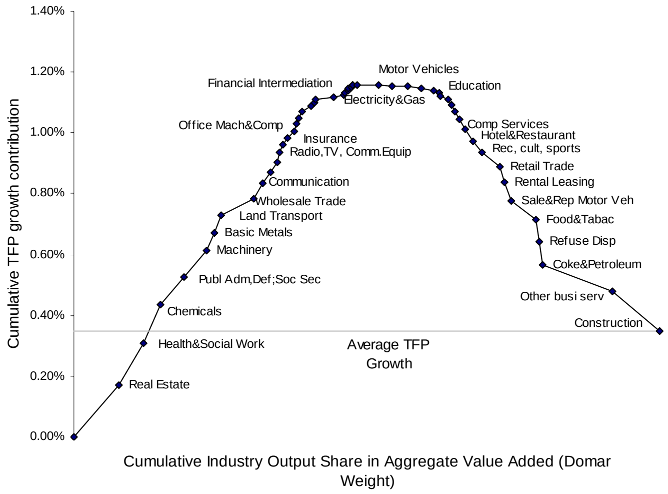
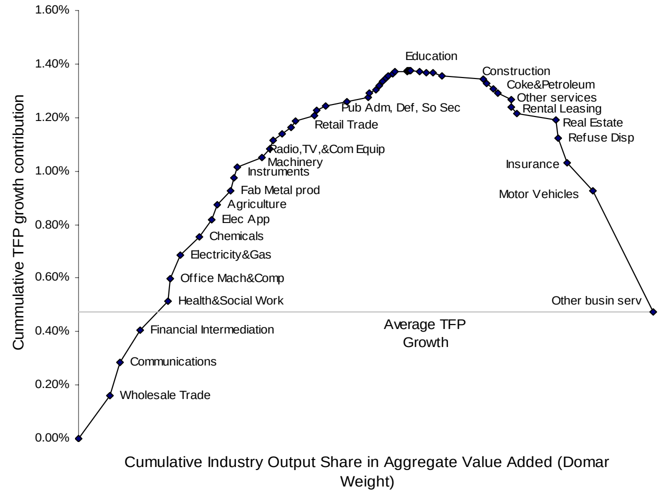


Figure 3
Industry TFP Contributions to German Total Factor Productivity Growth

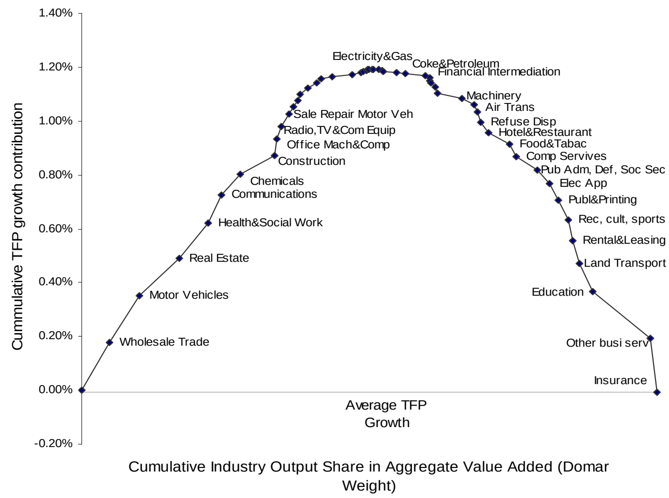
a) 1991–1995



b) 1995–2000



c) 2000–2003



Source: Eicher and Roehn (2007)

Appendix

Original Investment Data

The annual industry level investment data necessary to calculate capital stocks is provided by the *Ifo Investorenrechnung* from 1991 to 2003 and is documented in Gerstenberger et al. (1989). The *Ifo Investorenrechnung* collects 100 detailed subassets. Table A.1 lists the detailed subassets and their mapping to the 11 asset classes (excluding Structures and Buildings) used in the *Ifo Industry Growth Accounting Database*. Through individual agreements with each individual industry, the *Ifo Investorenrechnung* obtains annual investment data on all subassets. Specifically, the *Ifo Investorenrechnung* collects industry data on production, export and import, which then allows for the computation of *domestically available* production by subtracting the exports from the domestic production and adding the imports. In case of lacking industry data to calculate *domestically available* production in subassets, gross fixed investments provided by the GSO are used. The latter applies to the assets Metal Products; Computer and Office Equipment; Furniture, Music and Sports Equipment; Other Machines and Equipment; and Intangible Assets. For Other Vehicles gross fixed investments are provided by the German Institute for Economic Research (GIER). The sources of investments by subassets are listed in detail in Table A.2. To assure consistency to the GSO, the *Ifo Investorenrechnung* scales the 11 broader asset types to the respective GSO asset investments provided by the National Accounts (NA data provides gross fixed investments by all asset types as listed in Table A.3).

Distribution of (Sub-)Asset Investments to Industries

To distribute the GSO-adjusted investments by subassets to the industries, an Ifo investment flow matrix is used. This flow matrix contains a pre-determined user structure which relates the 100 subassets[6] to the 52 industries and therefore determines how much a certain industry uses of a particular subasset. More precisely, the user structure defines cells with 0 percentages, i.e. industries which do not use any of the subassets, and those with non-zero percentages. Sources for the determination of the percentages are *Ifo Investment Survey* questions, implicit industry specific information of a subasset category (e.g. the only user of food and packaging machines is the food industry), and explicit information of industry related associations (e.g. AGEEM, AGMEM). If none of the above sources is available, auxiliary indicators such as the size of an industry are used. This step results in a 52x100 investment matrix.

To eventually obtain a sectoral-subasset-investment matrix that is consistent with the GSO, GSO total investments by industries and GSO aggregate investment data by asset type serve as controls in each dimension of the matrix (sources listed in Table A.3). To assure that the column sums and row sums match the GSO controls, an iterative algorithm, the RAS-procedure, is applied. The goal of this procedure is to leave the original user structures as unchanged as possible and at the same time to erase any discrepancies to the GSO controls. Finally, after aggregation across subassets and including sectoral investments for the 12th asset Structures and Buildings as provided by the GSO, a 52x12 sectoral-asset-investment matrix is obtained. This sectoral-asset-investment matrix is available in current prices and in 2000 prices.[7]

[6] The user structure of the investment flow matrix was updated in the mid-1990s and then extended to incorporate 100 subasset types in 2002 due to the change of subasset classes in Automobiles. Prior to 2002, 88 subassets were implemented.

[7] The *Ifo Investorenrechnung* additionally collects leasing data from the *Ifo Investment Survey Leasing*, which enables conversions from the ownership to the economic usage concept.

Table A.1
Ifo Investorenrechnung Asset and Subasset Categories

Seq. Nr.	Asset Categories according to NA	Subdivision of Assets into Subassets
	Metal Products	
1		Metal Products
	Machinery	
2		Agricultural Machinery, Agricultural Tractors
3		Mining Machinery, Apparatus Engineering, Smelting, Roller Mill and Foundry Machinery, Industrial Furnace (incl. Electrical), Wood Working Machinery
4		Rubber and Plastic Machines
5		Machine Tools
6		Precision Tool
7		Testing Machines
8		Welding Equipment (without Electrical)
9		Printing and Paper Machines
10		Machinery for Footwear and Leather
11		Textile Machines
12		Apparel Machines
13		Food and Packaging Machines
14		Construction, Construction Material Machines
15		Conveyor Technique
16		Compressed-Air and Vacuum Engineering
17		Weighing Machines
18		Commodities and Services Machines
19		Laundry and Dry-Cleaning Machines
20		Robotics and Automation
21		Electrical Tools
22		Electrical Welding Equipment
23		Electrical Heating Generators
24		Other Machinery Manufactures
25		*IS Leasing* Machinery
	Computers and Office Equipment	
26		Computers and Office Equipment
27		*IS Leasing* Computers and Office Equipment
	Electrical Generation and Distribution	
28		Electrical Generation
29		Electrical Distribution
30		Plating
31		Signal and Security Installations
32		Lamps
33		*IS Leasing* Electrical Generation and Distribution
	Communication Equipment	
34		Communication Equipment for Communications (Industry 37)
35		Communication Equipment all Industries
36		*IS Leasing* Communication Equipment
	Instruments, Optics and Watches	
37		Watches
38		Electronic Measurement and Testing Technology
39		Kilowatt-Hour Meter
40		Material Testing and Measurement Devices, X-Ray Equipment (non Instruments)
41		Control Units
42		Electronic Instruments
43		Laser
44		Planning and Installation of Process Control Units
45		*IS Leasing* Instruments, Optics and Watches
	Furniture, Music and Sport Equipment	
46		Furniture, Music and Sports Equipment
	Other Machines and Equipment	
47		Other Machines and Equipment
48		*IS Leasing* Other Machines and Equipment

Seq. Nr.	Asset Categories according to NA	Subdivision of Assets into Subassets
	Automobiles	
49		Agriculture, Forestry
50		Fishing
51		Energy Mining and Quarrying
52		Mining and Quarrying, ex. Energy
53		Food and Tobacco
54		Textiles and Apparel
55		Leather
56		Wood Products
57		Paper, Pulp, Publishing, Printing
58		Petroleum
59		Chemicals
60		Rubber, Plastic
61		Non-Metallic Mineral Products
62		Basic Metals, Fabricated Metal Products
63		Machinery
64		Office Machinery and Computers, Electrical Apparatus n.e.c
65		Motor Vehicles and Other Transportation Equipment
66		Furniture and Manufacturing n.e.c., Recycling
67		Electricity, Gas
68		Water Supply
69		Construction
70		Sale and Repair of Motor Vehicles
71		Wholesale Trade
72		Retail Trade
73		Hotels and Restaurants
74		Land Transport
75		Water Transport
76		Air Transport
77		Auxiliaries Transport Activities
78		Communications
79		Financial Intermediation and Insurance
80		Real Estate
81		Rental Services (Short-Term Renting Motor Vehicles)
82		*IS Leasing* Automobiles
83		Public Administration, Defense, Social Security
84		Education
85		Health and Social Work
86		Sewage and Refuse Disposal
87		Organizations, n.e.c.
88		Recreational, Cultural, Sports Activities
89		Other Services
	Other Vehicles	
90		Railed Vehicles Land Transport (Industry 33)
91		Water Vehicles Water Transport (Industry 34)
92		Air Vehicles Air Transport (Industry 35)
93		Railed Vehicles Railroad Stations (Industry 36)
94		Water Vehicles Harbors (Industry 36)
95		Railed Vehicles remaining Industries
96		Water Vehicles remaining Industries
97		Air Vehicles remaining Industries
98		*IS Leasing* Other Vehicles
	Intangible Assets	
99		Intangible Assets
100		*IS Leasing* Intangible Assets

Source: *Ifo Investorenrechnung*

Table A.2
***Ifo Investorenrechnung* Investment Data Sources by (Sub-)Assets**

Seq. Nr.	Asset Categories	Sources
1	Metal Products (1)	National Accounts (NA), GSO: Calculation of gross domestic product, detailed annual accounts, Journal 18, Series 1.4, 3.3.7 Gross fixed investments by assets
2	Machinery (2-24)	Association of German Machinery and Equipment Manufacturing (AGMEM): Production, export and import figures of machinery products according to AGMEM categories, Yearbooks
3	Computers and Office Equipment (26)	National Accounts (NA), GSO: Calculation of gross domestic product, detailed annual accounts, Journal 18, Series 1.4, 3.3.7 Gross fixed investments by assets
4	Electrical Generation and Distribution (28-32)	Association of German Electrical and Electronic Manufactures (AGEEM): Production, export and import figures of electrical investment products, ELVIRA Database
5	Communication Equipment (34-35)	Association of German Electrical and Electronic Manufactures (AGEEM): Production, export and import figures of electrical investment products, ELVIRA Database
6	Instruments, Optics and Watches (37-44)	Association of German Electrical and Electronic Manufactures (AGEEM): Production, export and import figures of electrical investment products, ELVIRA Database
7	Furniture, Music and Sports Equipment (46)	National Accounts (NA), GSO: Calculation of gross domestic product, detailed annual accounts, Journal 18, Series 1.4, 3.3.7 Gross fixed investments by assets
8	Other Machines and Equipment (47)	National Accounts (NA), GSO: Calculation of gross domestic product, detailed annual accounts, Journal 18, Series 1.4, 3.3.7 Gross fixed investments by assets
9	Automobiles (49-89, excl. 82)	Federal Office of Automobiles (FOA): Numbers of new car registrations and trailers by groups of users and by car/ assembly types (for trucks and trailers), Monthly Reports, KBA-file by detailed groups of users (liable to pay costs)
		Association of German Automobile Manufactures (AGAM): Production figures of the German automobile industry, import and export figures of automobiles by foreign trade product numbers, official foreign trade statistics (specialized trade), Annual Reports
10	Other Vehicles (90-97)	German Institute for Economic Research (GIER): Gross fixed investments in vehicles, railed vehicles, water transport, public transport, truck transport, airlines and airports, Traffic in Numbers (liable to pay costs)
11	Intangible Assets (99)	National Accounts (NA), GSO: Calculation of gross domestic product, detailed annual accounts, Journal 18, Series 1.4, 3.3.7 Gross fixed investments by assets

Note: Data for the subassets *IS Leasing* is provided by the *Ifo Investment Survey Leasing*.

Table A.3
Investment Data Sources by Assets and Industries

Seq. Nr.	Asset Categories	Sources
1	Metal Products	National Accounts (NA), GSO: Calculation of gross domestic product, detailed annual accounts, Journal 18, Series 1.4, 3.3.7 Gross fixed investments by assets
2	Machinery	
3	Computers and Office Equipment	
4	Electrical Generation and Distribution	
5	Communication Equipment	
6	Instruments, Optics and Watches	
7	Furniture, Music and Sports Equipment	
8	Other Machines and Equipment	
9	Automobiles	
10	Other Vehicles	
11	Intangible Assets	
12	Structures and Buildings	
	Industries	
1-52	All industries.	National Accounts (NA), GSO: Calculation of gross domestic product, detailed annual accounts, Journal 18, Series 1.4, Gross fixed investments by industries, 3.2.8.1/ 3.2.9.1 New Assets 3.2.8.2/ 3.2.9.2 New Equipment and Other Assets 3.2.8.3/ 3.2.9.3 New Structures and Buildings

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