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## Evidence from Comparison of Growth Effects in German and US Manufacturing Sectors

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# ICT Intermediates, Growth and Productivity Spillovers
## Evidence from Comparison of Growth Effects in German and US Manufacturing Sectors*

Abstract

Recent pre-crisis growth accounting exercises attribute strong productivity growth to increased investments in information and communication technologies (ICT), especially during the mid-1990s. EU-wide stylized facts about a growing US–EU productivity gap are confirmed for Germany, particularly showing no substantially economy-wide effects from ICT for German sectors. Tracing the effect from ICT during the period 1991–2005, this study takes a different view by expanding the concept of value added to gross output, additionally including different types of intermediate inputs. The findings suggest that imported intermediate inputs played a more dominating role in Germany than in the US, particularly imported non-ICT and ICT materials, although domestically-produced ICT materials were important as well. In the US, main driving forces were domestically-produced non-ICT services and ICT materials, even though imported ICT materials were on the upraise post 1995. Moreover, there were decisive differences is countries' TFP growth rates with about twice the size in the US. According to robust econometric analysis there have been strong spillover effects from increasing domestically-produced ICT materials in German TFP growth, while for the US TFP growth originated from increasing imported ICT materials. It will be argued that these different productivity effects stem from different functions of ICT in the production process. However, TFP growth differentials between Germany and the US during 1991 to 2000 are explained to a great extent by strong US TFP growth in the Electrical & Electronic Machinery sector.

JEL Classification: C23, C43, L16, L23, L60, O33, O47.
Keywords: Industry productivity growth, information and communication technology, intermediate inputs, growth accounting, technology spillovers.

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## 1. Introduction

The analysis of industry-level productivity and output has a long tradition of implementing two different approaches of output measures. One of the approaches employs industry gross output, which is defined as the value of industry production (e.g. fabrication of machines, cars or semiconductors). Therefore primary inputs, like capital and labor, plus intermediate inputs purchased from other industries are used. An alternative approach employs industry value added, i.e. focusing on the contribution of primary inputs solely, which is obtained by calculating the difference between gross-output and the used up intermediate inputs in the production process. Regarding intermediate inputs, those are usually separated into energy, materials, and services.

The emergence of the New Economy made clear the importance of information and communication technology (ICT) equipment in generating output and increasing productivity growth (Bosworth and Triplett, 2004; Jorgenson, 2001; Jorgenson et al., 2005; Oliner and Sichel, 2002; Stiroh, 2002). However, most of the recent studies of the aggregate economy or studies that merely focus on value added as an output measure, do not explicitly account for the flow of intermediate inputs in ICT. Neither do they explicitly determine spillover effect from ICT intermediate inputs on sectoral productivity growth. Hence, by using a gross-output measure instead of value added, all growth effects from ICT and Non-ICT capital, labor, as well from ICT and Non-ICT intermediates inputs can be examined. This separation enables the researcher to trace the effects from information technology, like computers, telecommunication, and software, in sectors that either use ICT as capital input (i.e. firms that invest in new computer equipment) or as an intermediate input (i.e. firms that buy and incorporate semiconductors into their products).

One of the main contributions of this study is in applying the described gross-output concept to extend our knowledge about productivity effects from ICT, which so far received a lot of attention being classified as investments, while ICT as intermediate input has received relatively little attention. This may be of interest since ICT goods are primarily produced in the Electronic Components and Communications industry, but are purchased by many other industries for the use as intermediate inputs, e.g. in automobiles and machine tools. To distinguishing between ICT as a capital input and as an intermediate input necessitates the use of a complete model of industry gross output and inter-industry flows that provide an explicit role for intermediate inputs. The model implemented therefore will follow Jorgenson et al. (2005). Stiroh (2002) outlines that by concept firms and industries actually produce gross output from some combination of primary and intermediate inputs. This should be reflected in the production model. Value added, on the other hand, is an artificial construct that reflects only primary inputs and therefore does not correspond to a well-defined output concept at the industry level. Moreover, only under specific assumptions about the separability of primary inputs from intermediate inputs does a value-added production function exist and provide a valid description of the underlying production technology. Other former studies that accounted for intermediate input data to estimate industry productivity are Hulten (1978), Jorgenson, Gollop, and Fraumeni (1987), Gullickson and Harper (1987), Bosworth and Triplett (2004), and Bartelsman and Beaulieu (2004).

Besides studies on aggregate industry data, recent papers on development economics investigate the impact of imported intermediate inputs on firm-level productivity. Van Biesebroeck (2003), for example, does not find any supporting evidence that Brazilian firm productivity increased by importing more advanced intermediate inputs. On contrary, other studies like Amiti and Konings (2007) and Kasahara and Rodrigue (2008) suggest that better access to foreign inputs has increased firm productivity in countries like Indonesia and Chile, respectively. In general, in the growth literature productivity-enhancing effects from imported intermediate inputs are identified via two channels: increased variety and/or quality in inputs. Empirical evidence for the former channel has been provided by Goldberg at al. (2009), where combining foreign and domestic input varieties increased product scope of Indian firms. The second channel has been extensively discussed in terms of quality-ladder models postulated by Grossman and Helpman (1991) and Aghion and Howitt (1992). However, this study will be more in light of the latter as it focuses on different types of imported and domestically-produced intermediates embedding different levels of technologies (i.e. ICT and non-ICT), and the functionality of these inputs in the production process. In particular, embedded technology has been determined an important driving force of TFP differences across countries (Caselli and Wilson, 2004).

To analyzes the effects from intermediate inputs on gross-output growth differentiated by different intermediate types, we focus on the manufacturing sector of two industrialized countries, Germany and United States. Therefore we use 2-digit NACE industry-level data as provided by the *Ifo Industry Growth Accounting Database* (IIGAD) for Germany and the *EU KLEMS Growth and Productivity Accounts* (EU KLEMS) for the US.[1] The data employed covers the period from 1991 to 2005, including the emergence phase of the New Economy and its apex in 2000.

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[1] See Table A1 in the Appendix for a detailed list of industries.

The empirical investigation reveals that according to Jorgenson (1991) comparing the contribution of intermediate input with other sources of output growth, the former is by far the most significant source of gross-output growth. However, growth accounting analysis shows that the growth contribution from intermediates compared to value-added is much more important in case of Germany than in the US. US output growth us much more determined by increases in value added. Detailed analysis of intermediate input contributions shows that imported intermediates play a more dominating role in Germany than in the US. Thereby it is particularly the imported non-ICT and ICT materials that constitute the highest shares, although domestically-produced ICT materials in Germany are similarly high as imported ICT materials with both showing a persistent share. In the US it is the domestically-produced non-ICT services and domestically-produced ICT materials, which exhibit the highest growth contributions, even though imported ICT materials are on the upraise post 1995.

Turning to value-added growth as the second source of gross-output growth besides growth in intermediates, the growth accounting exercises show a strong drag on German value-added growth from declining growth in labor services. In the US, there are significant growth contributions from capital services, which are negligible in case of Germany. But the most decisive difference is countries' TFP growth, which is about twice the size in the US compared to Germany, especially post 1995. The econometric analysis of spillover effects on sectoral TFP growth suggests that there have been strong productivity effects from increasing domestically-produced ICT materials in Germany as well as from decreasing labor services. The latter is not found for the US as soon as fixed effects are introduced. For the US, the regression results suggest a strong productivity effect from increasing imported ICT-materials, but which is only half the size of Germany's positive productivity effect from domestically-produced ICT materials. As will be argued, the productivity effects from different ICT intermediate inputs are assumed to stem from different functional of ICT in the production process. Moreover, the TFP regression for the US show strong average productivity growth for the Electrical & Electronic Machinery sector, which to a great extent explains TFP growth differentials between Germany and the US during 1991 to 2000.

The paper is organized as follows: Section 2 explains the methodology of growth accounting for the case of utilizing the gross-output concept and incorporating intermediate inputs into production function. Section 3 describes the employed sectoral growth-accounting data for German and US manufacturing sectors. Section 4 provides the results for the gross-output growth accounting exercises separated by different types of intermediate inputs and sources of value-added growth. Section 5 tests whether there are significant spillover effects from primary or intermediate inputs on sectoral TFP growth, especially from ICT, for German and US manufacturing sectors, respectively. Section 6 concludes.

## 2. Growth Accounting Methodology

The methodology to measure sectoral output, intermediates, and value added was initiated by Jorgenson et al. (1987) and extended by Jorgenson (1991). Our specific approach to disentangle the various contributions to countries' gross output (GO) growth as decomposed into growth contributions from primary inputs and intermediate inputs follows Jorgenson et al. (2005). Hence, industry-level gross output growth can be decomposed into contributions from primary factor inputs (capital and labor), intermediate inputs and total factor productivity (TFP) growth according to

$$\Delta \ln Y_i = \bar{v}_{K,i}^{ICT} \Delta \ln K_i^{ICT} + \bar{v}_{K,i}^{NICT} \Delta \ln K_i^{NICT} + \bar{v}_{L,i} \Delta \ln L_i + \bar{v}_{X,i} \Delta \ln X_i + \Delta \ln TFP_i \ , \qquad (1)$$

where $Y_i$ is gross output of industry i, $K_i$ are capital services (separated by ICT and Non-ICT capital), $L_i$ represents labor services, and $X_i$ indicate as set of intermediate inputs used up during the production process. Because of implementation of a Tornqvist index the $\bar{v}$ 's are two-period average nominal input and intermediate shares in total gross output. Capital and labor services are defined as

$$\Delta \ln K_i^{ICT} = \sum_j \bar{\varpi}_{j,i}^{ICT} \Delta \ln K_{j,i}^{ICT} \ , \qquad (2)$$

$$\Delta \ln K_i^{NICT} = \sum_j \bar{\varpi}_{j,i}^{NICT} \Delta \ln K_{j,i}^{NICT} \ , \qquad (3)$$

$$\Delta \ln L_i = \sum_l \bar{\varpi}_{l,i}^{H} \Delta \ln H_{l,i} \ , \qquad (4)$$

$$\Delta \ln X_i = \sum_k \bar{\varpi}_{k,i}^{X} \Delta \ln X_{k,i} \ , \qquad (5)$$

where $K_{j,i}^{ICT}$ and $K_{j,i}^{NICT}$ are ICT and Non-ICT capital services, and $H_{l,i}$ and $X_{k,i}$ hours worked of capital type j, labor (skill) type l, and intermediate input type k in industry i, respectively. The weights $\bar{\varpi}_{j,i}^{ICT}$, $\bar{\varpi}_{j,i}^{NICT}$, $\bar{\varpi}_{l,i}^{H}$, and $\bar{\varpi}_{k,i}^{X}$ correspond to the two-period average compensation shares of ICT capital services of type j, non-ICT capital services of type j, labor services of type l, and intermediate input type k in total ICT capital services, non-ICT capital services, labor services, and intermediate input compensation of industry i, respectively. TFP is calculated as a residual capturing all those factors not explicitly accounted for in equation (1). In case of the neoclassical assumptions being fulfilled, it may be interpreted as disembodied (i.e. not in input factors embedded) technological progress.

Defining aggregate gross output growth as the weighted average of industry gross output growth, $\Delta \ln Y \equiv \sum_i \overline{w}_i \Delta \ln Y_i$ (where $\overline{w}_i$ is the average share of industry gross output in aggregate economy-wide gross output) and combining this expression with equation (1), we obtain

$$\Delta \ln Y = \sum_i \overline{w}_i \left( \overline{v}_{K,i}^{ICT} \Delta \ln K_i^{ICT} + \overline{v}_{K,i}^{NICT} \Delta \ln K_i^{NICT} + \overline{v}_{L,i} \Delta \ln L_i + \overline{v}_{X,i} \Delta \ln X_i + \Delta \ln TFP_i \right). \quad (6)$$

Because of our interest in the industry contributions to GO growth from different intermediate input types we further disaggregate the contributions from total intermediates into growth of ICT and Non-ICT materials, energy, and ICT and Non-ICT services separated by imported and domestically-produced: $\Delta \ln X_{Ii}^{ICTM}$, $\Delta \ln X_{Ii}^{NICTM}$, $\Delta \ln X_{Ii}^{ENE}$, $\Delta \ln x_{Ii}^{ICTS}$, $\Delta \ln x_{Ii}^{NICTS}$ (for imported intermediate inputs), $\Delta \ln X_{Di}^{ICTM}$, $\Delta \ln X_{Di}^{NICTM}$, $\Delta \ln X_{Di}^{ENE}$, $\Delta \ln X_{Di}^{ICTS}$, $\Delta \ln X_{Di}^{NICTS}$ (for domestically-produced intermediate inputs). This renders equation (6) into

$$\Delta \ln Y = \sum_i \overline{w}_i \begin{pmatrix} \overline{v}_{K,i}^{ICT} \Delta \ln K_i^{ICT} + \overline{v}_{K,i}^{NICT} \Delta \ln K_i^{NICT} + \overline{v}_{L,i} \Delta \ln L_i \\ + \overline{v}_{X_I,i}^{ICTM} \Delta \ln X_{Ii}^{ICTM} + \overline{v}_{X_I,i}^{NICTM} \Delta \ln X_{Ii}^{NICTM} + \overline{v}_{X_I,i}^{ENE} \Delta \ln X_{Ii}^{ENE} + \overline{v}_{X_I,i}^{ICTS} \Delta \ln x_{Ii}^{ICTS} + \overline{v}_{X_I,i}^{NICTS} \Delta \ln x_{Ii}^{NICTS} \\ + \overline{v}_{X_I,i}^{ICTM} \Delta \ln X_{Di}^{ICTM} + \overline{v}_{X_I,i}^{NICTM} \Delta \ln X_{Di}^{NICTM} + \overline{v}_{X_I,i}^{ENE} \Delta \ln X_{Di}^{ENE} + \overline{v}_{X_I,i}^{ICTS} \Delta \ln X_{Di}^{ICTS} + \overline{v}_{X_I,i}^{NICTS} \Delta \ln X_{Di}^{NICTS} \\ + \Delta \ln TFP_i \end{pmatrix} \quad (7)$$

with $\overline{v}_{X,i}$ resembling the two-period average nominal intermediate shares for imported and domestically-produced ICT and non-ICT materials, energy, and ICT and non-ICT services in total gross output. The gross-output growth decomposition in (7) has the advantage that sectoral contributions from inputs, intermediates, and TFP to gross-output growth from any industry subset simply equal the (weighted) sum of sectoral contributions from all industries in the subset.

## 3. Data

In this paper we focus on the effect of German and US intermediates, particularly in information and communication technology (ICT), separated by imported and domestic production. To extend sectoral Ifo industry accounts to the gross-output concept, we introduce sectoral intermediates for Germany and the US as provided by the *EU KLEMS Growth and Productivity Accounts* (Timmer et al., 2007a, b), henceforth EU KLEMS. Because of lacking detailed information on imported and domestically-produced ICT intermediates on German and US industry level, we infer ICT intermediates as being equal to the intermediates produced and supplied to the economy by ICT-producing sectors. Therefore we adopt the German Federal Statistical Office definition of ICT production including the five sectors provided (DeStatis, 2006): Office Machinery and Computers (NACE 30); Radio, TV and Communication Equipment (NACE 32); Instruments (NACE 33); Communication Services (NACE 64); and Computer and Related Services (NACE 72). To determine intermediate input flows by sectors we apply symmetric industry-by-industry input-output tables provided by the OECD (Yamano and Ahmad, 2006), which separate intermediates by imported and domestically-produced. In particular, we employ industry shares of intermediates in total intermediates supplied by the ICT-producing sectors. This is implemented for all types of intermediates, i.e. ICT materials and ICT services, energy, and non-ICT materials and non-ICT services.

Since the OECD industry-by-industry input-output tables are only published for 1995, 2000 and 2005, we need to linearly interpolate the input-output coefficients for the time periods in-between, i.e. for 1996–1999 and 2001–2004. Although the coefficients do not change dramatically over time for most of the sectors (see the aggregate sectoral shares in the Appendix), employing interpolations ensure a smoother transition in intermediate supplies over time instead of holding shares constant. For the pre–1995 period for which we do not have any information on shares which could be exploited for interpolation, we simply extrapolate the given 1995–2000 trends backwards until 1991. To be consistent with the total intermediate numbers provided by EU KLEMS the interpolated share of non-ICT services is ultimately determined as residual share in total intermediates.

For German intermediates inputs in real terms we apply an average of the ICT deflators provided by the *Ifo Industry Growth Accounting Database* (Roehn et al., 2007), henceforth IIGAD, which account for rapid changes in new technologies and which ensure consistency with the deflation of ICT investments as used in the Ifo database. Those deflators are based on industry-specific Ifo investment data for office equipment, communication, and software adjusted to match BEA IT deflators. In case of the US, average BEA ICT deflators as provided by EU KLEMS are employed. Those are average deflators for the computer, communication, and software. Imported and domestically-produced non-ICT material and services, as well as energy inputs are deflated by the intermediate deflators as provided by EU KLEMS. Imported and domestically-produced intermediates are assumed to have the same deflators.

The standard primary input as capital and labor services, as well as hours worked, value added and gross output are provided by the IIGAD and EU KLEMS for Germany and the US, respectively. Since the IIGAD comprises a more disaggregate level of manufacturing sectors regarding its investment series and capital services compared to EU KLEMS, we aggregate sectors to harmonize databases to the same industry aggregation level.

# 4. Growth Accounting Results: Output, Value Added and Intermediate Inputs

## 4.1 Decomposition of Gross-Output Growth

Beginning with a juxtaposition of indexed gross output, value added and imported and domestically produced intermediates for German and US manufacturing sectors shows similar developments regarding the growing importance of imported intermediates, but differences in the relation between gross output and value added (Figure 1a, b). Apparently real imported intermediate input increased by 70 for Germany from 1995 to 2005, and even 235 percent for the US during the same period. These findings correspond to Sinn (2005) for Germany and underline the growing importance of imported intermediates for US as mentioned by Yuskavage at al. (2008).

A main difference apparently is in the different developments of gross output and value added of both countries. While in case of Germany, gross output increased stronger than value added since 1997, whereas the gap between gross output to value added remained stable throughout recent periods, in the US value added increased stronger than gross output most of the time. The particular development in Germany of diverging gross-output and value-added trends has been analyzed by Sinn (2005), who coined the phrase of Germany representing a “bazaar economy” in which intermediate inputs are offshored to low wage countries, but patched together in Germany, and ultimately sold under the brand of being “Made in Germany”. This offshoring development is expected to eventually erode Germany’s manufacturing prowess. For the US, the picture seems to be somewhat different, especially as the development of value added and gross output is not characterized by such a strong divergence, and value added growth still performs better than growth in gross output.

Regarding average aggregate sectoral gross-output growth for Germany and the US, Figure 2 shows substantial differences between both countries’ trend growth in gross output. Germany experienced a strong decline during the period 1991–1995, in which gross output growth declined on average by -0.48 percent. However, during the economic recovery in 1996–2000, German gross-output growth increased by 3.52 percent and even managed an increase of 1.33 percent post 2000. In the US, gross output exhibits strong growth during 1991–1995 and 1996–2000 with an average growth rate ranging between 4.79 and 5.23 percent. The economic contraction in the wake of the burst of the Dotcom bubble in 2001, gross output saw a massive slump during 2001–2005 by -0.37 percent.

### *Aggregate-Level Growth Accounting*

Dissecting gross-output growth into its *growth contributions* from value added (as it is calculated from growth contributions of capital, labor, and TFP) and intermediates, Figure 3 provides an overview of the importance of each of the two components in generating gross-output growth. Apparently, German gross-output growth is much more determined by growth in intermediates than in the US. The fraction of German value-added to intermediate input growth is comparably small in Germany. In the US, this ratio is much more balanced, although intermediates make up a larger fraction of US gross-output growth than value-added, too. During the period of the US recession in 2001–2005 growth contributions from intermediate inputs slumped and even generated a drag by -0.89 percent, while value-added growth still contributed by 0.53 percent.

### *Sectoral-Level Growth Accounting*

Analyzing the sectoral sources of gross-output growth, in this section we will provide a more detailed analysis of growth contributions from value-added and intermediate inputs by single manufacturing sectors. Figure 4a provides growth accounting exercises for period averages of 13 German manufacturing sectors that aggregate up to the growth accounting numbers of the previous chapter. Apparently, there are some specific manufacturing sectors that experienced strong growth in gross output, which are mainly the three sectors Machinery (Id10), Electrical & Electronic Machinery (Id11), and Motor Vehicles & Transport (Id12). These sectors demonstrate the tremendous growth contributions from intermediate inputs compared to growth contributions from value added. Interestingly all three sectors started with a negative growth in value added but steadily increased over time. However, growth contributions from intermediate inputs peaked for all three sectors during 1996–2000, exhibiting the strongest increase in Motor Vehicles & Transport.

Compared to Germany, US sectors with strong gross-output growth are Electrical & Electronic Machinery (Id11) and Motor Vehicles & Transport (Id12), but also Basic & Fabricated Metals (Id9) and Machinery (Id10) show relatively strong gross-output growth (Figure 4b). Interestingly, regarding the composition of gross-output growth, the stronger growth contribution of value added throughout US manufacturing sectors becomes apparent. The aggregate picture is largely confirmed on the sectoral level, where intermediate inputs constitute a much smaller fraction of industry gross-output growth across sectors, contrary to German manufacturing sectors.

## 4.2 Different Types of Intermediates and Sources of Value-Added Growth

In this section we will further investigate different types of intermediates that generate aggregate intermediates growth contributions to gross-output growth as well as different sources of value-added growth. We start by examining the contributions on an aggregate level before we delve into sectoral analysis.

### *Aggregate-Level Growth Accounting*

In Figure 5 we start with a disaggregation of intermediates inputs by imported and domestically-produced intermediates. German intermediates reveal a strong dependence of imported intermediates during 1991–1995, where imported intermediates exhibit a contribution to gross-output growth of 0.81 percent. This dependence changes during 1996–2000. Domestically-produced intermediates regained strength and even outpaced growth contributions of imported intermediates. Nevertheless, imported intermediates still play a significant role in generating German gross-output growth. Post 2000 both types of intermediate contributions slumped to around 0.50 percent. In the US, there is a significant difference in the origin of intermediate inputs with imported intermediates playing a much less important role. While domestically-produced intermediates generated growth contributions of about 2.3 and 1.9 percent during 1991–1995 and 1996–2000, the contribution from imported intermediates was around 0.6 and 0.9 during the same periods, respectively. During the recession in 2001 both intermediate types experienced massive growth reductions.

Besides intermediate inputs as source of gross-output growth and juxtaposing the sources of value-added growth illustrates once gain major differences for both countries. Figure 6 depicts labor services as a major source of German value-added growth, which steadily declined throughout the periods and thus exerted a drag on the growth contributions from value-added. The growth contribution from capital, be it ICT or non-ICT, is negligible small in Germany, while TFP growth makes up the strongest positive contribution. Comparing these findings to the US, labor services show very low contributions during 1991–2000 but slumped during the period after the 2001 recession. In contrast, investments in ICT and non-ICT make up for a much more substantial part of US manufacturing value-added growth. But most importantly, TFP growth generated enormous growth contributions that lay above those of German manufacturing sectors thought the entire periods. Particularly, while contributions of TFP growth steadily declined in Germany from 0.99 to 0.65 percent, US TFP growth increased significantly during 1995–2000 from 1.22 to 1.60 percent, staying high even post 2000 with 1.45 percent.

*Sectoral-Level Growth Accounting*

Decomposing German intermediate growth contributions by imported and domestically-produced on the sectoral level, suggests that imported intermediates played an important role particularly during 1996–2000 (Figure 7a). As shown in the figure, growth contributions from imported intermediates increased from 1991–1995 to 1996–2000, but did not stabilize at such high growth rates. In contrast, their contributions declined. In some crucial German manufacturing sectors, as Motor Vehicles & Transport, the contributions from domestically-produced intermediate outpaced those of imported intermediates. Regarding growth contributions by intermediate type for US manufacturing sectors is similar to Germany to some extent as imported intermediates contributed stronger during 1991–2000 (Figure 7b), while domestically-produced intermediates also played an important role throughout this period. The aggregate picture of a slump in both intermediate types during 2001–2005 is again confirmed on across sectors.

Concerning dissected value-added growth by capital, labor, and TFP for German manufacturing sectors suggests that a lot of the decline in value-added growth was due to decreases in hours worked (Figure 7a). While investment contributions are relatively small, increasing TFP growth counters the declining in sectoral labor services. However, the steady declined in labor services is suggested to be heaviest during 1991–1995 with decreasing rates afterwards. TFP growth generated strong contributions in Electrical & Electronic Machinery, Basic & Fabricated Metals, and Chemicals & Chemical Products. For US manufacturing sectors the picture is different (Figure 7b). While declining labor services were less important across sectors, increases in TFP growth are found the fundamental driver of US manufacturing sectors' value-added growth. Some sector also managed to increase their value-added growth by significant growth in ICT and non-ICT investments. The latter was not observed in the German case.

## 4.3 Changes in the Structure of Intermediate Inputs

As we are interested in the change of the relative importance of different types of intermediate inputs in the production process and potential spillover effects on TFP growth resulting from these changes, we start with an investigation of shifts in the relative importance of imported versus domestically-produced intermediates. Therefore we calculate aggregate growth contributions of intermediates inputs to sum up to 100 percent. Figure 8 shows that during 1991–1995 imported intermediates inputs had a enormous influence on German gross-output growth, thereby entirely substituting imported for domestically-produced intermediates. But this picture changes post 1995, as domestically-produced intermediate regained strength and even outpaced the contributions of imported intermediates. Nevertheless, the importance of imported intermediates revived post 2000, but both input types stabilized at about similar fractions by post 2000. In the US, domestically-produced intermediate inputs generated strong influences throughout the period 1991–2000, with a magnitude of about two thirds of imported intermediates. However, domestically-produced intermediates significantly slumped post 2000.

In the next step we would like to know, which types of imported or domestically-produced intermediates contributed most to gross-output growth and how their importance changes over time. Therefore we split intermediates further into non-ICT materials and non-ICT-services (Figure 9) as well as ICT materials and ICT services (Figure 10). Figure 9 shows that the US generated most of intermediate-driven gross-output growth from domestically-produced non-ICT services and to some extent from imported non-ICT materials, while Germany on contrary experienced strong contributions from imported non-ICT materials but show a steadily growing importance of domestically-produced non-ICT materials.

In case of ICT intermediates Figure 10 illustrates that German manufacturing sectors exhibit similar shares in imported and domestically-produced ICT material. These shares are quite stable over time and hence do not indicate severe adjustments in purchasing ICT intermediate input during the New Economy. In the US the picture is different. Apparently the importance of domestically-produced ICT materials decreased in favor of increasingly imported ICT materials during 1996–2000. Post 2000 domestically-produced ICT materials – similar to domestically-produced non-ICT materials in Figure 9 – experienced a significant slump due to the 2001 recession.

# 5. Econometric Estimations of Spillover Effects on TFP Growth

## 5.1 Random- and Fixed-Effects Estimations

In the previous analysis we traced the effects of a) intermediate inputs by different types and b) primary inputs and TFP growth on aggregate gross-output growth. It was shown that imported intermediates played a much stronger role in Germany than in the US. Particularly, imported non-ICT and ICT materials generated strong contributions, although even domestically produced ICT materials contributed similar in size as their imported counterpart. In the US it was domestically-produced non-ICT services and ICT materials that generated the highest contributions, although during 1995–2000 imported ICT materials gained strength.

Regarding value-added growth, the US experienced substantially larger contributions to gross output than did Germany, while most of it was driven by stronger growth in TFP. Germany in addition experienced strong but diminishing declines in labor services, which dragged on German value-added and gross-output growth. In the subsequent analysis we trace the sources of differences in German and US manufacturing TFP growth. Therefore we identify spillover effects from primary and intermediates inputs on industry productivity growth by estimating TFP growth regressions. The regression specifications have the following general form:

$$\Delta \ln TFP_{i,t} = \alpha + \beta_1 \Delta \ln K^{ICT}_{i,t} + \beta_2 \Delta \ln K^{NICT}_{i,t} + \beta_3 \Delta \ln L_{i,t} + \beta_4 \Delta \ln X_{i,t} + \varepsilon_{i,t} \qquad (8)$$

$$\text{where } \varepsilon_{i,t} = u_i + \upsilon_{i,t}$$

with the corresponding variables notation as given in equation (1) and an error-term structure $\upsilon_{i,t}$ assumed to be i.i.d. and unobserved time-invariant industry heterogeneity $u_i$. Intermediate inputs (indicated by $X_{i,t}$) are further separated by type according to equation (7). To determine the spillover effects on sectoral productivity growth we employ two panel estimation techniques, random and fixed effects as well as several robustness checks. For the latter we additionally include sectors dummies for trade-intensive and high-tech sectors in the random-effects specifications and provide a comparison of fixed-effects and restricted fixed-effect regression, i.e. excluding capital and labor inputs from the specification. Moreover, econometric estimation techniques to account for cross-sectoral dependence in the disturbances are employed (see section 5.3)

As long as $u_i$ is uncorrelated with the explanatory variables the random-effects estimator provides unbiased results. Hence, estimating equation (8) by random effects assumes that the covariance between $u_i$ and the explanatory variables is zero. Since the latter assumption is seldom achieved in TFP growth regression, the fixed-effects estimator allows for a correlation unequal to zero. The reason for non-zero correlation may stem from industry-specific factors that enable sectors to be more productive than others throughout, and thus feed back into their decision on how to employ primary and intermediate inputs. Hence, spillover effects are no longer derived from the single employed input but due to industries' higher overall productivity.

To control for possible cluster effects among specific sectors' TFP growth, an industry taxonomy for trade-intensive and high-tech sectors is included in the regressions. Therefore trade intensity of sectors is determined by the nominal value of sectoral exports of goods and the quartiles of the sectoral export distribution. Sectors with the highest trade intensity are those whose value of exports is in the fourth quartile of the export distribution (TI-1) throughout the period from 1991–2005. Still trade intensive, but less than TI-2 are those sectors with a value of exports in the third quartile (TI-2). Sectors with medium trade intensity are those whose value of exports is below the median, but still above the 25th percentile (TI-3). Finally, low trade-intensive sectors have a value of exports lower than the 25th percentile (TI-4).[2] The trade-intensity classification is determined for both countries separately. However, countries' industry classifications by trade intensity provide the same results.

For the high-tech classification sectors are classified according to the OECD technology intensity definition (OECD, 2011). It comprises four groups of sectoral technology definitions: High-technology industries (HITE); Medium-high-technology industries (MHTE); Medium-low-technology industries (MLTE); Low-technology industries (LOTE). The high-tech classification is applied to both countries. A detailed list of trade-intensive and high-tech sectors is available in Table A3 in the Appendix.

According to Table 1a the input factors ICT and non-ICT capital deepening do not show any significant spillover effects on sectoral TFP growth. These findings hold for both countries and throughout all specifications, random (column RE-I to RE-IV) and fixed effects (column FE-I). On contrary, we find interesting spillovers on TFP growth regarding the effects of labor services. As shown in the table, there are robust findings on decreasing TFP growth when labor services are increased. This holds for all random effects specifications (column RE-I to RE-IV) and both countries. Decreasing labor services, which are mainly due to hours worked and less to quality effects, as latter are relatively constant over recent periods, help to raise profits and efficiency and thus positively affect residual value-added growth. The labor effects still hold for the fixed-effects estimations of German manufacturing sectors (column FE-I) but vanish for the US (column FE-I). This is interesting as apparently industry heterogeneity accounts for a significant fraction of the variation in US sectoral TFP growth, such that shedding labor is still estimated with a negative sign, but no longer appears to have statistical significance across all sectors.

Disaggregation of potential spillovers from different intermediate inputs, Table 1a reveals a clear pattern across specifications with regard to imported and domestically-produced ICT materials. For German manufacturing sectors, the random as well as the fixed-effects regression suggest that both imported and domestically-produced ICT materials generated positive TFP spillovers, while only the latter are estimated statistically significant. Even in

[2] To obtain trade intensity data provided by the OECD STAN Bilateral Trade Database is employed (OECD, 2008).

case of the restricted fixed-effects regression this effect remains significant (column FE-II). The significance of the spillover effect of domestically-produced ICT materials a) constitutes the capability of the German manufacturing sector to generate high-technology intermediate products and b) serves as an explanation for why ICT so far produced such weak results in productivity analysis for Germany. As standard growth accounting and productivity analysis usually focus on investments and capital stocks of ICT and their effect on value-added growth, these approaches are unable to detect ICT effects stemming from implementing ICT-embedded intermediates in the production process, as those are excluded from the value-added concept by definition. This seems to be particularly relevant for countries characterized by strong contributions of intermediates inputs, like Germany.

For the US the regressions show a clear picture that US manufacturing sectors strongly benefited from substituting domestically-produced for imported ICT materials. Positive effects from imported ICT materials are estimated highly statistically significant, while domestically-produced ICT material are estimated highly significant with a negative sign. This pattern is confirmed throughout all random effects specifications (column RE-I o RE-IV) and coincides with the rising importance of imported versus domestically-produced ICT materials detected in the previous growth accounting exercises. However, as soon as fixed effects are introduced in the regression the negatively estimated effect from domestically-produced ICT materials vanishes, but still is estimated with a negative sign (column FE-I and FE-II). These TFP spillover effects suggest that US manufacturing sectors – as opposed to German manufacturing sectors – managed to increase their productivity growth by importing instead of self-producing ICT materials.

Explaining these different results we start with an assumption of two different production structures regarding the German and the US manufacturing industry. We put forward that the reason for this is in the different capabilities of ICT components in the production of final goods. The US seemingly profited from importing cheap ICT components, which are subsequently embedded in new computers sold at high prices. We could call this the "modular system", as components are primarily implemented in to a new device, without any significant further adjustments and which are then eventually sold to the consumer after a well-conducted marketing process. This is where growth in revenues and according to the previous growth accounting exercises value-added growth comes from in the US, and what renders productivity spillovers from imported ICT materials highly significant.

In Germany, the case is different. While cheap ICT components might also be imported from abroad, German manufacturing is less in fabricating computers for the consumers and selling IT products after a well-conduced marketing but rather in producing sophisticated engineered, ICT-driven investment equipment, like machines. Hence, a comparable box system in which ICT is embedded into machinery equipment will not be sufficient in this production structure. Instead, adjusting ICT components during the fabrication of machinery equipment is highly customized to satisfy the downstream producing firm's needs and becomes an important source of generating value-added. This may serve as explanation why productivity spillovers from domestically-produced ICT materials are estimated statistically significant in Germany, while imported ICT materials are not. For example, Bosch, a global German supplier of technology and services in the areas of automotive and industrial and building technology, is more of the kind of a process-based innovator compared to US computer firms, like Dell, which resemble more of a highly developed marketing-oriented business concept. These different industry structures may also explain why especially TFP growth in the German Electrical & Electronic Machinery sector, which includes the Office Machinery and Computers industry, shows substantially lower increases than the US (see Table A2 in the Appendix).

Furthermore, substitution of imported for domestically-produced energy increased German manufacturing TFP growth in the random-effects estimation, while in the US none of these effects are statistically significant (column RE-I to RE-IV). In Germany, this effect remains valid even in the fixed-effects specification (column FE-I), but with a lower statistical significance. However, as soon as capital and labor is excluded from the regression, the spillover effects from imported energy turns statistically insignificant (column FE-II).

Further interesting insights in the determinants of sectoral TFP growth are provided by the estimated fixed effects as well as the estimated time dummies for both countries. According to Table 1b, which displays the industry fixed effects of the regression specification of Table 1a, column FE-I and FE-II, controlling for primary and intermediate inputs significantly decreases productivity growth of German manufacturing sectors on a broad industry basis (column FE-I). After exclusion of primary inputs industry heterogeneity turns statistically insignificant. This result suggests that conditioning industry TFP growth on the highly significant labor services variable already explains a lot of the variation in German manufacturing TFP growth. As soon as labor is excluded there is too much variation left in the error term that is not captured by the time-invariant industry fixed effects. For the US, independent of the regression specification the sectoral industry fixed effect for Electrical & Electronic Machinery reveals strong positive TFP growth, which is missing in in case of Germany.

Analyzing the time dummies suggests similar results for the two different fixed effects specification in case of German manufacturing sectors (Table 1c, column FE-I and FE-II). While the unrestricted specification (column FE-I) shows some relevant common time effects on TFP growth across manufacturing sectors, the restricted specification (column FE-II) renders all time effects statistically significant. Once again, labor services turns out to be a very important variable capturing a lot of the variation in German manufacturing TFP growth. For the US, neither the unrestricted nor the restricted model affects the statistical inference of the common time effects. The table shows that cyclical effects during 1996–1998 exerted a drag on US manufacturing sectors' TFP growth as well as the recession in 2001 due to the bursting of the Dotcom bubble.

## 5.2 Estimated Contributions of Spillover Effects and the Electrical & Electronic Machinery Sector to Manufacturing TFP Growth

### *Contributions of Spillover Effects*

As the previous econometric analysis has shown, there are different spillover effects from ICT materials on German and US manufacturing TFP growth. Since the regression results mainly estimate elasticities, but do not provide an assessment of the magnitude of the actual effect in the data, we further employ an analysis of the contribution of each of the significant variables. Therefore we calculate the averages of the variables in the population and determine the variables' effects at these averages. Since the inclusion of labor services was shown to be an influential factor in determining sectoral TFP growth in Germany, we focus on a comparison of the variables' magnitude on TFP growth using the unrestricted fixed-effects model of specification FE-I in Table 1a.

According to Figure 11 German manufacturing sectors reveal a substantial growth effect from labor services. As labor services exhibit a negative impact on TFP growth and there has been a strong decline in this variable throughout the period, the estimated contribution is positive. However, a much stronger contribution stems from the domestically-produced ICT materials, which is almost twice in magnitude as the contribution of the labor services effect. For the US, imported ICT materials show a significant TFP growth contribution but with a substantially lower magnitude as in case of domestically-produced ICT materials in Germany. However, according to this contribution analysis the strong US TFP growth contributions and the resulting high value-added growth cannot be sufficiently explained.

*Contributions of the Electrical & Electronic Machinery Sector*

To overcome the insufficient explanation of the strong TFP growth in US manufacturing sectors, we extend the analysis towards sectoral TFP growth contributions as depicted in Table A2 in the Appendix. Apparently, the TFP growth difference between German and US manufacturing sectors is largely determined by the immense contributions generated in the Electrical & Electronic Machinery sector, which includes the Office Machinery and Electronic Equipment industry. The growth contributions of this specific sector are about twice as high in the US and during 1996–2000 even more than threefold that of Germany's. If we exclude the Electrical & Electronic Machinery sector, the total economy US TFP growth, which is the aggregate of sectoral contributions, converges to aggregate German TFP growth; at least for the period from 1991–2000. But there is still an unexplained part in TFP growth differences during the post–2000 period, when manufacturing TFP growth in Germany and the US started to diverge, even after the Electrical & Electronic Machinery sectors are excluded.

## 5.3 Further Robustness Checks: Cross-Sectional TFP Growth Dependences

Instead of estimating regressions to be robust in terms of individual heterogeneity (as well as heteroscedasticity and intra-industry correlation), this section will provide further estimates for panel models with cross-sectional dependence. The reasoning for this is possible correlation of regression disturbances over time and between industries, which may produce misleading statistical inference. For validation of the previous estimates, we therefore adjust the standard errors of the estimated coefficients for possible dependence in the residuals by employing panel models with AR(1) disturbance. This may be relevant in determining the drivers of TFP growth, particularly as common macroeconomic factors possibly underlie sectoral growth generating processes. In the latter case, assuming that sectoral disturbances are independent across sectors would be inappropriate. Hence, the regression equation is assumed to have the following form:

$$\Delta \ln TFP_{i,t} = \alpha + \beta_1 \Delta \ln K_{i,t}^{ICT} + \beta_2 \Delta \ln K_{i,t}^{NICT} + \beta_3 \Delta \ln L_{i,t} + \beta_4 \Delta \ln X_{i,t} + \varepsilon_{i,t} \qquad (9)$$

$$\text{where } \varepsilon_{i,t} = u_i + \upsilon_{i,t} \text{ and } \upsilon_{i,t} = \rho\, \upsilon_{i,t-1} + z_{i,t}$$

with the parameter ρ resembling the estimated autocorrelation coefficient of the disturbances $\upsilon_{i,t}$ and $z_{i,t}$ being assumed to be i.i.d.

According to the estimation results in Table 2, the parameter ρ is close to zero for the random and the fixed-effects specification of German manufacturing sectors (column REAR-

I to FEAR-II). Hence, there is only negligible statistical evidence of cross-sectional dependence across German sectors. Give these results it is not surprising that statistical inference of spillover effects provide qualitatively similar results compared to the estimated German TFP effects in Table 1a. In particular, labor services still are determined a highly significant driver of German manufacturing TFP growth. The same is true for domestically-produced ICT materials, although statistical significance decreases in case of the restricted fixed-effects specification (column FEAR-II). A reason for this may be that exclusion of labor services, which is an important determinant of TFP growth across a wide range of German manufacturing sectors, increases the correlation between the unobserved heterogeneity and the explanatory variables, thereby reducing statistical efficiency of both time-invariant fixed effects as well as explanatory variables. An increase in negative correlation between unobserved heterogeneity and the explanatory variables to -0.27 is indicated by the regression results (column FEAR-II). Once again, the regression results confirm the importance of labor services and domestically-produced ICT materials to be included in German manufacturing TFP growth regressions over the period from 1991 to 2005.

In case of the US, cross-sectional dependence seems to be more important, as the estimated parameter $\rho$ is about 0.2 across the two different panel estimators and specifications (column REAR-I to FEAR-II). Interestingly, adjusting standard errors to account for cross-sectional dependence of sectoral TFP growth disturbances significantly increases statistical inference of spillover effects from imported ICT materials on US manufacturing TFP growth. These results hold independent of the employed panel estimator and specification. Exclusion of primary inputs does not shown any server changes in the statistical inference of imported ICT spillover effects, associated by a decrease in correlation between unobserved heterogeneity and the explanatory variables to 0.02 for the restricted specification (column FEAR-II). Hence, imported ICT materials are suggested to be an isolated growth factor that spurred sectoral TFP growth of US manufacturing sectors without showing any markedly interaction with any of the primary input factors. These regressions, which adjust for cross-sectional dependence in sectoral TFP growth disturbances, confirm imported ICT materials to be the main driver of US manufacturing TFP growth during the New Economy.

## 6. Summary and Conclusion

Recent growth accounting exercises attribute strong productivity growth to increased investments in information and communication technologies (ICT). Particularly, differing ICT intensities across countries provide a useful explanation for cross-country productivity growth differentials, especially with regard to the post–1995 productivity acceleration in the US and the widening of the US-EU productivity gap. In contrast to the US, the German economy is characterized by relatively low average ICT investment intensities and low productivity effects from ICT investments during the period from 1991–2005.

Trying to trace the effect from ICT during the period 1991–2005, this study takes a different view by expanding the usually used concept of value added to gross output, additionally including different types of intermediate inputs. Thereby the focus is on ICT intermediate inputs separated by origin, which is imported and domestically produced. Expanding the concept of value added to gross output provides us to investigate the effect from ICT on output and productivity growth beyond its direct channel of increasing investments. The decomposition not only allows for tracing the various sources of output growth, but further enables formally testing the productivity growth effect of ICT via the indirect channel of spillovers on TFP stemming from implementation of new technologies in the production process of final investment goods.

The findings of this study suggest that imported intermediate inputs played a more dominating role in Germany than in the US, particularly imported non-ICT and ICT materials, although domestically-produced ICT materials were important as well. In the US, main driving forces were domestically-produced non-ICT services and ICT materials, even though imported ICT materials were on the upraise post 1995. Moreover, there were decisive differences is countries' TFP growth rates with about twice the size in the US.

According to robust econometric analysis there have been strong spillover effects on TFP growth from increasing domestically-produced ICT materials in Germany, while for the US TFP growth originated from increasing imported ICT-materials. As argued in this study the productivity effects from different ICT intermediate inputs stem from different functions of ICT in the production process. While German manufacturing productivity growth is associated with highly customized ICT-driven investment equipment incorporating domestically adjusted ICT inputs, US manufacturing productivity growth suggests to depend on components, which are primarily implemented in to new devices without any significant further domestic adjustments and are produced more cost-efficiently by being imported from abroad (modular system). Furthermore, the distinctive treatment of ICT as an investment on the one hand and an intermediate inputs on the other, may serve as an explanation for why productivity effects in general and specifically in Germany are hard to detect using the concept of value added.

Besides these effects there are substantial TFP growth differentials between Germany and the US during 1991–2000 stemming to a great extent from strong US TFP growth in the Electrical & Electronic Machinery sector. However, there are still open questions, especially since post 2000 the differential in German-US manufacturing TFP growth is widened, despite controlling for the contribution of the Electrical & Electronic Machinery sector. What are the underlying sources of sectoral TFP growth difference post 2000? And much of it can be attributed to lagging ICT effects? Moreover, despite the US Electronic industry's ability to produce highly innovative IT equipment, manifested in ICT investments, why does a positive spillover effect from ICT not show up across manufacturing industries aggregate TFP growth? These are intriguing questions which could be usefully explored in further research.

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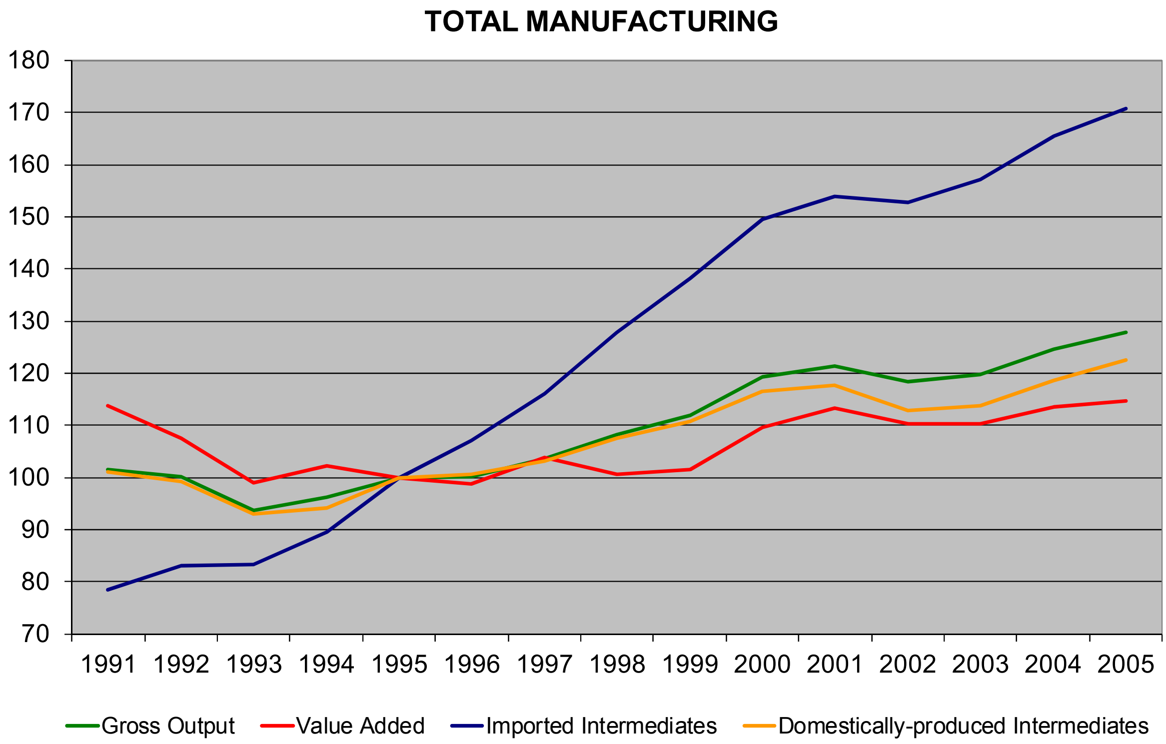
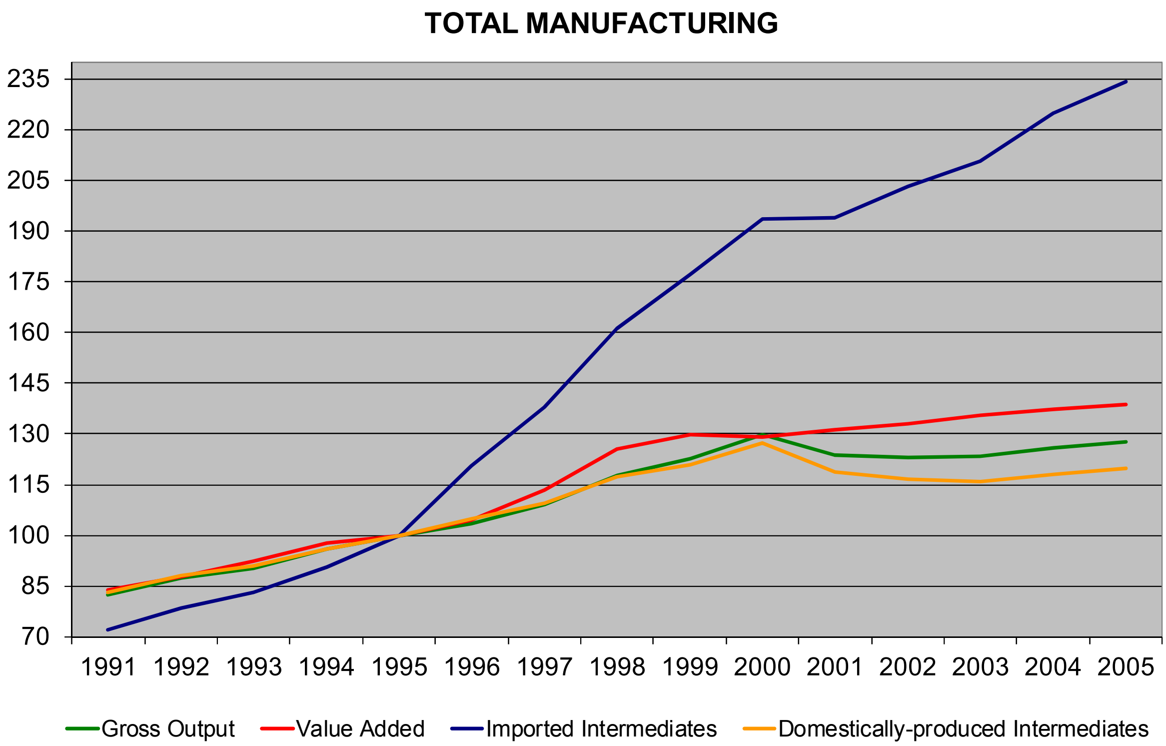
**Figure 1a:**
**Development of Key Statistics, Germany**



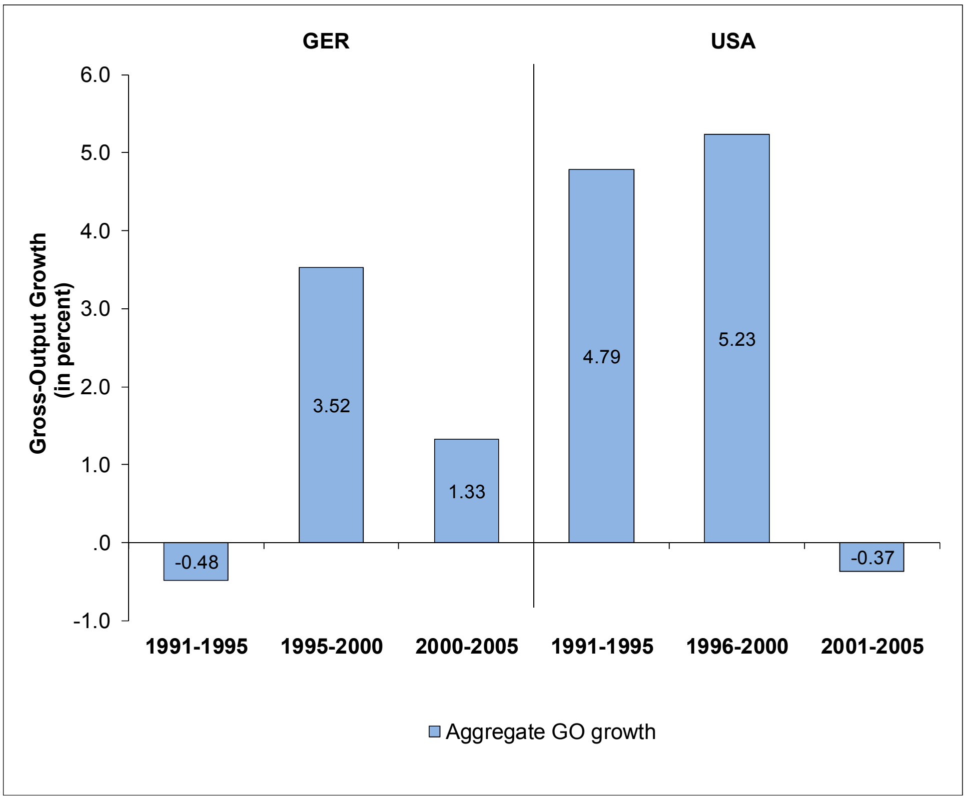

*Note:* Numbers are real volumes with 1995 = 100. *Sources:* IIGAD (2008), EU KLEMS (2009), OECD (2006).

**Figure 1b:**
**Development of Key Statistics, USA**



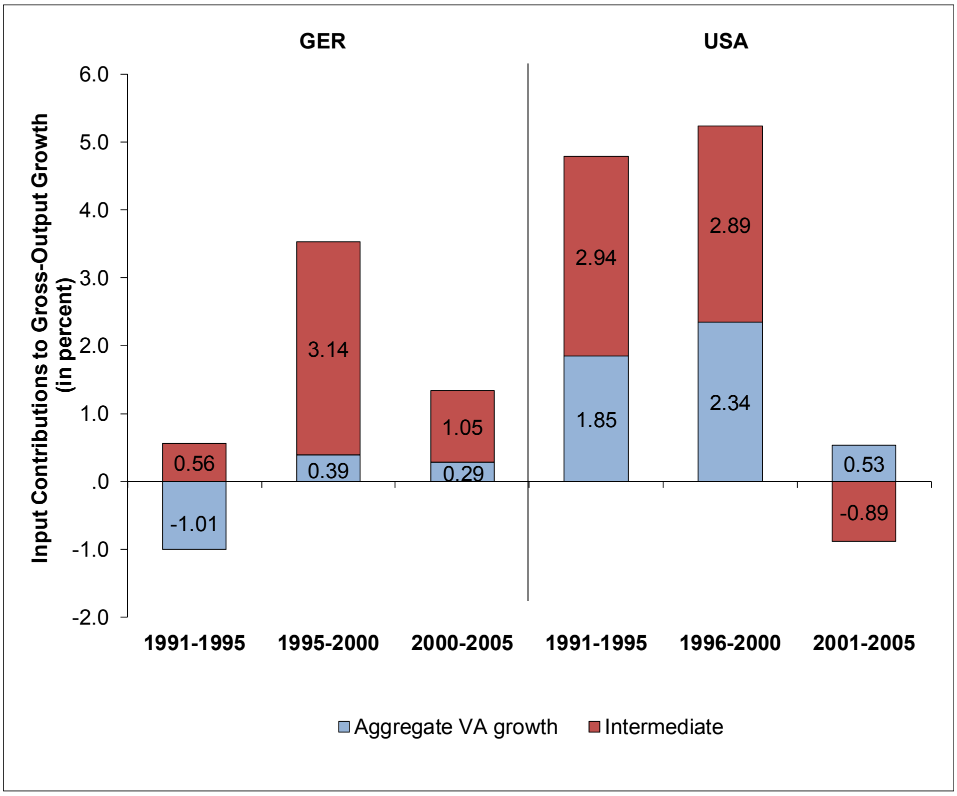

*Note:* Numbers are real volumes with 1995 = 100. *Sources:* EU KLEMS (2009), OECD (2006).

**Figure 2: Gross-Output Growth,**
**By Input Type, GER vs. USA**



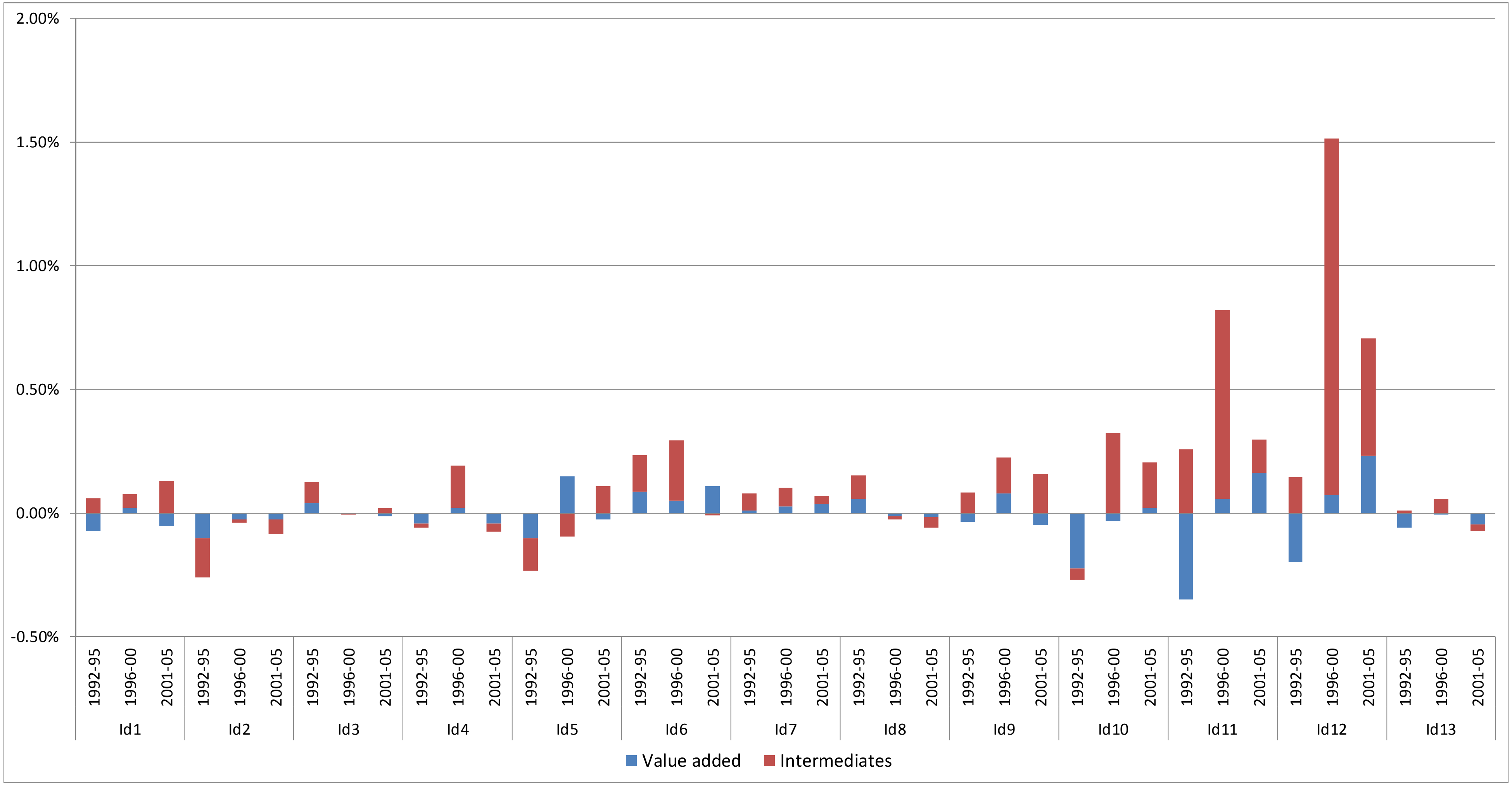

*Note:* Contributions are aggregate manufacturing sectoral averages over the three periods 1991–95, 1996–2000, and 2001–2005. *Sources:* IIGAD (2008), EU KLEMS (2009).

**Figure 3: Input Contributions to Gross-Output Growth,**
**By Value Added and Intermediates, GER vs. USA**



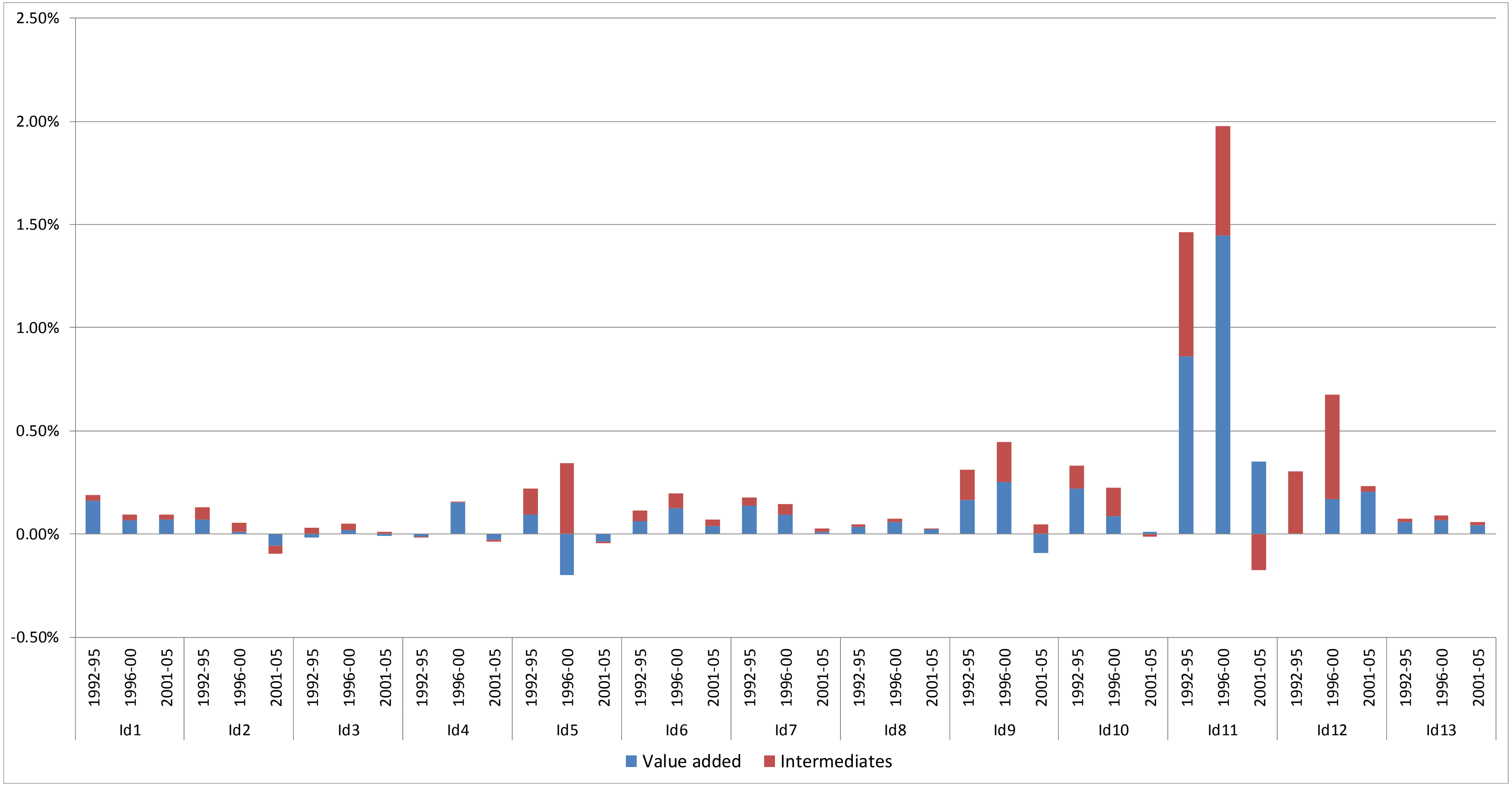

*Note:* Contributions are aggregate manufacturing sectoral averages over the three periods 1991–95, 1996–2000, and 2001–2005. *Sources:* EU KLEMS (2009).

**Figure 4a: Input Contributions to Gross-Output Growth,**
**By Value Added and Intermediates, GER Manufacturing Sectors**



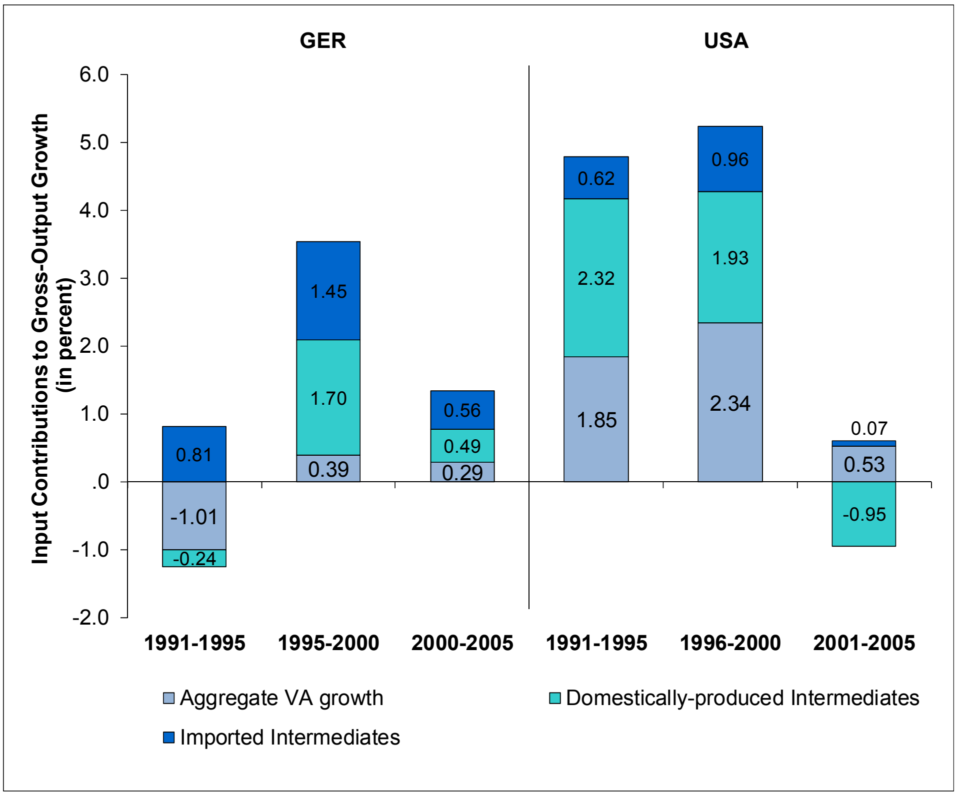

*Note:* Contributions are sectoral averages over the three periods 1991–95, 1996–2000, and 2001–2005. *Sources:* IIGAD (2008), EU KLEMS (2009).

**Figure 4b: Input Contributions to Gross-Output Growth,
By Value Added and Intermediates, US Manufacturing Sectors**



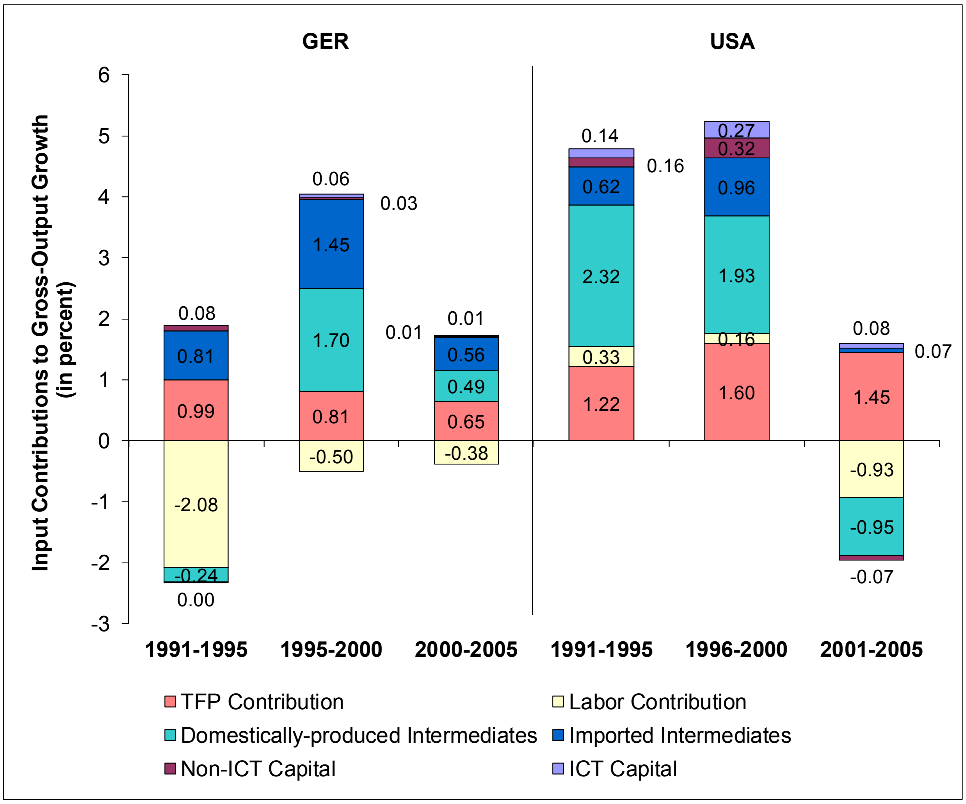

*Note:* Contributions are sectoral averages over the three periods 1991–95, 1996–2000, and 2001–2005. *Sources:* EU KLEMS (2009).

**Figure 5: Contributions to Gross-Output Growth, By Value Added and Type of Intermediates, GER vs. USA**



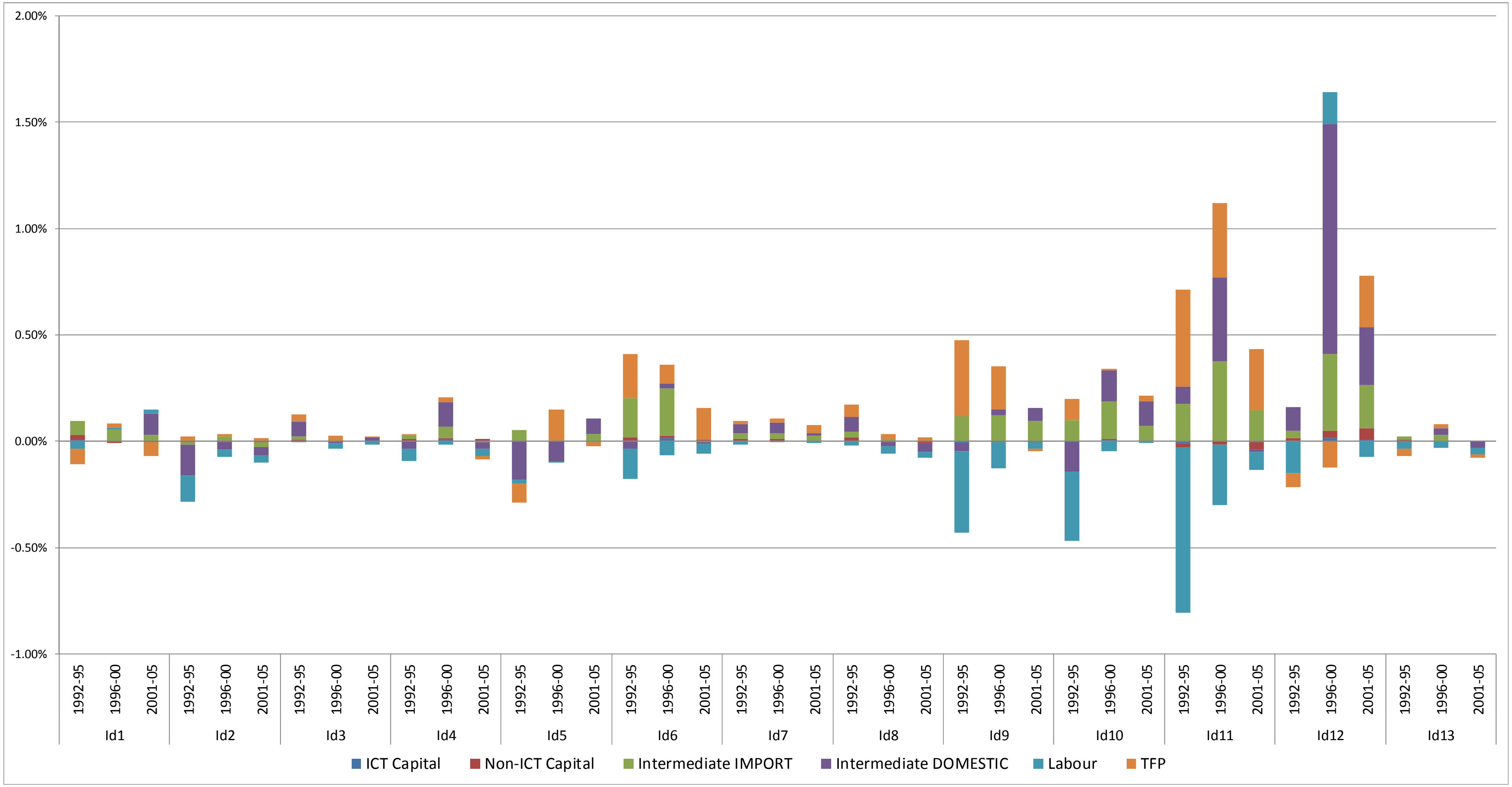

*Note:* Contributions are aggregate manufacturing sectoral averages over the three periods 1991–95, 1996–2000, and 2001–2005. *Sources:* IIGAD (2008), EU KLEMS (2009).

**Figure 6: Contributions to Gross-Output Growth, By Input Type, GER vs. USA**



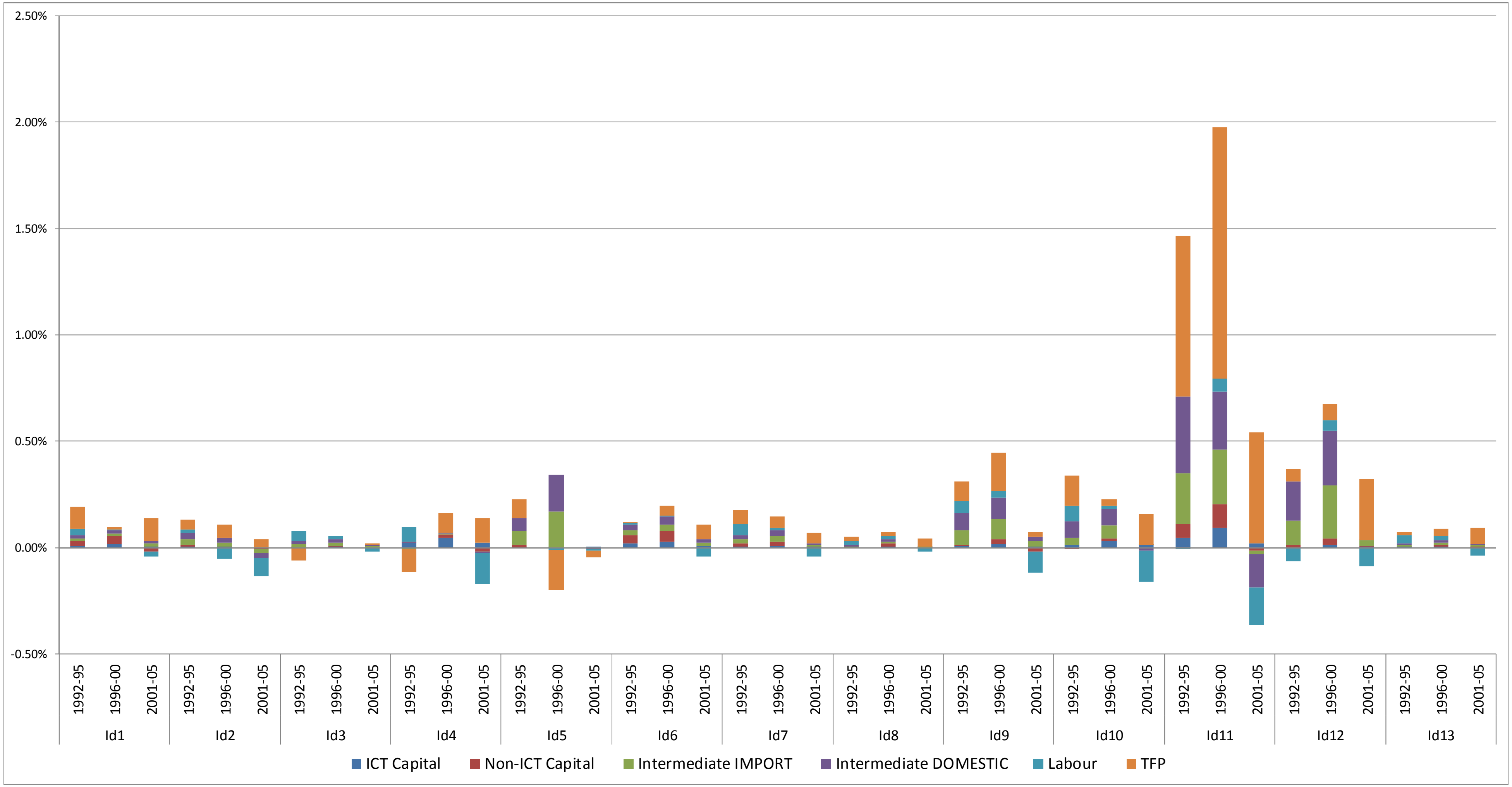

*Note:* Contributions are aggregate manufacturing sectoral averages over the three periods 1991–95, 1996–2000, and 2001–2005. *Sources:* IIGAD (2008), EU KLEMS (2009).

**Figure 7a: Contributions to Gross-Output Growth,
By Input Type, GER Manufacturing Sectors**



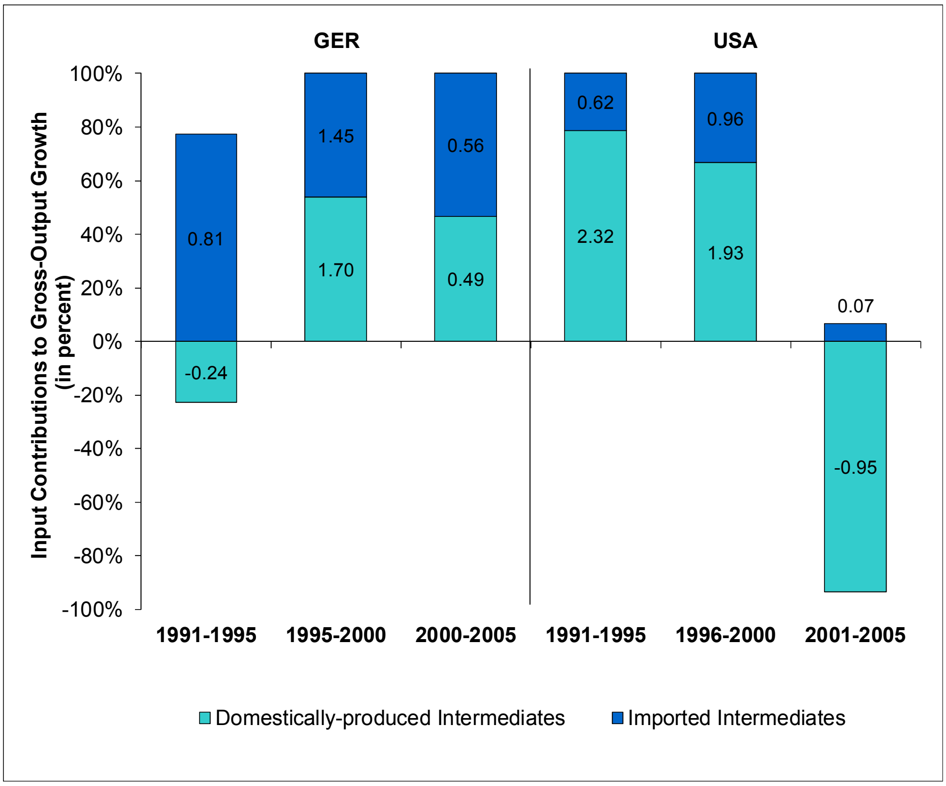

*Note:* Contributions are sectoral averages over the three periods 1991–95, 1996–2000, and 2001–2005. *Sources:* IIGAD (2008), EU KLEMS (2009).

**Figure 7b: Contributions to Gross-Output Growth,
By Input Type, US Manufacturing Sectors**



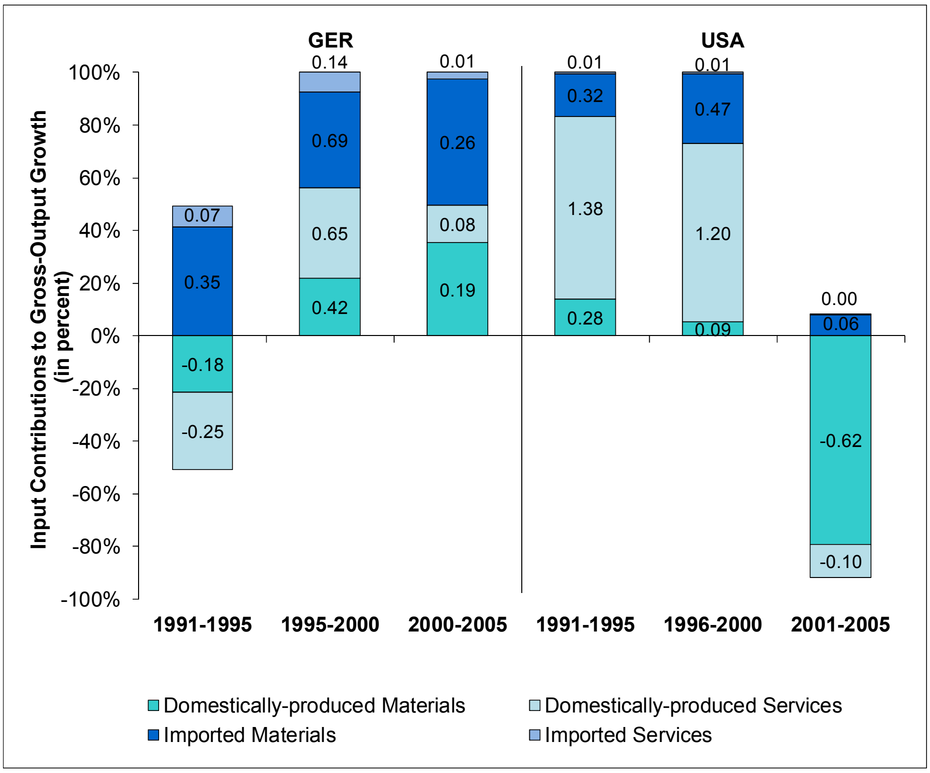

*Note:* Contributions are sectoral averages over the three periods 1991–95, 1996–2000, and 2001–2005. *Sources:* EU KLEMS (2009).

**Figure 8: Intermediates Contributions to Gross-Output Growth, By Type, GER vs. USA**



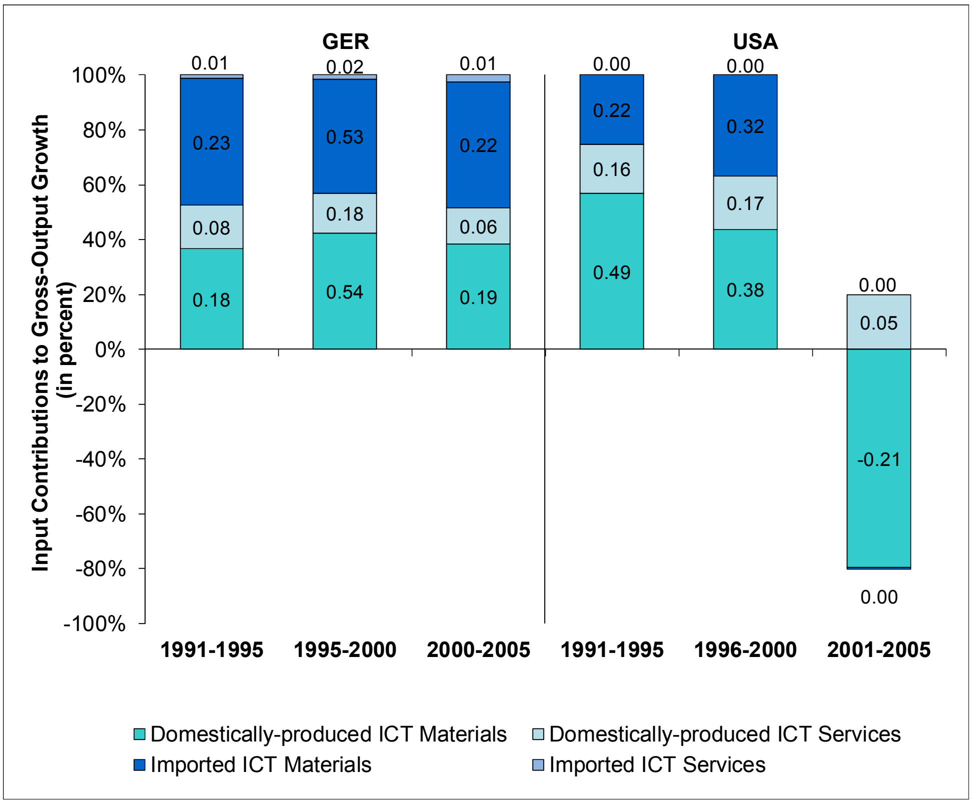

*Note:* Contributions are aggregate manufacturing sectoral averages over the three periods 1991–95, 1996–2000, and 2001–2005. *Sources:* IIGAD (2008), EU KLEMS (2009).

**Figure 9: Intermediates Contributions to Gross-Output Growth, By Non-ICT (excluding Energy), GER vs. USA**



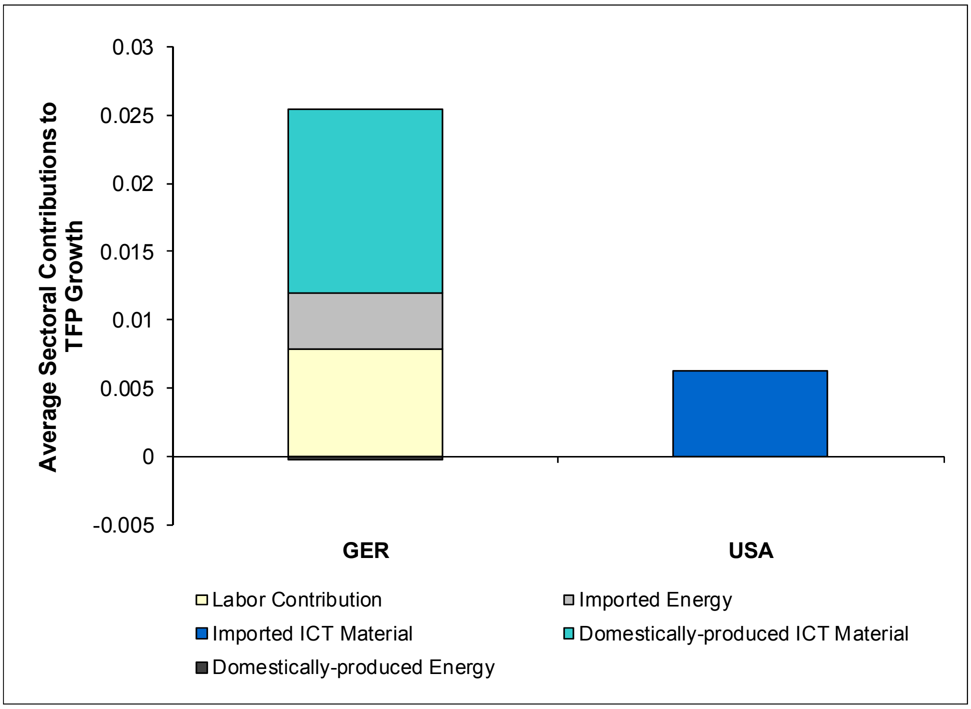

*Note:* Contributions are aggregate manufacturing sectoral averages over the three periods 1991–95, 1996–2000, and 2001–2005. *Sources:* IIGAD (2008), EU KLEMS (2009).

**Figure 10: Intermediates Contributions to Gross-Output Growth, By ICT, GER vs. USA**




*Note:* Contributions are aggregate manufacturing sectoral averages over the three periods 1991–95, 1996–2000, and 2001–2005. *Sources:* IIGAD (2008), EU KLEMS (2009).

**Figure 11: Contributions to TFP Growth, by Input Type, GER vs. USA (Specification FE-I, Table 1a)**




*Note:* Contributions are average growth effects over the period 1991–2005. *Sources:* IIGAD (2008), EU KLEMS (2009).

## Table 1a: TFP Growth Regressions, 1991–2005

| | GER | | | | | | USA | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RE-I | RE-II | RE-III | RE-IV | FE-I | FE-II | RE-I | RE-II | RE-III | RE-IV | FE-I | FE-II |
| kict_ | 0.021 | 0.025 | 0.004 | 0.002 | -0.002 | | 0.011 | 0.026 | 0.037 | 0.037 | -0.026 | |
| | [0.028] | [0.030] | [0.025] | [0.025] | [0.027] | | [0.042] | [0.046] | [0.048] | [0.049] | [0.043] | |
| knict_ | -0.097 | -0.112 | -0.079 | -0.073 | -0.020 | | 0.064 | 0.026 | -0.022 | -0.023 | 0.026 | |
| | [0.060] | [0.070] | [0.070] | [0.067] | [0.081] | | [0.113] | [0.101] | [0.080] | [0.078] | [0.085] | |
| l_ | **-0.274*** ** | **-0.267*** ** | **-0.257*** ** | **-0.258*** ** | **-0.265*** ** | | **-0.250*** ** | **-0.206** ** | **-0.242*** ** | **-0.249*** ** | -0.106 | |
| | [0.047] | [0.049] | [0.050] | [0.050] | [0.046] | | [0.095] | [0.084] | [0.087] | [0.091] | [0.072] | |
| imict_ | 0.023 | 0.019 | 0.015 | 0.015 | 0.011 | 0.022 | **0.043* ** | **0.047** ** | **0.043** ** | **0.043** ** | **0.045* ** | **0.050* ** |
| | [0.027] | [0.024] | [0.028] | [0.029] | [0.040] | [0.036] | [0.023] | [0.022] | [0.018] | [0.019] | [0.024] | [0.027] |
| im_ | **0.071* ** | 0.028 | 0.018 | 0.024 | 0.019 | 0.048 | 0.114 | 0.066 | 0.062 | 0.065 | 0.088 | 0.088 |
| | [0.043] | [0.057] | [0.039] | [0.042] | [0.037] | [0.059] | [0.087] | [0.086] | [0.077] | [0.083] | [0.097] | [0.093] |
| ie_ | **0.052*** ** | **0.063*** ** | **0.068*** ** | **0.067*** ** | **0.046* ** | 0.005 | 0.014 | 0.016 | 0.012 | 0.012 | 0.012 | 0.014 |
| | [0.016] | [0.018] | [0.017] | [0.018] | [0.021] | [0.019] | [0.010] | [0.012] | [0.012] | [0.013] | [0.012] | [0.012] |
| isict_ | 0.014 | 0.018 | **0.026* ** | **0.026* ** | 0.040 | 0.006 | 0.031 | 0.022 | 0.025 | 0.026 | 0.018 | 0.017 |
| | [0.011] | [0.011] | [0.014] | [0.014] | [0.023] | [0.023] | [0.022] | [0.020] | [0.017] | [0.018] | [0.015] | [0.014] |
| is_ | 0.008 | 0.010 | 0.007 | 0.006 | -0.002 | 0.008 | 0.061 | 0.063 | 0.065 | 0.065 | -0.047 | -0.077 |
| | [0.011] | [0.011] | [0.012] | [0.012] | [0.017] | [0.023] | [0.075] | [0.067] | [0.053] | [0.053] | [0.105] | [0.108] |
| dmict_ | 0.045 | **0.080* ** | **0.114*** ** | **0.111*** ** | **0.121*** ** | **0.092*** ** | **-0.065* ** | **-0.062* ** | **-0.056** ** | **-0.056** ** | -0.024 | -0.030 |
| | [0.032] | [0.045] | [0.023] | [0.026] | [0.023] | [0.022] | [0.036] | [0.032] | [0.027] | [0.028] | [0.035] | [0.038] |
| dm_ | -0.013 | 0.043 | 0.049 | 0.040 | 0.072 | 0.073 | 0.101 | **0.148* ** | **0.131* ** | 0.125 | 0.109 | 0.099 |
| | [0.068] | [0.066] | [0.046] | [0.052] | [0.069] | [0.044] | [0.073] | [0.083] | [0.067] | [0.079] | [0.104] | [0.104] |
| de_ | -0.014 | -0.013 | **-0.022* ** | **-0.023* ** | **-0.023** ** | -0.023 | -0.017 | -0.024 | -0.033 | -0.033 | 0.000 | 0.004 |
| | [0.020] | [0.017] | [0.013] | [0.013] | [0.009] | [0.021] | [0.037] | [0.039] | [0.034] | [0.034] | [0.029] | [0.027] |
| dsict_ | **0.064** ** | 0.036 | 0.006 | 0.008 | 0.010 | 0.005 | -0.096 | -0.126 | -0.098 | -0.093 | -0.024 | -0.005 |
| | [0.032] | [0.034] | [0.018] | [0.023] | [0.014] | [0.017] | [0.082] | [0.082] | [0.068] | [0.076] | [0.091] | [0.097] |
| ds_ | -0.051 | -0.086 | **-0.094** ** | **-0.089** ** | -0.099 | **-0.131* ** | -0.027 | -0.001 | -0.019 | -0.023 | -0.071 | **-0.082* ** |
| | [0.055] | [0.057] | [0.039] | [0.042] | [0.056] | [0.063] | [0.058] | [0.067] | [0.057] | [0.059] | [0.043] | [0.044] |
| EXP | | 0.003 | | -0.001 | | | | 0.004 | | -0.001 | | |
| | | [0.002] | | [0.001] | | | | [0.003] | | [0.003] | | |
| TECH | | | **0.007*** ** | **0.007*** ** | | | | | **0.006** ** | **0.006* ** | | |
| | | | [0.001] | [0.001] | | | | | [0.003] | [0.003] | | |
| Obs. | 167 | 167 | 167 | 167 | 167 | 167 | 164 | 164 | 164 | 164 | 164 | 164 |
| $R^2$ (within) | 0.42 | 0.43 | 0.46 | 0.46 | 0.47♦ | 0.21♦ | 0.32 | 0.33 | 0.33 | 0.33 | 0.38♦ | 0.37♦ |
| corr($u_i$,Xb) | 0.00 | 0.00 | 0.00 | 0.00 | -0.14♦ | -0.23♦ | 0.00 | 0.00 | 0.00 | 0.00 | 0.11♦ | 0.04♦ |

*Notes:* All variables are in exponential growth rates. Regressions control for industry and time effects. Robust standard errors in brackets allow for intra-industry correlation. FE resembles LSDV estimations. ♦ Based on within transformation instead of LSDV. Outliers excluded. Significance levels: * significant at 10, ** significant at 5, *** significant at 1 percent. *Sources:* IIGAD (2008), EU KLEMS (2009).

## Table 1b: Fixed Effects Estimates (according to Table 1a), 1991–2005

| | GER | | USA | |
|---|---|---|---|---|
| | FE-I | FE-II | FE-I | FE-II |
| Food , Beverages & Tobacco | **-0.042**** | -0.025 | 0.021 | 0.018 |
| | [0.014] | [0.014] | [0.017] | [0.017] |
| Textiles, Apparel & Leather | **-0.047***** | -0.018 | 0.029 | 0.031 |
| | [0.015] | [0.014] | [0.019] | [0.018] |
| Wood Products | **-0.050***** | -0.023 | 0.009 | 0.004 |
| | [0.014] | [0.014] | [0.018] | [0.018] |
| Pulp, Paper & Printing | **-0.045**** | -0.023 | 0.033 | 0.029 |
| | [0.017] | [0.014] | [0.019] | [0.018] |
| Chemicals & Chemical Products | **-0.033*** | -0.008 | 0.020 | 0.017 |
| | [0.017] | [0.014] | [0.017] | [0.017] |
| Rubber & Plastics | **-0.034**** | -0.014 | 0.025 | 0.021 |
| | [0.015] | [0.013] | [0.016] | [0.017] |
| Other Non-Metallic Minerals | **-0.041**** | -0.018 | 0.029 | 0.026 |
| | [0.014] | [0.015] | [0.017] | [0.017] |
| Basic & Fabricated Metals | **-0.039**** | -0.011 | 0.025 | 0.023 |
| | [0.016] | [0.017] | [0.019] | [0.019] |
| Machinery, nec | **-0.037**** | -0.018 | 0.030 | 0.027 |
| | [0.015] | [0.014] | [0.019] | [0.019] |
| Electrical & Electronic Machinery | -0.021 | 0.011 | **0.059***** | **0.060***** |
| | [0.014] | [0.013] | [0.017] | [0.018] |
| Motor Vehicles & Transport | **-0.041**** | -0.021 | 0.019 | 0.017 |
| | [0.016] | [0.013] | [0.017] | [0.018] |
| Manufacturing, nec & Recycling | **-0.051***** | -0.026 | **0.030**** | **0.027*** |
| | [0.016] | [0.016] | [0.013] | [0.013] |

*Notes:* All variables are in exponential growth rates. Estimates are industry-fixed effects. Robust standard errors in brackets allow for intra-industry correlation. FE resembles LSDV estimations. Outliers excluded. Significance levels: * significant at 10, ** significant at 5, *** significant at 1 percent. *Sources:* IIGAD (2008), EU KLEMS (2009).

**Table 1c: Time Effects Estimates (according to Table 1a), 1991–2005**

| | GER | | USA | |
|---|---|---|---|---|
| | FE-I | FE-II | FE-I | FE-II |
| 1993 | -0.001 | 0.010 | -0.010 | -0.013 |
| | [0.007] | [0.006] | [0.008] | [0.008] |
| 1994 | **0.018*** | 0.017 | 0.000 | -0.001 |
| | [0.009] | [0.011] | [0.005] | [0.005] |
| 1995 | -0.003 | -0.003 | -0.011 | -0.012 |
| | [0.008] | [0.013] | [0.011] | [0.009] |
| 1996 | -0.007 | -0.003 | **-0.040**** | **-0.045***** |
| | [0.005] | [0.008] | [0.014] | [0.013] |
| 1997 | 0.006 | 0.002 | **-0.021*** | **-0.025**** |
| | [0.007] | [0.014] | [0.011] | [0.011] |
| 1998 | 0.001 | -0.003 | **-0.025*** | **-0.029*** |
| | [0.009] | [0.008] | [0.014] | [0.014] |
| 1999 | 0.007 | 0.000 | -0.012 | -0.013 |
| | [0.010] | [0.010] | [0.010] | [0.010] |
| 2000 | **0.022*** | 0.010 | 0.000 | 0.001 |
| | [0.011] | [0.011] | [0.012] | [0.013] |
| 2001 | 0.016 | 0.003 | **-0.037*** | **-0.034*** |
| | [0.009] | [0.016] | [0.020] | [0.019] |
| 2002 | 0.022 | 0.014 | -0.013 | -0.008 |
| | [0.014] | [0.009] | [0.021] | [0.020] |
| 2003 | **0.024*** | 0.008 | -0.010 | -0.005 |
| | [0.013] | [0.010] | [0.016] | [0.015] |
| 2004 | **0.032*** | 0.016 | -0.018 | -0.018 |
| | [0.015] | [0.013] | [0.019] | [0.019] |
| 2005 | 0.022 | 0.012 | -0.013 | -0.013 |
| | [0.013] | [0.013] | [0.018] | [0.018] |

*Notes:* All variables are in exponential growth rates. Estimates are common time effects. Robust standard errors in brackets allow for intra-industry correlation. FE resembles LSDV estimations. Outliers excluded. Significance levels: * significant at 10, ** significant at 5, *** significant at 1 percent. *Sources:* IIGAD (2008), EU KLEMS (2009).

**Table 2:**
**TFP Growth Regressions (Panel Models with AR(1) Disturbance), 1991–2005**

| | GER | | | | USA | | | |
|---|---|---|---|---|---|---|---|---|
| | REAR-I | REAR-II | FEAR-I | FEAR-II | REAR-I | REAR-II | FEAR-I | FEAR-II |
| kict_ | 0.014 | 0.002 | 0.010 | | -0.006 | 0.012 | -0.042 | |
| | [0.024] | [0.023] | [0.026] | | [0.051] | [0.051] | [0.053] | |
| knict_ | -0.076 | -0.072 | -0.071 | | -0.003 | -0.044 | 0.006 | |
| | [0.075] | [0.070] | [0.102] | | [0.096] | [0.098] | [0.111] | |
| l_ | **-0.272*** ** | **-0.258*** ** | **-0.270*** ** | | **-0.170** ** | **-0.179** ** | -0.100 | |
| | [0.034] | [0.032] | [0.035] | | [0.071] | [0.073] | [0.078] | |
| imict_ | 0.019 | 0.016 | -0.007 | -0.030 | **0.055*** ** | **0.053*** ** | **0.066*** ** | **0.071*** ** |
| | [0.035] | [0.031] | [0.051] | [0.063] | [0.018] | [0.018] | [0.020] | [0.020] |
| im_ | 0.066 | 0.024 | 0.037 | 0.066 | 0.098 | 0.064 | 0.093 | 0.087 |
| | [0.049] | [0.047] | [0.066] | [0.081] | [0.065] | [0.066] | [0.077] | [0.076] |
| ie_ | **0.048** ** | **0.066*** ** | **0.080** ** | 0.034 | 0.013 | 0.011 | 0.015 | 0.018 |
| | [0.021] | [0.019] | [0.031] | [0.037] | [0.012] | [0.012] | [0.012] | [0.012] |
| isict_ | 0.019 | **0.026* ** | **0.051** ** | 0.022 | 0.024 | 0.023 | 0.014 | 0.012 |
| | [0.016] | [0.015] | [0.022] | [0.027] | [0.017] | [0.017] | [0.020] | [0.020] |
| is_ | 0.005 | 0.006 | 0.038 | 0.046 | 0.019 | 0.030 | -0.085 | -0.111 |
| | [0.019] | [0.018] | [0.033] | [0.041] | [0.071] | [0.066] | [0.104] | [0.102] |
| dmict_ | **0.059* ** | **0.111*** ** | **0.138*** ** | **0.092* ** | **-0.056** ** | **-0.052* ** | -0.048 | **-0.052* ** |
| | [0.031] | [0.033] | [0.046] | [0.049] | [0.027] | [0.027] | [0.031] | [0.030] |
| dm_ | -0.001 | 0.040 | 0.028 | 0.038 | 0.123 | **0.145* ** | 0.140 | 0.136 |
| | [0.055] | [0.055] | [0.073] | [0.089] | [0.075] | [0.077] | [0.087] | [0.087] |
| de_ | -0.015 | **-0.023* ** | **-0.032* ** | -0.029 | 0.000 | -0.014 | 0.005 | 0.009 |
| | [0.014] | [0.013] | [0.017] | [0.021] | [0.037] | [0.036] | [0.041] | [0.040] |
| dsict_ | **0.055* ** | 0.009 | -0.006 | 0.017 | -0.078 | -0.088 | -0.033 | -0.018 |
| | [0.031] | [0.031] | [0.040] | [0.050] | [0.067] | [0.067] | [0.085] | [0.084] |
| ds_ | -0.059 | **-0.090** ** | **-0.117* ** | **-0.135* ** | -0.069 | -0.052 | -0.048 | -0.051 |
| | [0.046] | [0.045] | [0.064] | [0.074] | [0.058] | [0.058] | [0.074] | [0.073] |
| EXP | | -0.001 | | | | 0.000 | | |
| | | [0.002] | | | | [0.004] | | |
| TECH | | **0.007*** ** | | | | 0.006 | | |
| | | [0.002] | | | | [0.004] | | |
| Obs. | 167 | 167 | 155 | 155 | 164 | 164 | 152 | 152 |
| $R^2$ (within) | 0.44 | 0.46 | 0.49 | 0.23 | 0.37 | 0.36 | 0.44 | 0.42 |
| ρ | -0.02 | -0.02 | 0.00 | 0.05 | 0.20 | 0.20 | 0.19 | 0.18 |
| corr($u_i$,Xb) | 0.00 | 0.00 | -0.17 | -0.27 | 0.00 | 0.00 | 0.10 | 0.02 |

*Notes:* All variables are in exponential growth rates. Regressions control for industry and time effects. Standard errors in brackets control for autocorrelation of AR(1). FE employs within transformations, while ρ resembles the autocorrelation coefficient. Outliers excluded. Significance levels: * significant at 10, ** significant at 5, *** significant at 1 percent. *Sources:* IIGAD (2008), EU KLEMS (2009).

## Appendix

### Table A1:
### ISIC Rev. 3.0 Classification

| Id | Manufacturing Industries | ISIC |
|---|---|---|
| 1 | Food , Beverages & Tobacco | D: 15 to 16 |
| 2 | Textiles, Apparel & Leather | D: 17 to 19 |
| 3 | Wood Products | D: 20 |
| 4 | Pulp, Paper & Printing | D: 21 to 22 |
| 5 | Coke & Petroleum | D: 23 |
| 6 | Chemicals & Chemical Products | D: 24 |
| 7 | Rubber & Plastics | D: 25 |
| 8 | Other Non-Metallic Minerals | D: 26 |
| 9 | Basic & Fabricated Metals | D: 27 to 28 |
| 10 | Machinery, nec | D: 29 |
| 11 | Electrical & Electronic Machinery | D: 30 to 33 |
| 12 | Motor Vehicles & Transport | D: 34 to 35 |
| 13 | Manufacturing, nec & Recycling | D: 36 to 37 |

### Table A2:
### Average TFP Contributions to Gross-Output Growth By Sector, 1991–2005

| | GER | | | USA | | |
|---|---|---|---|---|---|---|
| | 1991–1995 | 1996–2000 | 2001–2005 | 1991–1995 | 1996–2000 | 2001–2005 |
| Food , Beverages & Tobacco | -0.07 | 0.02 | -0.07 | 0.10 | 0.01 | 0.11 |
| Textiles, Apparel & Leather | 0.02 | 0.01 | 0.02 | 0.05 | 0.06 | 0.04 |
| Wood Products | 0.03 | 0.02 | 0.00 | -0.06 | 0.00 | 0.01 |
| Pulp, Paper & Printing | 0.01 | 0.02 | -0.02 | -0.11 | 0.09 | 0.12 |
| Coke & Petroleum | -0.09 | 0.15 | -0.02 | 0.09 | -0.19 | -0.03 |
| Chemicals & Chemical Products | 0.21 | 0.09 | 0.15 | 0.00 | 0.05 | 0.07 |
| Rubber & Plastics | 0.02 | 0.02 | 0.04 | 0.07 | 0.05 | 0.05 |
| Other Non-Metallic Minerals | 0.06 | 0.02 | 0.02 | 0.02 | 0.02 | 0.04 |
| Basic & Fabricated Metals | 0.36 | 0.20 | -0.01 | 0.10 | 0.18 | 0.02 |
| Machinery, nec | 0.10 | 0.00 | 0.03 | 0.14 | 0.03 | 0.14 |
| Electrical & Electronic Machinery | 0.46 | 0.35 | 0.29 | 0.76 | 1.18 | 0.52 |
| Motor Vehicles & Transport | -0.06 | -0.12 | 0.24 | 0.06 | 0.08 | 0.29 |
| Manufacturing, nec & Recycling | -0.04 | 0.02 | -0.01 | 0.02 | 0.03 | 0.08 |
| Avg. Total Economy TFP Growth | 1.00 | 0.81 | 0.65 | 1.22 | 1.60 | 1.45 |
| ex. Electrical & Electronic Machinery | 0.54 | 0.46 | 0.36 | 0.46 | 0.42 | 0.93 |

*Notes:* All variables are in exponential growth rates. Variables are averages over the three periods 1991–95, 1996–2000, and 2001–2005. *Sources:* IIGAD (2008), EU KLEMS (2009).

**Table A3:**
**Industry Taxonomy**

| | GER | | USA | |
|---|---|---|---|---|
| | **Trade Intensive** | **High Tech** | **Trade Intensive** | **High Tech** |
| Food , Beverages & Tobacco | TI-3 | LOTE | TI-3 | LOTE |
| Textiles, Apparel & Leather | TI-2 | LOTE | TI-2 | LOTE |
| Wood Products | TI-4 | LOTE | TI-4 | LOTE |
| Pulp, Paper & Printing | TI-3 | LOTE | TI-3 | LOTE |
| Coke & Petroleum | TI-4 | MLTE | TI-4 | MLTE |
| Chemicals & Chemical Products | TI-2 | MHTE | TI-2 | MHTE |
| Rubber & Plastics | TI-3 | MLTE | TI-3 | MLTE |
| Other Non-Metallic Minerals | TI-4 | MLTE | TI-4 | MLTE |
| Basic & Fabricated Metals | TI-2 | MLTE | TI-2 | MLTE |
| Machinery, nec | TI-1 | MHTE | TI-1 | MHTE |
| Electrical & Electronic Machinery | TI-1 | HITE | TI-1 | HITE |
| Motor Vehicles & Transport | TI-1 | MHTE | TI-1 | MHTE |
| Manufacturing, nec & Recycling | TI-4 | LOTE | TI-4 | LOTE |

*Notes:* TI-1 = Exports of goods in the fourth quartile (> 75$^{th}$ percentile); TI-2 = Exports of goods in the third quartile (50$^{th}$–75$^{th}$ percentile), TI-3 = Exports of goods in the second quartile (25$^{th}$–50$^{th}$ percentile); TI-4 = Exports of goods in the first quartile (< 25$^{th}$ percentile). HITE = High-technology industries; MHTE = Medium-high-technology industries; MLTE = Medium-low-technology industries; LOTE = Low-technology industries. *Sources:* OECD (2008) and author’s calculations, OECD (2011).

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