# Mind the gap! International Comparisons of Productivity in Services and Goods Production

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Research Memorandum GD-89

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RESEARCH MEMORANDUM

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**Abstract**

In this paper, we make a comparison of industry output, inputs and productivity growth and levels between seven advanced economies (Australia, Canada, France, Germany, Netherlands, UK and U.S.). Our industry-level growth accounts make use of input data on labour quantity (hours) and composition (schooling levels), and distinguish between six different types of capital assets (including three ICT assets). The comparisons of levels rely on industry-specific purchasing power parities (PPPs) for output and inputs, within a consistent input-output framework for the year 1997. Our results show that differences in productivity growth and levels can mainly be traced to market services, not to goods-producing industries. Part of the strong productivity growth in market services in Anglo-Saxon countries, such as Australia and Canada, may be related to relatively low productivity levels compared to the U.S. In contrast, services productivity levels in continental European countries were on par with the U.S. in 1997, but growth in Europe was much weaker since then. In terms of factor input use, the U.S. is very different from all other countries, mostly because of the more intensive use of ICT capital in the U.S.

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## 1. Introduction

During the second half of the 1990s the comparative growth performance of many OECD countries has undergone a marked change. For the first time since World War II labour productivity growth in most countries that have been part of the European Union (EU) for a decade or more (the EU-15) has fallen behind the U.S. for a considerable length of time. Whereas average annual labour productivity growth in the U.S. accelerated from 1.2 percent during the period 1987-1995 to 2.3 percent during 1995-2005, EU-15 productivity growth declined from 2.2 to 1.4 percent. The downward trend in the EU-15 was rather continuous as growth slowed from 1.7 percent from 1995-2000 to 1.1 percent from 2000-2005. Just like the U.S., various other Anglo-Saxon countries, in particular Australia and Canada, experienced a significant improvement in productivity growth during the late 1990s (2.3 and 1.7 percent from 1995-2000 respectively), but since 2000 productivity in these countries slowed down again to growth rates comparable to the pre-1995 period (1.7 and 1.3 percent in 2000-2005 respectively). In contrast, U.S. productivity accelerated from 2.2 percent in 1995-2000 to 2.5 percent in 2000-2005.[1]

The striking acceleration in U.S. output and productivity growth since the mid 1990s and in particular the role of information and communication technology (ICT) has been much discussed in the literature.[2] ICT had an impact on growth through a surge in ICT investment, strong productivity contributions from ICT-producing industries and a more productive use of ICT in the rest of the economy. Notably the market services sector of the U.S. economy seems to have strongly benefited from the increase in ICT use. Unfortunately, there is much less agreement on the reasons for the slower productivity growth in Europe. Compared to the U.S., ICT investment, ICT production and the productive use of ICT in Europe generated less productivity growth during the late 1990s (van Ark et al., 2003; Inklaar et al., 2005, Eicher and Roehn, 2006). But the reasons for the limited impact of new technology, innovation and structural reforms on economic growth in Europe are still poorly understood. The acceleration and subsequent deceleration in Australia and Canada has also puzzled various scholars (Parham, 2005; Rao et al., 2005). Cyclical slowdown might be one reason, but there may be other reasons related to short term shocks, the innovation system and a possible slowdown in reforms in the labour and product markets.

This paper extends our previous studies in this research field by providing a combined analysis of productivity growth and levels by industry. The major novelty in this paper is the comparison of output, input and productivity levels in a comprehensive framework. Looking at growth and levels together enables one to better understand the differences in contributions of inputs (labour composition, ICT and non-ICT capital) to output performance. In this paper we focus our analysis on a comparison of seven advanced economies (Australia, Canada, France, Germany, Netherlands, the United Kingdom and the United States). While our present growth and level accounting dataset provides detail on 26 industries (of which 25 in the market economy), we focus the discussion in this paper on the comparative performance of three major sectors which constitute the market economy: the ICT production sector, goods-producing industries and market services.

[1] See TCB/GGDC (2006)

[2] See e.g. Oliner and Sichel (2000, 2002); Jorgenson and Stiroh (2000); Jorgenson, Ho and Stiroh (2005); Gordon (2003, 2004); Stiroh (2002a); Triplett and Bosworth (2004); Botsch and Stiroh (2006); Basu and Fernald (2006) and Corrado, Lengermann, Bartelsman and Beaulieu (2006).

We find that a distinction between the Anglo-Saxon countries (Australia, Canada, UK and U.S.) and the continental European countries (France, Germany and the Netherlands) is useful. In the Anglo-Saxon countries market services have been contributing more to labour productivity growth since 1995 than before. Only part of the increase in labour productivity growth can be traced to higher direct contributions from ICT investment. A large part of the acceleration of growth in this sector is also due to higher total factor productivity growth. Strikingly, the continental European countries have not experienced this acceleration in TFP growth. Evidence from other studies suggests that this may be related to a more productive use of ICT in Anglo-Saxon economies, although this can be neither confirmed nor rejected on the basis of the industry-level data presented here.

Our comparison of productivity levels for 1997 suggests that TFP levels in goods production are relatively close between countries. In contrast, productivity levels in market services show relatively large gaps for Australia, Canada and the U.K. relative to the U.S., whereas the continental European countries are at or even above the U.S. TFP level in market services. This raises the possibility that the three Anglo-Saxon countries exhibit some kind of catching-up to the U.S. in particular in market services. But it also raises questions concerning the interpretation of the high productivity levels in continental Europe.

The paper proceeds as follows. In Section 2 we outline our basic growth and level accounting methodology. In Section 3, the data and results of our growth accounts are presented at the level of three major sectors of the economy. Section 4 briefly introduces our level accounting methodology, followed by a discussion of the level estimates. In the concluding section we summarize our main results, and indicate the areas for future research.

## 2. Growth and level accounting methodology

The productivity analysis in this study is rooted in the tradition of national accounting, input-output analysis and growth accounting, as pioneered by – among others – Simon Kuznets, Wassily Leontief, Robert Solow, Edward Denison, Zvi Griliches and Dale Jorgenson. Using these techniques macroeconomic and industry and aggregate measures of output can be decomposed into the contributions of inputs and productivity.[3] In this section we outline the basic growth accounting methodology and discuss how this framework is augmented to account for productivity level differences across countries.

To assess the contribution of the various inputs to aggregate growth, we apply the growth accounting framework as developed by Jorgenson and associates (see, for example, Jorgenson, Ho and Stiroh, 2005). For each industry gross value added (*VA*) is computed according to a production function *f* using ICT capital services ( $K^{ICT}$ ), non-ICT capital services ( $K^{N}$ ) and labour services (*L*). Productivity (*A*) is represented as a Hicks-neutral augmentation of aggregate inputs. The industry production function (industry subscripts are omitted) takes the following form:[4]

[3] See Schreyer (2001) for a more detailed exposition.
[4] In equations (1) to (5) we drop industry subscripts *i* for sake of convenience

$$VA_t = A\,f\left(L_t, K_t^N, K_t^{ICT}\right) \tag{1}$$

Under the assumption of competitive factor markets, full input utilization and constant returns to scale, the growth of output can be expressed as the (compensation share) weighted growth of inputs and total factor productivity, denoted by A, which is derived as a residual:

$$\ln\frac{VA_t}{VA_{t-1}} = \bar{v}^L \ln\frac{L_t}{L_{t-1}} + \bar{v}^N \ln\frac{K_t^N}{K_{t-1}^N} + \bar{v}^{ICT} \ln\frac{K_t^{ICT}}{K_{t-1}^{ICT}} + \ln\frac{A_t}{A_{t-1}} \tag{2}$$

where $\bar{v}^i$ denotes the two-period average share of input i in nominal value added. Imposing constant returns to scale implies $\bar{v}^L + \bar{v}^N + \bar{v}^{ICT} = 1$. Capital services are defined in (3) as the aggregate of the individual capital stocks weighted by the capital compensation share:

$$\ln\frac{K_t}{K_{t-1}} = \sum_j \bar{v}_j^K \ln\frac{K_{j,t}}{K_{j,t-1}} \tag{3}$$

where $\bar{v}_j^K$ is the two-period average share of asset type $j$ in total nominal capital compensation. For our growth accounts we use ICT capital services, which are calculated by weighting each of the ICT capital stocks by the share of the asset in total ICT capital compensation. Non-ICT capital services are calculated analogously.

We define the change in labour composition as the difference between the growth of labour input and the growth of total hours worked:[5]

$$\ln\frac{q_t^L}{q_{t-1}^L} = \sum_h \bar{v}_h^L \ln\frac{L_{h,t}}{L_{h,t-1}} - \ln\left(\sum_h L_{h,t} \Big/ \sum_h L_{h,t-1}\right) = \ln\frac{L_t}{L_{t-1}} - \ln\frac{H_t}{H_{t-1}} \tag{4}$$

Here Lt is the labour input index, aggregated over the h labour types using labour compensation shares and $H_t$ is total hours worked, summed over the different labour types. By rearranging equation (2) the results can be presented in terms of average labour productivity growth defined as the ratio of output to hours worked, $va = VA/H$, the ratio of capital services to hours worked, $k = K/H$, labour composition and TFP as follows:

$$\ln\frac{va_t}{va_{t-1}} = \bar{v}^L \ln\frac{q_t^L}{q_{t-1}^L} + \bar{v}^N \ln\frac{k_t^N}{k_{t-1}^N} + \bar{v}^{ICT} \ln\frac{k_t^{ICT}}{k_{t-1}^{ICT}} + \ln\frac{A_t}{A_{t-1}} \tag{5}$$

[5] This is sometimes referred to as 'labour quality growth' such as in Jorgenson et al. (2005). However, the advantage of the term 'labour composition change' is that it does not imply that workers with lower wages have a lower quality. Instead, positive labour composition change only implies a shift towards workers with higher wages and hence, higher marginal productivity.

We name the decomposition in equation (5) an “input decomposition”. As we also focus in this paper on the contribution of industries to aggregate labour productivity growth, an “industry decomposition” measures industry contributions to GDP as follows (Stiroh, 2002a):

$$\ln\frac{va_t}{va_{t-1}} = \sum_i \bar{v}_i^{VA} \ln\frac{va_{i,t}}{va_{i,t-1}} + \left( \sum_i \bar{v}_i^{VA} \ln\frac{H_{i,t}}{H_{i,-1}} - \ln\frac{H_t}{H_{t-1}} \right) = \sum_i \bar{v}_i^{VA} \ln\frac{va_{i,t}}{va_{i,t-1}} + R \tag{6}$$

where $\bar{v}_i^{VA}$ is the two-period average share of industry $i$ in aggregate value added. The term in brackets in equation (6) is the reallocation of hours. It reflects differences in the share of an industry in aggregate value added and its share in aggregate hours worked. This term will be positive when industries with an above-average labour productivity level show positive employment growth or when industries with below average labour productivity have declining employment shares.

Obviously, one can go one step further by combining the input and industry decompositions of industry labour productivity. Labour productivity growth at an aggregate level is then decomposed into input contributions and a reallocation term for each industry:

$$\ln\frac{va_t}{va_{t-1}} = \sum_i \bar{v}_i^{VA}\bar{v}_i^{L} \ln\frac{q_{i,t}^{L}}{q_{i,t-1}^{L}} + \sum_i \bar{v}_i^{VA}\bar{v}_i^{N} \ln\frac{k_{i,t}^{N}}{k_{i,t-1}^{N}} + \sum_i \bar{v}_i^{VA}\bar{v}_i^{ICT} \ln\frac{k_{i,t}^{ICT}}{k_{i,t-1}^{ICT}} + \sum_i \bar{v}_i^{VA} \ln\frac{A_{i,t}}{A_{i,t-1}} + R \tag{7}$$

In similar fashion, the contribution from industry TFP growth to aggregate TFP growth can be calculated:

$$\ln\frac{A_t}{A_{t-1}} = \sum_i \bar{v}_i^{VA} \ln\frac{A_{i,t}}{A_{i,t-1}} \tag{8}$$

*Level accounting*

Comparing productivity levels across countries is in many ways analogous to comparisons over time. Under the assumption of a common production function across countries, equations (2) to (8) can be used after replacing time subscripts t and t-1 by country subscripts. Our level accounts differ from the growth accounts in two respects. First, while one typically compares productivity in one year with productivity in the next or previous year, there is no such natural ordering of countries. Therefore the comparison should not depend on the country that is chosen as the base country. There are various index number methods that can be used to make multilateral comparisons. We use the method suggested by Caves, Christensen and Diewert (1982). This index mirrors the Törnqvist index approach used in our growth accounting, but all countries are compared to an artificial 'average' country (AC).6 This average country is defined as the simple average of all M countries in the set. For example, a multilateral index of capital services in country c is given by:

$$\ln \frac{K_c}{K_{AC}} = \sum_j \bar{v}_j \ln \frac{K_{j,c}}{K_{j,AC}} \tag{9}$$

with $\bar{v}_j = \frac{1}{2}\left[v_{j,c} + v_{j,AC}\right]$, $v_{j,c}$ the share of asset type j in total nominal capital compensation in country c, $v_{j,AC} = 1/N \sum v_{j,c}$ the average compensation share of capital asset j over all countries N and $K_{j,AC} = 1/N \sum K_{j,c}$, the average capital stock. This mirrors equation (3). A comparison between two countries, say Germany and the US, can be made indirectly: by first comparing each country with the average country and then comparing the differences in German and US levels relative to the average country. Similarly, gaps in labour productivity levels can be decomposed by mirroring equation (5):

$$\ln \frac{va_c}{va_{AC}} = \bar{v}^L \ln \frac{q_c^L}{q_{AC}^L} + \bar{v}^N \ln \frac{k_c^N}{k_{AC}^N} + \bar{v}^{ICT} \ln \frac{k_c^{ICT}}{k_{AC}^{ICT}} + \ln \frac{A_c}{A_{AC}} \tag{10}$$

with $\bar{v}$ 's the input shares in value added averaged between country c and the average country AC. Analogous to equation (8), the contribution of industry TFP gaps to aggregate TFP gaps between country c and the average country is given by

$$\ln \frac{A_c}{A_{AC}} = \sum_i \bar{v}_i^{VA} \ln \frac{A_{i,c}}{A_{i,AC}} \tag{11}$$

Furthermore, while each country's national accounts presents information about value added at constant prices over time, such data is not available for directly comparing industry value added across countries. As described in more detail below, our starting point is to measure relative prices

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[6] In practice this means applying an EKS procedure to the bilateral Törnqvist indices. The results below are expressed by using the U.S. as the benchmark country. It should be stressed that the decompositions of equations (5)-(8) are noticeably less accurate approximations to the underlying aggregator functions for level accounting than for growth accounting. See the appendix for further discussion of these index number issues.

(PPPs) for gross output at the industry level. In combination with Supply and Use tables, we use these relative gross output prices to implicitly calculate relative value added prices based on the following expression:

$$\ln\frac{P_c^{GO}}{P_{AC}^{GO}} = \overline{w}\ln\frac{P_c^{VA}}{P_{AC}^{VA}} + \left(1-\overline{w}\right)\ln\frac{P_c^{II}}{P_{AC}^{II}} \tag{12}$$

where $\overline{w}$ is the share of value added in gross output averaged between the country and the average country, and the superscripts *GO*, *VA* and *II* denote gross output, value added and intermediate inputs, respectively. The relative VA price levels are used to calculate implicit relative VA quantity indices which are the output measures we use below.

## 3. Data and results for growth accounting

### *Data*

For the growth accounts in this paper we developed a database on output and labour and capital inputs for seven countries, including Australia, Canada, France, Germany, the Netherlands, the United Kingdom and the United States, for 26 industries covering the period 1987 to 2003 (see Table A.1).[7] The data on value added and total hours worked are based on the most recent release of the GGDC (2006a) *60-Industry Database*, while the full industry growth accounts are from the GGDC (2006b) *Industry Growth Accounting Database*.[8]

Output is defined as value added at constant prices and is taken from national accounts complemented with measures from industrial and business surveys. Labour input is measured as hours worked defined as the total number of persons employed (including self-employed) times the average number of hours worked. For labour input in each country we distinguish between three and seven types of educational attainment. For our capital input measures we use data on investment in current and constant prices for six asset types. Three assets refer to ICT goods (computers, communication equipment and software) and three to non-ICT goods (transport equipment, other (non-ICT) machinery and equipment and non-residential structures).[9] To estimate capital stocks we use industry-specific geometric depreciation rates for detailed assets in the U.S., provided in Fraumeni (1997), in combination with industry shares of these assets from the BEA NIPA. The deflators for ICT producing manufacturing industries and ICT investment have been harmonised across countries as discussed by Inklaar et al. (2005), except in the case of Canada and Australia which already use constant-quality price indices to a similar extent as the U.S.

[7] Together, the four European countries cover about 70 percent of output in the EU-15. See O'Mahony and van Ark (2003) and van Ark and Inklaar (2005) for figures at the aggregate level for all EU-15 countries. The Australian data covers fiscal years running from July to June. Following OECD convention, we allocate data for July 2000 to June 2001 to the year 2000.

[8] All data and more detailed source descriptions are downloadable at www.ggdc.net/dseries.

[9] Residential buildings are not taken into account to allow for a sharper focus on the productivity contribution of business-related assets. Since most of the outputs and inputs of the real estate industry consists of housing and imputed rents from housing we would have to make an adjustment for this. However, it is hard to separate imputed rents from the other output in the real estate sector. Hence we decided to leave the entire real estate industry out of our dataset.

The series for the European countries were published earlier by Inklaar et al. (2005), but were revised and updated to 2003 using the same sources and methods as before. For the United States, we have developed an entirely new dataset, which is largely based on the latest releases by the Bureau of Economic Analysis (BEA) of GDP- by-Industry data that cover the period 1947-2004. These data are organized according to the NAICS 1997 classification system and are consistent with the *2003 Comprehensive Revision of the National Income and Product Accounts* (NIPA). In addition to the GDP by Industry data, we use numerous other sources, most notably industry output and employment data from the BLS, to obtain a complete set of growth accounts. For U.S. investment we used two main sources from the BEA, namely the *1997 Capital Flow Table* and the BEA *Detailed Data for Fixed Assets* with time series for the period 1901-2004. We made substantial adjustments to the U.S. data to fit the ISIC rev. 3 industrial classification, which is the basis of our internationally comparative database.[10]

Data for Canada and Australia were developed specifically for the purpose of this paper. In the case of Canada the new NAICS-based use tables for the period 1961-2001 have been used to construct the output series. These data were extrapolated to 2003 using industry output series.[11] Employment data were drawn mostly from the OECD STAN database (2004 release). Detailed tables on investment by industry and asset tables from Statistics Canada were obtained through Industry Canada. For manufacturing industries, we supplemented those tables with information from the final demand part of the input-output tables. Ho, Rao and Tang (2004, Tables 10-12) provide data on labour composition change for Canada, which were compiled in a broadly comparable fashion to our methodology for the other countries.

Output series for Australia are mainly taken from the national accounts, supplemented by industry surveys. Data on employment are taken from the Australia's labour force statistics. Detailed investment by industry and asset tables are part of the Australian national accounts, and were supplemented with data from manufacturing surveys to distinguish investment by detailed manufacturing industries. Investment in communication equipment was split off from the broader category (electrical and electronic equipment) using input-output tables. For Australia we only had access to information from the national accounts on labour composition change for the aggregate market sector from the national accounts. This rate was applied to each of the individual industries.

### *Industry decomposition of labour productivity growth*

On the basis of the dataset described above, measures of labour productivity growth and the contribution of individual industries and major industry groups to aggregate productivity growth can be calculated. **Table 1** shows the results of the industry decomposition from equation (6) for the market sector of the economy for the 1987-1995 and 1995-2003 periods.[12] The table shows a large

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[10] For the U.S., no educational attainment data has been collected for years after 2000, so labour composition change is assumed to be zero for the latest three years.

[11] Industry output series for 2002 and 2003 are at constant prices. Current price data are estimated using producer price indices for most goods-producing industries and the GDP deflator for other industries. The 2002 input-output tables were released by Statistics Canada after we completed the dataset for this paper.

[12] The exact definition of the market economy (or business sector) differs by country and organization. We classify government (ISIC 75), education (ISIC 80) and health (ISIC 85) as non-market services, even though some or even most of education and health may be operated or owned by non-governmental organizations. The

acceleration in productivity growth in Australia, Canada and the U.S. for the market sector as a whole since 1995. Labour productivity growth in France and Germany slowed down substantially, while growth in the Netherlands stagnated. In the UK, growth also slowed down somewhat, but it remained high compared to the continental European countries.

For the industry decomposition we present the results for three major industry groups.[13] Firstly, the contribution of ICT production sector, which includes both ICT manufacturing and services (communications, software, etc.), differs between countries. The U.S. and the UK show rather high contributions from ICT-producers to productivity growth, whereas the continental European countries take an intermediate position and Australia and Canada show very small contributions. Secondly, the differences in average contributions of 'other' goods-producing industries (excluding ICT producing manufacturing) have been very small since 1995. Of course, there are differences between contributions of individual goods-producing industries, but mostly these contributions are positive and small and therefore matter relatively little for the aggregate performance.

Finally, and most importantly, the differences in contributions of market services (excluding ICT services) are quite large between the countries. All Anglo-Saxon countries show accelerations in the contributions from market services to labour productivity growth since 1995, ranging from 0.5 percentage point acceleration in the UK to 1.5 percentage points in Australia. In the U.S., labour productivity in market services increased by 0.9 percentage point from 0.9 per cent per year in 1987-1995 to 1.8 per cent per year from 1995-2003. In the Netherlands market services showed a slight increase in the contribution of 0.2 percentage point, but France and Germany experienced a deceleration of 0.1 and 0.6 percentage points, respectively.

*Input decomposition for market services*

Using data on capital services and labour composition, labour productivity growth rates for each industry and industry group are decomposed into contributions from ICT capital deepening, non-ICT capital deepening, labour composition change, TFP growth and reallocation of hours worked (see equation 7). Here we focus exclusively on an input decomposition of labour productivity growth in market services which are the most intensive users of ICT assets. The results are given in **Table 2**. All countries in the table show a moderate to substantial acceleration in the contribution of ICT capital deepening in market services. However, what stands out in Table 2 is the rapid acceleration in TFP growth in market services in the Anglo-Saxon countries (Australia, Canada, United Kingdom and United States). Before 1995, TFP growth in market services was negative in these countries, but

reason for excluding these sectors from the analysis is mainly due to severe measurement problems in these industries. Moreover the international comparability of non-market output measures is very weak, which makes affects the interpretation of differences in growth performance at the total economy level. Table 1 also shows the total economy aggregates, including non-market services and these results were more extensively analyzed in Timmer and van Ark (2005).

[13] Reallocation effects are generally negative, which suggests that industries with an above-average labour productivity level exhibit declining employment shares. In earlier work, such as van Ark et al. (2003), we also distinguished between industries that used ICT intensive and those that did not – based on U.S. estimates of ICT investment relative to total investment. This approach necessitates a somewhat arbitrary distinction that has been criticized by, for example, Daveri (2004). More importantly though is the fact that it has become less important to make this distinction because we now have actual measures of ICT use for countries outside the U.S.

turned positive after 1995. In contrast, all continental European countries (France, Germany and the Netherlands) showed deteriorating TFP growth in market services after 1995. Germany and the Netherlands experienced negative TFP growth in market services after 1995 and France shows only a small positive growth rate.

**Table 3**, based on equation (8), looks at the contribution of individual service industries to total factor productivity growth in market services from 1995-2003, with a breakdown for 1995-2000 and 2000-2003. The table shows a strong contribution from wholesale trade in the Netherlands and the U.S., even though it slowed down since 2000, in particular in the Netherlands. Retail trade showed a particularly strong performance in Australia and Canada from 1995-2000, but the retail sector's contribution to overall market services TFP growth slowed down almost everywhere since 2000. Financial intermediation was particularly strong in the United States since 2000, but not in other countries. A distinctive difference since 2000, however, is the strong improvement of productivity growth in business services in all four Anglo-Saxon economies. The category of "other market services" only showed a sizeable effect for Australia after 2000, which is primarily due to a productivity boom in construction.

The precise reasons for the differences in productivity dynamics of market services are difficult to generalize. One possibility is that in some countries investments in ICT do not lead to faster TFP growth whereas in other countries they do. There may be many reasons for this, among which cyclical effects and the effects of unmeasured intangible investments stand out. Estimates of ICT output elasticities that are larger than the marginal cost of ICT capital services would violate a basic growth accounting assumption. However, Inklaar (2005) and van Ark and Inklaar (2005), in line with, for example, Stiroh (2002b), find that industry data do not exhibit supra-normal returns. There is even some evidence that it takes a number of years of below-normal returns before the productive returns of ICT become high enough to outweigh the cost.[14]

The slow uptake of productivity in market services also emerges from studies that take a more industry-specific orientation. For example, McGuckin, Spiegelman and van Ark (2005) analyze labour productivity growth in European and U.S. wholesale and retail trade in detail. They find that technology adoption in Europe lags the U.S. by several years, which has been holding back European productivity growth. They also find that this lag can be (partly) attributed to stricter regulations in European countries.[15] But the explanation for the slowdown since 2000 has so far remained unexplained, and more work in this area (for retail and other service industries) is therefore required.

To shed more light on the reasons for the large differences in the contribution of market services to productivity growth one might focus not exclusively on comparisons of growth rates but

[14] An alternative approach is to directly estimate each of the output elasticities separately. For example, O'Mahony and Vecchi (2005) find super-normal returns on ICT, which they attribute (at least in part) to the returns to unmeasured intangible investment, such as organizational change or training programs. An advantage of their approach is that no assumptions about the other output elasticities have to be made, but the disadvantage is that it requires a rather restrictive functional form for the production function (such as Cobb-Douglas) for the estimation (see van Ark and Inklaar, 2005).

[15] For a more detailed statistical analysis of growth differences in the trade sector, see Timmer and Inklaar (2005).

also on comparative levels of productivity. For example, rapid TFP growth could point towards catching-up and imitation when starting from a relatively low productivity level. Similarly, stagnating TFP growth at a relatively high level of TFP might be indicative of a lack of innovation. Therefore we turn to level comparisons for the remainder of this paper.

## 4. Data and results for level accounting

A level accounting approach to output and productivity comparisons has not been widely applied, which is primarily due to the lack of adequate industry-specific PPPs for output and inputs. PPPs are needed to adjust output and inputs for differences in relative price levels between countries. Since there is little reason to assume that price differences are negligible between countries or the same across industries, such PPPs have to be industry-specific.

Only few studies have attempted to measure industry-specific PPPs. Most comparisons have tended to restrict themselves to the total economy (e.g. Schreyer, 2006). Jorgenson, Kuroda and Nishimizu (1987) make use of specific PPPs for expenditure categories from OECD to measure TFP for about 30 industries between Japan and the U.S. These expenditure PPPs are adjusted for differences in transport and distribution margins across countries. Other studies have aimed to directly measure producer-price based PPPs. Van Ark and Pilat (1993) provided TFP level measures for manufacturing industries in Germany, Japan and the United States using a ratio of unit values which are based on producer quantities and values from production censuses in different countries. Similarly, Timmer (2000) measured TFP for manufacturing in Asian countries using a similar methodology. Pilat (1996), Mulder (1999), O'Mahony (1999), and O'Mahony and de Boer (2002) extended the industry-specific PPP approach to measuring output and productivity levels beyond manufacturing. Most studies had to rely on bilateral comparisons of pairs of countries. It has also turned out to be difficult to develop a consistent PPP methodology across the various studies because of differences in data availability. In particular, value added is often deflated by gross output price relatives, without taking into account differences in prices of intermediate inputs (so-called single versus double deflation).

In this paper we make use of a new and comprehensive dataset of industry PPPs for 1997, in combination with a benchmark set of Supply and Use tables from the relevant statistical offices. PPPs for value added are constructed by double deflation of gross output and intermediate inputs within a consistent input-output framework (see equation (12)). In addition, relative price ratios for labour and capital input are developed. For a full discussion of the new industry PPPs, the reader is referred to Timmer, Ypma and van Ark (2006). For the integration of gross output PPPs and the derivation of input PPPs in a level accounting framework, details are spelled out in Inklaar and Timmer (2006). Below we only present the most important elements of our methodology.

PPPs for gross output are defined from the producer's point of view and are at basic prices, which measures the amount received by the producer for a unit of a good or service produced. These PPPs have partly been constructed by way of unit value ratios for agricultural, mining, manufacturing and transport and communication services. For other industries, PPPs are based on specific expenditure prices from Eurostat and the OECD, which are allocated to individual industries producing the specific item. The value was adjusted from expenditure to producer level with relative transport and distribution margins and by adjusting for differences in relative tax rates. Margins and tax rates were derived from benchmark supply and use tables for 1997. This set of gross output PPPs for 1997, covering 45 industries at (roughly) 2-digit industry level, has been made transitive across countries by applying the multilateral EKS-procedure for a total of 26 countries, which are all OECD countries but also includes Taiwan). For this study the gross output PPPs were then are allocated to the 26 industries in Input-Output tables for 1997.

Intermediate input PPPs are required in order to double deflate value added. These input PPPs should reflect the costs of acquiring intermediate deliveries, hence they need to be based on purchasers' prices. Assuming that the basic price of a good is independent of its use, we can use the same gross output PPP for a particular industry, after adjustment for margins and net taxes, to deflate all intermediate deliveries from that industry to other industries. The aggregate intermediate input PPP for an industry is then derived by weighting its intermediate inputs at the gross output PPPs from the delivering industries. Imports are separately identified for which exchange rates are used as PPP, hence assuming no price differences across countries for imported commodities.

To obtain PPPs for capital and labour input, we follow the methodology outlined by Jorgenson and Nishimizu (1978). The PPP for capital services is based on the expenditure PPP for investment from Eurostat and the OECD, adjusted for differences in the user costs between countries. The user cost of capital input depends on the rate of return to capital, the depreciation rate and the investment price change. This data is taken from the growth accounts discussed in the previous section. The procedure to obtain a PPP for labour is more straightforward than for capital as it simply involves aggregating relative wages across different labour types using labour compensation for each type as weights. For this purpose we only distinguish between two labour categories: workers with a university degree or higher, and those without. This limited number of skill types is due to difficulties in matching schooling systems across the various countries.

### *Industry decomposition of labour productivity levels*

The first step in presenting our level results, it to focus on the comparative levels of labour productivity for the same major industry groups (ICT production, other goods production and market services) as in the first part of the paper. **Table 4** shows comparative levels of labour productivity, measured as value added per hour worked. The results for 1997 are for our benchmark year, and developed according to the methodology outlined above.

Table 4 shows that the U.S. shows a labour productivity level in the market economy which is similar to that of the three continental European countries, ranging from France at 96 per cent of the U.S. level to the Netherlands at 107 per cent.[16] The other Anglo-Saxon countries show between 15

[16] The margin of error around level estimates is non-negligible. Although (formal) research on this issue is limited, Schreyer (2006) arrives at a confidence interval of (at least) 10 percent using a simulation exercise. Strikingly, the relative total economy levels are all higher relative to the U.S. than the market economy levels, signalling high relative TFP levels in non-market services in countries outside the U.S. These differences are largest in European countries, like France and the Netherlands. As before, when dealing with the growth, it is not clear how to interpret the results for the non-market sector given the substantial measurement problems that remain.

and 20 percent lower levels than the U.S, ranging from Australia at 73 per cent of the U.S. level to Canada at 88 per cent.

Table 4 also shows relative labour productivity levels in ICT production, other goods-producing industries and other market services in 1997. The relative productivity levels in market services correspond most closely to those at the level of the market economy, with productivity levels in France, Germany and the Netherlands relatively close to that of the United States, while Australia, Canada and the UK are at a large distance from the other countries. Productivity levels in goods-producing industries are generally closer together, with the exception of Canada which has high productivity levels in some resource-intensive and heavy manufacturing industries, like oil refining, metal products and machinery. The high productivity levels in ICT production in France, Germany and the UK can mostly be traced to communications services, with again smaller differences in ICT manufacturing.

Table 4 also shows an extrapolation of the benchmark results for labour productivity in 1997 to 2003. Starting from the relative labour productivity levels for 1997, we have applied the relative growth between 1997 and 2003 at the aggregate and industry group level (see Table 1).[17] The faster productivity growth in the U.S. since 1997 has resulted in lower productivity levels relative to the U.S. for the other countries, but the cumulative impact is still relatively small over a period of only six years.

*Input decomposition of level accounts for market services*

The relatively low productivity levels in market services in the Anglo-Saxon economies (except the U.S.) sheds additional light on the possible reasons for rapid productivity growth in the market services sector for these countries, as was observed earlier. Rapid growth might typically be related to catching up-effects as the industries started from low levels of productivity, and benefited from technological progress, innovation and institutional changes – more than the continental European countries which started from much higher levels. To explore this possibility further, an input decomposition of differences in the level of productivity is useful.

**Table 5** shows an input decomposition of the labour productivity gap in market services into the contributions of ICT capital intensity, non-ICT capital intensity, labour composition and TFP to the gap following equation (10). For example, the (log) labour productivity gap between Australia and the U.S. is 39 percentage points,[18] of which nine percentage points are due to lower ICT intensity, four percentage points to lower non-ICT intensity and lower labour composition, and 21 percentage points due to lower TFP levels.

[17] The data requirements for a level comparison for one year are quite substantial, and in many cases these data only become available with a considerable lag. As a result, a fully consistent level accounting exercise cannot yet be done for a later year than our benchmark year 1997. Extrapolating the 1997 benchmark results forward is also not straightforward since ideally this should be done at most detailed level before re-aggregating using the CCD-method. As the data requirements for such an extrapolation would be comparable to that of a new benchmark, this is also not feasible at the moment.

[18] The gap here is defined as the difference in the natural log of the levels, to stay consistent with the growth accounts and the decomposition formulae which are also in terms of logs.

A number of observations stand out from Table 5. Firstly, ICT capital input per hour worked is higher in U.S. market services than anywhere else, and accounts for between 3 and 10 percentage points of the U.S. labour productivity level advantage. In contrast, non-ICT capital levels are higher in the continental European countries, and account for the bulk of the productivity advantage in market services for France and Germany. In Germany, higher capital intensity adds as much as 21 percentage points to Germany's advantage relative to the U.S., accounting for more than the total labour productivity gap.[19] This is partly compensated by lower ICT capital intensity and less skilled labour. In the Anglo-Saxon countries, non-ICT capital intensity in market services is lower than in the U.S. Labour composition levels in market services are also below the U.S. levels, with the exception of Canada and the Netherlands where it is relatively close to the U.S. level.

The major factor accounting for the productivity gap between the U.S. and the other Anglo-Saxon countries is the lower TFP level in market services in the latter countries. It accounts for between 21 percentage points of the Australian gap relative to the U.S. and 26 percentage points of the Canadian gap. In France and Germany, the TFP level is comparable to the U.S. Only in the Netherlands, the higher productivity level in market services relative to the United States is largely due to a higher TFP level.

Finally, **Table 6** provides an industry decomposition of the TFP gaps in market services relative to the United States. In contrast to the input decomposition of market services in table 5, productivity gaps are now decomposed to the contribution of productivity gaps in the more detailed industries, see equation (11). So, for example, the 21 percentage point TFP gap in market services between Australia and the U.S. is mainly due to the gap in business services, contributing almost 15 percentage points, followed by "other" market services at 7 percentage points. In finance, the TFP level in Australia is higher than in the U.S., so its contribution to the overall gap is positive.

There is clear evidence that the productivity level advantage of the continental European countries is primarily located in wholesale trade and – to a lesser extent – in retail trade. The Netherlands also shows a productivity level advantage in transport and storage and financial intermediation. Financial intermediation shows positive contributions from high productivity levels in Australia, France and Germany. Strikingly, business services contribute negatively to the productivity gap relative to the U.S. for all countries.

## 5. Summary and concluding remarks

In this paper we combined a growth and level accounting approach to compare productivity at industry level among seven advanced economies (Australia, Canada, France, Germany, Netherlands, the United Kingdom and the United States). Our analysis uses an industry decomposition for 26 industries, of which 25 are part of the market economy, and an input decomposition of labour productivity into the contributions from ICT capital intensity, non-ICT capital intensity, labour composition and total factor productivity. By looking at both growth and levels together, which is the

[19] The quality of data on investment by industry and asset as well as the investment PPPs are areas for potential improvement of the results. However, any adjustment would have to be implausibly large to account for the high non-ICT capital intensity level in Germany.

major novelty of this paper, we may get a better view of the extent to which fast (or slow) growth rates may be due to catching-up effects.

Our analysis shows that market services play a key role in explaining the stronger productivity growth of the Anglo-Saxon economies (Australia, Canada, the UK and the U.S.). We also find that the continental European countries (France, Germany and the Netherlands) experienced a strong slowdown in market services. Our input decomposition shows that the differential growth performance is mostly strongly related to differences in TFP growth, whereas ICT capital deepening accelerated everywhere since 1995 – also in the countries with slow productivity growth.[20] An industry decomposition of market services attributes a large role to slower productivity growth in business services in Europe.

The level analysis in the second part of the paper reveals that total factor productivity gaps at the aggregate level mainly emerge for Anglo-Saxon economies (other than the U.S.) which can also be largely traced to market services. For the Anglo-Saxon economies lower TFP levels in market services are the key explanation for lower aggregate labour productivity levels. An industry decomposition again points in the direction of the importance of business services accounting for a large part of the productivity shortfall relative to the U.S. TFP levels in continental European countries are at or even substantially above the U.S. productivity level in market services. The advantage for France and Germany is in part related to higher levels of non-ICT capital intensity, but in the Netherlands higher TFP levels also play a role.

The combination of low productivity levels and high productivity growth in market services in the Anglo-Saxon economies (Australia, Canada and the United Kingdom), suggests a role for catching up on the U.S. productivity level. This catching up may be related to a rapid adoption of ICT, which is an input of major importance in market services, and TFP growth. Even though a direct relationship between ICT capital deepening and TFP growth cannot be derived from the industry data as used in this study (Inklaar, 2005; van Ark and Inklaar, 2005), other studies using firm level data or specific case studies show that the productive impact of ICT depends crucially on investments in intangible capital such as organizational change and employee training programs. But Brynjolfsson and Hitt (2003), for example, argue that it takes a substantial amount of time for these complementary intangible investments to have their full effect on productivity. Reforms in product and labour markets may also be needed to exploit the productivity potential of ICT (Nicoletti and Scarpetta, 2003).

The combination of high productivity levels and slow productivity growth in market services in continental European countries may be due to an element of "perversity" in the productivity performance of many European service industries. This perversity may be related to underutilization of the consumer market potential. For example, if all the shopping needs to be done between 9 am and 6 pm instead of having access to retail facilities 24 hours per day, productivity may turn out higher in the former case. As a result of rigid markets a higher utilization of labour and capital (shop floor) capacity is realized. These observations raise new questions concerning an old debate on the need to

[20] A further decomposition of growth between 1995 and 2003 into the pre and post-2000 period, shows that the absolute contribution of ICT capital deepening after 2000 returned to pre-1995 levels in most countries.

adjust productivity measures for users' convenience, and the adjustment of inputs for utilisation rates, which goes beyond the scope of this paper.

Finally, we stress that at this stage, caution is needed when drawing far-reaching conclusions from the integrated productivity growth and level comparisons as this type integrated measurement is still in its infancy. Some of the hypotheses about industry group and aggregate productivity differences are not necessarily borne out by the detailed industry results. Measurement and conceptualization within a national accounts framework still offers much scope for improvement. Some of the detailed industry results suggest there is room to improve the comparability and quality of the underlying data. The dataset for this paper provides a bridge between our earlier datasets on industry and growth accounts and a more comprehensive growth and level accounts framework in the EU KLEMS project which will be published in 2007. The results from the latter project need to be awaited to find confirmation at the level of individual industries and for additional countries of the broad trends sketched here.

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**Table 1: Industry Contributions to Market Economy Labour Productivity Growth, 1987-2003 (value added per hour worked, percentage growth and contributions)**

| | Australia | Canada | France | Germany | Nether-lands | United Kingdom | United States |
|---|---|---|---|---|---|---|---|
| ***1987-1995*** | | | | | | | |
| Market economy | 1.1 | 1.2 | 2.7 | 2.8 | 1.7 | 2.9 | 1.9 |
| *contributions from:* | | | | | | | |
| ICT production | 0.4 | 0.3 | 0.4 | 0.6 | 0.2 | 0.7 | 0.6 |
| Goods-producing industries | 1.1 | 0.7 | 1.3 | 1.2 | 1.2 | 1.8 | 0.5 |
| Market services | 0.0 | 0.3 | 0.7 | 0.8 | 0.5 | 1.0 | 0.9 |
| Reallocation of hours | -0.3 | 0.0 | 0.3 | 0.2 | -0.2 | -0.6 | -0.2 |
| Total economy | 1.3 | 0.8 | 2.0 | 2.5 | 1.6 | 3.0 | 1.3 |
| ***1995-2003*** | | | | | | | |
| Market economy | 2.7 | 2.0 | 2.0 | 2.0 | 1.7 | 2.7 | 3.0 |
| *contributions from:* | | | | | | | |
| ICT production | 0.3 | 0.2 | 0.6 | 0.6 | 0.4 | 0.9 | 0.8 |
| Goods-producing industries | 0.8 | 0.7 | 0.8 | 0.9 | 0.8 | 0.6 | 0.7 |
| Market services | 1.8 | 1.3 | 0.6 | 0.2 | 0.7 | 1.5 | 1.8 |
| Reallocation of hours | -0.1 | -0.2 | 0.0 | 0.3 | -0.2 | -0.3 | -0.2 |
| Total economy | 2.5 | 1.9 | 1.8 | 1.7 | 1.5 | 2.5 | 2.5 |

Source: GGDC Industry Growth Accounting Database, see www.ggdc.net for data. See Section 2 and Inklaar et al. (2005) for methods, and Section 3 and Appendix B for sources

Notes: Market economy includes all industries except real estate (ISIC70) government (ISIC75), education (ISIC80) and health (ISIC85). Labour productivity and TFP contributions are calculated using the share of industry value added in market economy value added. ICT/non-ICT capital contributions are calculated using the share of industry ICT/non-ICT capital compensation in aggregate value added. Labour quality contributions are calculated analogously based on industry labour compensation. Reallocation of hours is the difference between output-weighted industry growth in total hours worked and employment-weighted growth in total hours worked. ICT production includes electrical and optical equipment (ISIC30-33) and telecommunications (ISIC64). Goods-producing industries include all industries between ISIC01-41, except ICT production, market services includes all industries between ISIC45-74, except ICT production.

**Table 2: Input Contributions to Market Services Labour Productivity Growth, 1995-2003 (value added per hour worked, percentage growth and contributions)**

| | Australia | Canada | France | Germany | Nether-lands | United Kingdom | United States |
|---|---|---|---|---|---|---|---|
| ***1987-1995*** | | | | | | | |
| Market services (excl. ICT services) | 0.0 | 0.5 | 1.2 | 1.9 | 0.8 | 1.7 | 1.5 |
| *contributions from:* | | | | | | | |
| ICT capital deepening | 0.5 | 0.4 | 0.3 | 0.4 | 0.6 | 0.6 | 0.9 |
| Non-ICT capital deepening | -0.2 | 0.4 | 0.3 | 0.6 | 0.3 | 0.9 | 0.3 |
| Labour quality growth | 0.3 | 0.3 | 0.2 | 0.2 | 0.3 | 0.7 | 0.3 |
| TFP growth | -0.6 | -0.7 | 0.3 | 0.4 | -0.3 | -0.5 | 0.2 |
| Reallocation of hours | 0.0 | 0.0 | 0.1 | 0.4 | 0.0 | 0.0 | 0.0 |
| ***1995-2003*** | | | | | | | |
| Market services (excl. ICT services) | 2.8 | 2.4 | 0.9 | 0.9 | 1.1 | 2.2 | 2.7 |
| *contributions from:* | | | | | | | |
| ICT capital deepening | 0.9 | 0.5 | 0.5 | 0.6 | 0.9 | 0.9 | 1.3 |
| Non-ICT capital deepening | 0.1 | 0.2 | 0.0 | 0.3 | 0.4 | 0.6 | 0.4 |
| Labour quality growth | 0.2 | 0.1 | 0.2 | 0.0 | 0.1 | 0.2 | 0.1 |
| TFP growth | 1.7 | 1.4 | 0.1 | -0.5 | -0.4 | 0.5 | 0.9 |
| Reallocation of hours | -0.1 | 0.1 | 0.0 | 0.5 | 0.0 | 0.0 | -0.1 |

Sources and notes: see Table 1

**Table 3: Industry Contributions to Total Factor Productivity Growth in Market Services, 1995-2003, (percentage growth and contributions)**

| | Australia | Canada | France | Germany | Nether-lands | United Kingdom | United States |
|---|---|---|---|---|---|---|---|
| ***1995-2000*** | | | | | | | |
| Market services (excl. ICT services) | 0.8 | 1.3 | 0.3 | -0.4 | 0.2 | 0.0 | 0.6 |
| *contributions from:* | | | | | | | |
| Wholesale trade | 0.3 | 0.0 | 0.3 | 0.4 | 0.7 | 0.0 | 0.9 |
| Retail trade | 0.5 | 0.7 | 0.0 | 0.1 | 0.1 | -0.2 | 0.3 |
| Transport & storage | -0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.0 | 0.0 |
| Financial intermediation | 0.2 | -0.3 | 0.2 | 0.0 | -0.5 | 0.1 | 0.0 |
| Business services | -0.1 | 0.4 | -0.4 | -1.0 | -0.2 | 0.0 | -0.4 |
| Other market services(a) | 0.1 | 0.3 | -0.1 | -0.1 | -0.1 | 0.1 | -0.2 |
| ***2000-2003*** | | | | | | | |
| Market services (excl. ICT services) | 3.2 | 1.7 | -0.1 | -0.7 | -1.4 | 1.4 | 1.3 |
| *contributions from:* | | | | | | | |
| Wholesale trade | 0.4 | 0.4 | 0.2 | 0.2 | -0.1 | 0.4 | 0.3 |
| Retail trade | 0.0 | 0.3 | 0.0 | 0.3 | -0.1 | 0.2 | 0.2 |
| Transport & storage | 0.7 | 0.2 | -0.2 | -0.1 | -0.1 | 0.0 | 0.2 |
| Financial intermediation | 0.0 | 0.1 | -0.2 | 0.0 | -0.1 | 0.0 | 0.4 |
| Business services | 0.9 | 0.5 | -0.5 | -0.8 | -0.7 | 0.6 | 0.3 |
| Other market services(a) | 1.2 | 0.2 | 0.6 | -0.2 | -0.4 | 0.1 | -0.1 |

(a) Other market services include construction, hotels and restaurants and social & personal services.

Sources and notes: See Table 1

**Table 4: Labour Productivity Levels Relative to United States, 1987 and 2003 (value added per hour worked, US=100)**

| | Australia | Canada | France | Germany | Nether-lands | United Kingdom | United States |
|---|---|---|---|---|---|---|---|
| ***1997*** | | | | | | | |
| Market economy | 73 | 88 | 96 | 103 | 107 | 73 | 100 |
| ICT production | 65 | 89 | 100 | 98 | 73 | 117 | 100 |
| Goods-producing industries | 82 | 127 | 92 | 89 | 102 | 80 | 100 |
| Market services | 68 | 65 | 96 | 113 | 118 | 64 | 100 |
| Total economy | 83 | 98 | 107 | 112 | 122 | 84 | 100 |
| ***2003*** | | | | | | | |
| Market economy | 71 | 83 | 89 | 92 | 99 | 72 | 100 |
| ICT production | 42 | 59 | 98 | 84 | 68 | 124 | 100 |
| Goods-producing industries | 78 | 123 | 92 | 85 | 102 | 81 | 100 |
| Market services | 69 | 65 | 89 | 102 | 108 | 63 | 100 |
| Total economy | 82 | 95 | 103 | 105 | 115 | 84 | 100 |

Source: 1997: Supply and Use tables for individual countries from Inklaar and Timmer (2006) and PPPs from Timmer, Ypma and van Ark (2006); 2003 updated from 1997 with time series underlying table 1.

Notes: For methodology, see Inklaar and Timmer (2006)

**Table 5: Input Contributions to the Gap in Labour Productivity in Market Services, 1997 (value added per hour worked, gap measured as percentage productivity differential relative to the US)**

| | Australia | Canada | France | Germany | Nether-lands | United Kingdom |
|---|---|---|---|---|---|---|
| ***Market services (excl. ICT services)*** | -38.7 | -43.2 | -3.6 | 12.3 | 16.2 | -44.1 |
| *contributions from:* | | | | | | |
| ICT capital per hour worked | -9.3 | -9.1 | -7.4 | -3.2 | -4.9 | -10.1 |
| Non-ICT capital per hour worked | -3.9 | -6.8 | 8.4 | 21.2 | 4.0 | -7.2 |
| Labour composition | -4.1 | -1.6 | -6.3 | -8.0 | -0.6 | -4.2 |
| TFP | -21.3 | -25.6 | 1.6 | 2.3 | 17.8 | -22.5 |

Sources and notes: see Table 4. The gap is defined as the natural log of the level. The contributions of the different inputs are calculated by multiplying the gap in input level by the share of each input in value added.

**Table 6: Industry Contributions to the Gap in Total Factor Productivity in Market Services, 1997 (gap measured as percentage productivity differential relative to the US)**

| | Australia | Canada | France | Germany | Nether-lands | United Kingdom |
|---|---|---|---|---|---|---|
| ***Total Factor Productivity*** | | | | | | |
| Market services (excl. ICT services) | -21.3 | -25.6 | 1.6 | 2.3 | 17.8 | -22.5 |
| *contributions from:* | | | | | | |
| Wholesale trade | -5.0 | -1.8 | 5.1 | 6.6 | 7.8 | 0.6 |
| Retail trade | -2.1 | -2.0 | 3.0 | 2.9 | 2.3 | -1.5 |
| Transport & storage | -0.4 | -0.8 | -0.4 | -1.7 | 4.4 | -2.2 |
| Financial intermediation | 7.4 | -1.9 | 4.6 | 1.8 | 6.6 | 3.4 |
| Business services | -14.5 | -12.7 | -12.6 | -8.8 | -9.7 | -11.1 |
| Other market services(a) | -6.7 | -6.4 | 1.9 | 1.4 | 6.3 | -11.8 |

(a) Other market services include construction, hotels and restaurants and social & personal services.
Sources and notes: see Table 4. The gap is defined as the natural log of the level. The contributions of the different industries are calculated by multiplying the gap in productivity levels by the share of each industry in value added. Due to index number problems, the contributions have to be normalized by distributing the difference between the sum of the contributions and the aggregate according to each industry's share in value added.

## Appendix: Price and quantity aggregation and the CCD index

The main conceptual challenge in comparing productivity across countries rather than over time is that production structures across countries are generally much more different than the structure of a particular country in one year compared to the next. This means the assumption of a common translog production function (up to a scalar) that is the theoretical basis for the Caves *et al.* (CCD, 1982) index, becomes harder to justify. Translog functions provide an approximation to any twice differentiable production function, but countries might very well differ in their second-order parameters. This leads to increased sensitivity to the choice of the index number formula in calculating productivity. A large difference in prices and quantities across countries also means that the choice between aggregating quantities directly or aggregating prices (and calculating relative quantities implicitly) is no longer trivial for index numbers which do not pass the factor reversal test, such as the Törnqvist underlying CCD (see Allen and Diewert, 1981).

One straightforward way of dealing with the latter problem is using the Fisher index (or its EKS-counterpart), as direct and implicit quantity indices are the same for this index, i.e. the index does pass the factor reversal test. This is not the case for the CCD index, so then a choice has to be made between a direct and an implicit quantity index. Allen and Diewert (1981) argue that if the price ratios vary more than the quantity ratios, a direct quantity index is to be preferred. However, in our dataset, price ratios are less variable in nearly all cases, suggesting that price aggregation and implicit quantity indices will yield more precise results. On average, the difference between direct and implicit quantity indices when aggregating over inputs for each industry in our dataset is about 5 percent, but in some cases the difference is larger than 20 percent. Therefore, we choose to work with implicit quantity indices in the main body of this paper.

However, the choice for direct or implicit quantity indices will do nothing to address the first problem, namely that any index number will be a worse approximation to an underlying production function if differences in production structure are larger. An approach that is gaining currency is to determine which countries are more similar to each other and either to give those country couples a larger weight in a multi-country comparison or to find a method to 'chain' the most similar country couples. This makes the comparisons less sensitive to the choice of the index number formula.[21]

Weighted methods have been proposed for minimum spanning tree (MST) and EKS. Hill (1999) proposed the minimum spanning tree (MST) method to 'chain' the most similar country couples in the context of comparing expenditure price levels across countries.[22] In this method, the country couple that is most similar is the first element of the chain, the country couple that is the most similar after that is the second element, and so on until all countries are connected once either directly or indirectly. Rao and Timmer (2003) describe a weighted EKS method, where the country couples receive a larger weight if

[21] The latter method is an extreme form of chaining as it put zero weight on comparisons that are not along the chain of most similar country couples.
[22] The basic problem that an index number is not a good approximation if country differences are large holds for utility functions in the same way as for production functions.

they are more similar. One advantage of this index is that, unlike the MST-index, the weighted EKS index is still transitive. Of course, to implement either method, weights measures are needed. One well-known measure is the Paasche-Laspeyres spread, but Diewert (2006) provides a more general overview of dissimilarity indices. Hill and Timmer (2006) suggest the use of standard errors as weights in multilateral price indexes.

In the main text we presented results based on implicit CCD quantity indices, i.e. we aggregated price ratios and computed the quantity indices implicitly. To test the sensitivity of this approach, we calculated a series of aggregate input indices for each industry and country relative to the U.S. So we aggregate over 53 inputs (45 intermediates, six capital types and two labour types) for 26 industries and six countries relative to the U.S. Our base case is the CCD index of prices or quantities and we compare each alternative index to the CCD index. Various alternatives are considered. The first distinction is between indices that are based on bilateral Törnqvist indices, such as the CCD index, and indices based on bilateral Fisher indices. Second, in addition to the standard, unweighted EKS index, we compute a series of weighted EKS indices and a series of MST indices. For the weighted multilateral indices three variants are introduced: weights based on the Paasche-Laspeyres spread and the two dissimilarity indices as recommended by Diewert (2006).

Table A.2 shows the results from this exercise. The first two columns refer to price indices, whereas the last two columns refer to quantities. First of all, this table shows that in the case of multilateralization of price indices, the choice of either Törnqvist or Fisher bilateral indices is inconsequential. The difference between an EKS based on Törnqvist input price indices and one based on Fisher indices differs on average only 0.2 percent over the 26 industries and six country comparisons relative to the U.S. (see first row). However, quantity indices can vary widely: direct Törnqvist and Fisher based PPPs differ on average 7.4 percent with a large standard deviation (see first row). This is in line with Allen and Diewert (1981) who recommended using implicit quantity indices if price ratios are less variable than quantity ratios as is the case in this dataset.

The second finding is that using weights in the multilateralization procedure leads to only modest differences. Column 1 indicates that weights EKS price indices differ on average one percent or less from the CCD index. Differences with MST variants are bigger, but no larger than 2.5 percent and the holds for Fisher-based multilateral indices as well (see column 2).

These findings argue in favour of using aggregate price indices to implicitly estimate quantity indices as the results will be less affected by the choice of index number method. It is also worth noting that the correlation between the different price and quantity indices is very high (>0.99 on average). In other words, the choice of index number method is a relatively minor source of variation compared to other price and quantity differences across industries and countries. Taken together, the reasons for using another index than the CCD index do not seem pressing.

**Table A.1, Industry list**

| *Industry* | *ISIC rev3 code* |
|---|---|
| Agriculture, forestry and fishing | 01-05 |
| Mining and quarrying | 10-14 |
| Food products | 15-16 |
| Textiles, clothing and leather | 17-19 |
| Wood products | 20 |
| Paper, printing and publishing | 21-22 |
| Petroleum and coal products | 23 |
| Chemical products | 24 |
| Rubber and plastics | 25 |
| Non-metalic mineral products | 26 |
| Metal products | 27-28 |
| Machinery | 29 |
| Electrical and optical equipment | 30-33 |
| Transport equipment | 34-35 |
| Furniture and miscellaneous manufacturing | 36-37 |
| Electricity, gas and water | 40-41 |
| Construction | 45 |
| Wholesale trade | 50-51 |
| Retail trade | 52 |
| Hotels and restaurants | 55 |
| Transport & storage | 60-63 |
| Communications | 64 |
| Financial intermediation | 65-67 |
| Business services | 71-74 |
| Social and personal services | 90-99 |
| Non-market services | 75-85 |

**Table A.2: Absolute differences of alternative index number formula relative to the CCD index, average % difference (standard deviation)**

| | Price | | | | Quantity | | | |
|---|---|---|---|---|---|---|---|---|
| | Törnqvist | | Fisher | | Törnqvist | | Fisher | |
| EKS | *(base case)* | | 0.2 | (0.2) | *(base case)* | | 7.4 | (7.9) |
| Weighted EKS (P-L spread) | 0.6 | (0.9) | 0.6 | (0.9) | 1.7 | (1.6) | 7.0 | (7.4) |
| Weighted EKS (linear dissimilarity) | 0.6 | (0.7) | 0.6 | (0.7) | 1.9 | (2.4) | 7.4 | (8.1) |
| Weighted EKS (quadratic dissimilarity) | 1.0 | (0.9) | 1.0 | (0.9) | 3.4 | (3.5) | 7.5 | (8.2) |
| MST (P-L spread) | 1.6 | (1.5) | 1.5 | (1.4) | 4.1 | (4.8) | 6.2 | (6.6) |
| MST (linear dissimilarity) | 1.8 | (1.9) | 1.8 | (1.7) | 4.4 | (4.1) | 7.9 | (8.3) |
| MST (quadratic dissimilarity) | 2.5 | (3.3) | 2.4 | (3.1) | 4.0 | (3.7) | 7.4 | (7.5) |

Notes: Input prices and quantities are aggregated to a single input index for each industry (out of 26) for each country relative to the U.S. (6 countries). CCD: Caves *et al.* (1982), see main text. EKS: multilateral index based on geometric mean of all bilateral indices. Weighted EKS: same as EKS, but weighted geometric mean. MST: Minimum Spanning Tree index based on Hill (1999); see Appendix text for further details. P-L spread: log difference between Paasche and Laspeyres indices. Linear dissimilarity: sum of weighted asymptotically linear index of relative price dissimilarity and relative quantity dissimilarity (Diewert, 2006). Quadratic dissimilarity: sum of weighted asymptotically quadratic index of relative price dissimilarity and relative quantity dissimilarity (Diewert, 2006).

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