GGDC PRODUCTIVITY LEVEL DATABASE:

INTERNATIONAL COMPARISONS OF OUTPUT, INPUTS AND PRODUCTIVITY AT THE INDUSTRY LEVEL

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Abstract
In this paper we introduce the GGDC Productivity Level database. This database provides comparisons of output, inputs and productivity at a detailed industry level for a set of thirty OECD countries. It complements the EU KLEMS growth and productivity accounts by providing comparative levels and follows it in terms of country and industry coverage, variable definition and basic data (O'Mahony and Timmer, 2008). As such, the level and growth accounts can be used together in comparative analyses of productivity trends. The methodology followed is based on Jorgenson and Nishimizu (1985), but includes a number of refinements such as the use of sectoral output and input measures that exclude intra-industry flows; the application of multilateral indices; use of relative output prices from the production side and the use of the ex-ante approach to capital price measurement. The paper outlines the construction and contents of the database and presents some empirical results. The GGDC Productivity Level database is publicly available at www.ggdc.net/databases/levels.htm.

CONTENTS

1. INTRODUCTION

This paper introduces the GGDC Productivity Level database. This database provides comparisons of output, inputs and productivity at a detailed industry level for a set of thirty OECD countries. It complements the EU KLEMS growth and productivity accounts by providing comparative levels and follows it in terms of country and industry coverage, variable definition and basic data (O'Mahony and Timmer, 2008). As such, the level and growth accounts can be used together in comparative analyses of productivity trends

Productivity level comparisons at the aggregate economy level for large set of countries are nowadays routinely being produced by various statistical organisations and in academia.[1] The most useful analytical applications of productivity levels, however, are at the level of individual industries. Because of significant methodological and data-related problems comprehensive sets of industry productivity levels have been scarce.[2] There is a long tradition at the Groningen Growth and Development Centre (GGDC) and the National Institute for Economic and Social Research (NIESR) to provide industry-level productivity comparisons for sets of countries and industries. Recent studies include Inklaar, Timmer and van Ark (2006); Timmer and Ypma (2006); Inklaar, O'Mahony, Robinson and Timmer (2003); O'Mahony and de Boer (2002) and various other sectoral studies by the GGDC.[3] The GGDC estimates for manufacturing and selected services industries have been published on a continuous basis in the bi-annual ILO Key Indicators of the Labour Market (KILM) database.

However, so far most of these studies were on comparative labour productivity levels, rather than multi-factor productivity. Also, they were based on a value added rather than a gross output concept. The main reason has been a lack of comparable data on inter-industry transactions, labour and capital service flows and purchasing power parities.[4] In this paper we extend the work by Inklaar and Timmer (2007) and present the GGDC Productivity Level database. These accounts provide new multilateral comparisons of output, inputs and productivity for 26 detailed industries covering the whole economy for a set of 30 OECD countries.

[1] Most notably, the OECD Productivity database provides estimates for OECD countries (OECD 2008) and the The Conference Board and Groningen Growth and Development Centre, Total Economy Database, (http://www.conference-board.org/economics/database.cfm), provides estimates for 125 countries world wide.

[2] These include studies at the Groningen Growth and Development Centre, the National Institute of Economic and Social Research, OECD (Pilat, 1996) and Jorgenson and collaborators (Jorgenson, 1995).

[3] See www.ggdc.net for an overview.

[4] Jorgenson and Yip (2001) and Schreyer (2007) provide relative MFP levels at the aggregate level for G7 countries. At the industry level, interspatial comparisons of multifactor productivity at industry level are available for only a limited number of OECD countries. Dollar and Wolff (1993), van Ark and Pilat (1993), O'Mahony (1996) and O'Mahony and de Boer (2002) provide (single deflated) value added-based MFP comparisons. The seminal application of the gross-output MFP methodology at industry level is Conrad and Jorgenson (1985) on Germany-Japan-US. Jorgenson, Nishimizu and Kuroda (1987) and Jorgenson and Nomura (2007) provide comparisons of Japan and the US; and Gu, Lee and Tang (2000) and Baldwin, Gu and Yan (2008) on Canada and the US. Most recently Inklaar and Timmer (2007) provide gross-output MFP comparisons of on Australia, Canada, France, Germany, Netherlands, UK and US.

The paper is organised as follows. In **Section 2**, we introduce various measures of productivity levels, their meaning and possible uses. **Section 3** describes the basic methodology of productivity level comparisons. The methodology for level comparisons has been firmly based in the neo-classical theory of production by Jorgenson and associates (Jorgenson and Nishimizu, 1985; Jorgenson, 1995). Instead of comparing output and input combinations of one country at two different points in time as in growth accounting, one compares input-output combinations of two different countries at a similar point of time. Hence the term "level comparison" is used to contrast it with growth comparisons. Our approach includes a range of refinements such as the use of sectoral output and input measures that exclude intra-industry flows (as advocated by Gollop 1979 for growth acounts, and applied in a level account setting by Inklaar and Timmer, 2007); the application of multilateral indices (as suggested by Christensen, Cummings and Diewert, 1982); use of relative output prices from the production side (as developed in Timmer, Ypma and van Ark 2007) and the use of the exogenous approach to capital measurement (as advocated by Oulton, 2007). These issues are discussed in **Section 4**. In **Section 5**, we present our basic data sources. Basically, our level comparisons are based on deflating nominal inputs and output as given in national input-output tables by a set of relative prices (PPPs). We use a new set of relative output prices which is specifically developed for making cross-country, industry-level productivity comparisons. These are complemented by relative prices for capital and labour inputs. Prices for capital are derived using the ex-ante (or exogenous) approach. In **Section 6**, the contents and the coverage of the database are being discussed. **Section 7** provides some empirical results by way of illustration of the possible applications of the database. **Section 8** concludes

2. PRODUCTIVITY LEVELS AND THEIR USES

This paper is about comparisons of output, inputs and productivity levels across space (countries or regions). Level comparisons can be useful for various purposes, for example, in the light of the debate on sources of growth. In recent years there has been an intense interest in the effects of ICT on economic growth. Much of this was sparked by research showing that ICT played an important role in the acceleration in U.S. labour productivity growth after 1995. Comparative studies tried to explain Europe's lagging behind and showed that differences in ICT investment played a major role in the transatlantic divergence process, and MFP growth lagged mainly in market services.[5] The results from these growth accounting studies can be put in perspective by linking them to the level comparisons provided in this paper. The interpretation of comparative growth patterns will depend on the initial starting position in terms of levels. For example, if growth is fastest in the country with the lowest initial level, this can be seen as catch-up growth in which follower countries converge to more advanced countries through imitation and spillover of technologies. In this framework one can study the impact of regulation, trade or R&D

[5] See for an overview Jorgenson *et al.* (2005) and van Ark, O'Mahony and Timmer (2008).

expenditures on economic growth.[6] In addition, comparisons of input levels can shed new light on issues such as the relative ICT capital intensity of various economies. It measures the differences in the penetration of new technology in the production process. Relative levels of energy, materials and services inputs can be important measures in debates on outsourcing of service activities, international differences in production structures and energy use and reduction strategies.

Comparative productivity levels require ratios of output as well as ratios of inputs between two (or more) countries. The simplest way to obtain output ratios is to compare physical output measures, such as weight, volume or area. For example, when a labourer in the cement industry in country A produces 100 tons of cement per year on average compared to 200 tons per labourer in country B, 'physical labour productivity' in the cement industry in country A is half that of country B. Nowadays the use of physical units of output for productivity measurement is mostly restricted to benchmarking the efficiency of a particular production process for a specified product or for a closely related group of products over time. When comparing productivity at firm or industry level, the heterogeneity of output and the large variety of products makes the use of physical units irrelevant. Moreover it is often difficult to exclusively allocate inputs to one single output. In services, the use of physical units is often not at all possible. In practice, one is more likely to have only access to figures on the total values rather than quantities of output and inputs. For comparisons of productivity levels across space, value measures need to be corrected for differences in relative prices between countries. This correction can be made by using purchasing power parities (PPPs), which specify the ratio of the price for a good or service, or for a bundle of goods and services, between two countries (see Section 4.2).[7]

The literature distinguishes many different measures and concepts of productivity, each of which has its particular meaning and use. Broadly, productivity measures can be classified into single-factor productivity measures (relating a measure of output to a single measure of input) and multi-factor productivity measures (relating a measure of output to a bundle of inputs). Another distinction is between productivity measures that relate gross output to one or several inputs and those that use a value-added concept to capture movements of output. The choice between the various measures depends in first instance on the focus and the purpose of the comparison. In Table 1 an overview is given of the productivity measures used in this study and their abbreviations

Table 1 Overview of the industry-level productivity measures used in this study

	Value added based	Sectoral output based
Single productivity measures	LP_VASD, LP_VADD	LP_SO
Multi factor productivity measures	MFP_VASD, MFP_VADD	MFP_SO

[6] See e.g. Griffith *et al.* (2004) and Inklaar, Timmer and van Ark (2008).

[7] A term "purchasing power parity" typically indicates relative levels of expenditure prices, but in practice is also used for relative levels of production prices between countries (see Section 4).

Most single productivity comparisons have focused on comparisons of value added per person employed or per hour worked. Combined with information for wages, this measure allows the comparison of unit labour cost, which shed light on the relationship between productivity and competitiveness (ILO, 2001; OECD 2008). At the aggregate level, labour productivity measures can be combined with measures on the utilisation of the labour potential (*e.g.* employment-population rates) to provide measures of cross-country differentials in per capita income levels (Van Ark and McGuckin, 1999; OECD, 2008). At industry level, gaps in labour productivity levels indicate the scope for further catch up relative to the productivity leaders. They capture differences in technology in its broadest sense including differences in capital intensity, capital quality, human capital, economies of scale and intangibles such as management techniques.

One might also be interested in single productivity measures based on other inputs than labour only. These measures provides insights from a production technology perspective. For example, they can indicate the use of energy inputs per unit of output in an industry. One might also be interested in the use of other intermediate inputs such as materials or services (see e.g. Inklaar and Timmer, 2007). Labour and capital inputs can be further subdivided into various groups of labour and capital so that one can compare the use of high-skilled labour or ICT-capital across countries. This is illustrated in section 6.

Measures of multi-factor productivity (MFP) provide an indication of relative levels of the efficiency of input use between countries. MFP levels are measured as the difference in output between countries when differences in all inputs have been accounted for. Based on the economic theory of production, differences in MFP levels can be interpreted as differences in the level of disembodied technology. Technology is defined here narrowly as level differences in the production functions of countries. MFP does not, for example, include technology differences that are embodied in the use of capital goods. However, this interpretation of MFP levels is only true under a stringent set of assumptions including an identical production function, constant returns to scale, competitive markets and technical and allocative efficiency. Moreover, input measures must adequately reflect differences in adjustment costs, cyclical effects and input quality between countries (see Schreyer 2001, Chapter 2, for further discussion). Finally, the interpretation from economic theory of MFP as a measure of technology is based on firms as decision-making units involved in revenue maximisation or cost minimisation. In analyses of higher level aggregates such as industries, sectors or aggregate economies, this interpretation only applies under very restrictive aggregation conditions. Hence MFP is also called a "measure of our ignorance" and differences in MFP levels should therefore be interpreted with care.

Multifactor-based productivity measures are well rooted in economic theory but due to their heavy data requirements much less common in international comparisons of relative levels than single factor-based measures. For multi-factor productivity comparisons, in theory, gross-output MFP measures are to be preferred over value-added MFP measures at all levels of aggregation. As technological change often affects all inputs, and not only the primary factor inputs labour and capital, gross output-based MFP levels better reflect differences in technology than value added-based ones. From the producer's perspective there is no inherent difference in the primary inputs (labour and capital) and intermediate inputs (materials, energy and service inputs). Production decisions are made for all inputs simultaneously and substitution between all inputs can take place, making them non-separable. Instead, value added-based MFP measures provide only an indication of the importance of the productivity differences in factor inputs (capital and labour) for the economy as a whole.

In principle, when the value added-based measure is obtained by independent comparisons of gross output and intermediate inputs with their own PPPs (so-called "*double deflation*"), the data requirements for value-added and gross output-based comparisons of productivity are the same. Therefore, *single-deflated* value added measures (using the PPPs for gross output to deflate value added) are often used in MFP comparisons due to lack of detailed price and quantity data on intermediate inputs. This is discussed extensively in section 4.3. An additional problem in deriving meaningful gross-output based MFP comparisons at the industry level concerns the need for *sectoral output* measures, that is, output in an industry excluding the transactions that occur within the industry, *i.e.* intra-industry deliveries of intermediate products. This is discussed in Section 4.4.

MFP and labour productivity measures are not independent from each other. Multifactor productivity measures can be used to explain single factor productivity differences. For example, differences in labour productivity levels can be explained by differences in the ratio of capital to labour, and differences in multi-factor productivity. These, and other, links have been established with the help of the economic theory of production (see section 3.1.3). In practice, single and multifactor productivity measures are close when one input accounts for a large part of the total value of inputs. For example, in some service sectors, where labour makes up the bulk of input costs, labour productivity measures will be close to measures of MFP. However, this is not to be expected in all industries.

The GGDC Productivity Level database provides estimates of productivity based on both gross output and value added. In the latter case, estimates are based both on single- and double deflation. The full contents of the database are described in Section 5.

3. BASIC METHODOLOGY

In this section we present our methodology for comparing levels of output, input and productivity across countries. As we are trying to construct a consistent set of productivity measures for a large number of countries and industries at the same time, various choices have to be made not only concerning the use of particular index number formulae, but also their actual implementation. In Section 4 we describe the various implementation issues. In this section the basic methodology is laid out.

Basically, our approach has two stages: at the lowest level, comparable sets of national symmetric input-output tables (SIOT) and detailed output and input PPPs are constructed at the level of 45 sub-industries. The construction of this basic data and the underlying data sources are discussed in Section 5. In this section we describe the second stage which consists of two steps. In the first step, PPPs for output, capital, labour and intermediate inputs for 29 industries are derived based on the data for 45 sub-industries. This is done with the price-variant of the multilateral index number approach advocated by Caves *et al.* (1982), also known as CCD-method. These PPPs are used to implicitly derive quantities of all inputs (capital, labour and intermediate inputs) and output. In the second step, productivity comparisons are made for each industry on the basis of input and output quantities in a bilateral Tornqvist model following Jorgenson and Nishimizu (1987). This approach is also known as primal level accounting. In this section we first outline our basic methodology for measuring productivity (3.1), followed by our approach to deriving PPPs for outputs and inputs (section 3.2).

3.1 Productivity measures

The main aim of the GGDC Productivity Level database is to provide productivity comparisons between countries. The accounts provide so-called binary comparisons, that is comparisons between a country c and a base country which is the same in all comparisons. As most interest is in comparing the performance of countries to the world productivity and technology leader, it is natural to choose the U.S. as our base country. Alternative bilateral comparisons with other countries as the base can be made using the same approach by simply replacing the US by another base country (see Section 4.5 for a discussion of multilateral models). In this section we assume that all comparisons are made with the U.S.

3.1.1 Labour productivity levels

The most commonly used single productivity measure for international comparisons of levels is labour productivity. This is generally defined as an output measure divided by a labour input measure. The labour input measure can be the number of persons employed, employees or hours worked. The output measure can either be the volume of gross output or the volume of value added. We define the gross output-based measure of labour productivity as follows. Let Q^{SO} be a volume measure of gross output and let H be hours worked. Then the volume measure of labour productivity in country c relative to the US based on gross output (LP_SO) is given by:[8]

$$LP\_SO_c = \frac{Q_c^{SO} / H_c}{Q_{US}^{SO} / H_{US}} \qquad (3.1)$$

Similarly, comparisons of value-added based labour productivity (LP_VA) are given by

$$LP\_VA_c = \frac{Q_c^{VA} / H_c}{Q_{US}^{VA} / H_{US}} \qquad (3.2)$$

[8]For simplicity, a time index t is omitted. All prices, quantities and values refer to the same point of time. See section 7 for spatial comparisons over time.

3.1.2 Multi-factor productivity levels

Comparisons of multi-factor productivity account for more than one input. The GGDC Level accounts provide estimates for value-added based MFP taking into account both labour and capital services, and gross-output based MFP taking into account labour, capital and intermediate inputs. Following Jorgenson and Nishimizu (1987), we define the following translog quantity index of difference in multi factor productivity based on gross output (MFP_SO) as follows

$$\ln MFP\_SO_c = \ln \frac{Q_c^{SO}}{Q_{US}^{SO}} - \hat{v}_K \ln \frac{Q_c^K}{Q_{US}^K} - \hat{v}_L \ln \frac{Q_c^L}{Q_{US}^L} - \hat{v}_{II} \ln \frac{Q_c^{II}}{Q_{US}^{II}} \qquad (3.3)$$

with Q^K a quantity index of capital services, Q^L a quantity index of labour services and Q^{II} a quantity index of intermediate input services. $\hat{v}_K$ is the share of capital services in total costs averaged over the two countries: $\hat{v}_K = v_c^K + v_{US}^K$ with $v_c^K = \frac{V_c^K}{\left(V_c^K + V_c^L + V_c^{II}\right)}$ and V_c^K is the nominal value of capital services. $\hat{v}_L$ and $\hat{v}_{II}$ are defined in a similar way for labour and intermediate inputs. Because of the assumption of constant returns to scale, the shares add to one: $\hat{v}_K + \hat{v}_L + \hat{v}_{II} = 1$.

Alternatively, one can also define relative MFP measures based on value added rather than sectoral output (MFP_VA). This index is defined as follows:

$$\ln MFP\_VA_c = \ln \frac{Q_c^{VA}}{Q_{US}^{VA}} - \hat{w}_K \ln \frac{Q_c^K}{Q_{US}^K} - \hat{w}_L \ln \frac{Q_c^L}{Q_{US}^L} \qquad (3.4)$$

where $\hat{w}_K$ is the share of capital services in value added averaged over the two countries $\hat{w}_K = w_c^K + w_{US}^K$ with $w_c^K = \frac{V_c^K}{\left(V_c^K + V_c^L\right)}$ and similarly for labour such that $\hat{w}_K + \hat{w}_L = 1$.

Although value added-based and gross-output based MFP measures reflect different concepts, there is a direct theoretical relationship between the two MFP measures. For two countries with identical value added-gross output ratios, the difference in value-added based MFP equals the difference in gross-output MFP, multiplied by the inverse of the nominal share of value added in gross output.[9] However, value added shares are generally not the same across countries and an adjustment reflecting the difference in the value added-gross output ratios is needed (see Baily, 1986 for the intertemporal case).

The formulas indicate that comparable volume measures of output and input for the two countries are needed. When a single output is being compared, physical measures, such as numbers of cars, are possible. However, when comparisons are made at the industry or aggregate level where output is not represented by a single product, output is given in value terms. In that case a correction for differences in relative price levels between countries is needed. This is usually done

[9] Obviously, this relationship only exists when volume measures of value added and output are consistent, that is, value added is double deflated, see section 4.3.

with a purchasing power parity (PPP) which indicates the relative price of output in one country relative to another country. The derivation of the PPPs is further discussed in Section 5.

Volume indices are calculated implicitly by the ratio of the nominal values and the relevant price indices. For example, aggregate output quantity in country c is given by

$$Q_c^{SO} = \frac{V_c^{SO}}{PPP_c^{SO}} \qquad (3.5)$$

with V_c^{SO} the nominal value of output in country c (that is, in national currency) and PPP_c^{SO} the relative price of output in country c compared to the base country. Similarly, for value added:

$$Q_c^{VA} = \frac{V_c^{VA}}{PPP_c^{VA}} \qquad (3.6)$$

and for intermediate inputs:

$$Q_c^{II} = \frac{V_c^{II}}{PPP_c^{II}} \qquad (3.7)$$

For labour input one can use number of workers or total hours worked as a volume measure. This is typically done in labour productivity measures such as (3.1) and (3.2). However, for multi factor productivity comparisons one would also like to include the composition of labour in terms of various labour types with different productivities, e.g. low- and high-skilled labour. This can be done by choosing an appropriate PPP based on relative wages as discussed in section 5:

$$Q_c^{L} = \frac{V_c^{L}}{PPP_c^{L}} \qquad (3.8)$$

with V_c^L the nominal value of labour compensation in country c (that is, in national currency) and PPP_c^L the relative price of labour services in country c. And similarly for aggregate capital input in country c:

$$Q_c^{K} = \frac{\widetilde{V}_c^{K}}{PPP_c^{K}} \qquad (3.9)$$

with $\widetilde{V}_c^K$ the nominal value of ex-ante capital compensation in country c and PPP_c^K the relative price of capital services in country c. Note that because of our approach to capital measurement, capital compensation in this formula ($\widetilde{V}_c^K$) is based on ex-ante measures of rates of return and will differ from the ex-post measure of capital compensation V_c^K used in equations (3.3) and (3.4). More specifically,

$$V_c^{K} = \widetilde{V}_c^{K} + V_c^{R} \qquad (3.10)$$

where V_c^R is (supra-normal) profits, see section 4.1 for an elaborate discussion.

3.1.3 Level Accounting

One of the main applications in productivity comparisons is the so-called level accounting.[10] Level accounts provide a decomposition of differences in value added per hour worked into differences in capital per hour worked (capital intensity), in labour composition (skill intensity) and in MFP. This decomposition is done as follows:

$$\ln \frac{VA_c / H_c}{VA_{US} / H_{US}} = \hat{w}_L \ln \frac{Q_c^L / H_c}{Q_{US}^L / H_{US}} + \hat{w}_K \ln \frac{Q_c^K / H_c}{Q_{US}^K / H_{US}} + \ln MFP\_VA_c \quad (3.11)$$

where $\hat{w}_L$ and $\hat{w}_K$ are defined as in equation (3.4).

Similarly, one can decompose output per hour worked as follows:

$$\ln \frac{VA_c / H_c}{VA_{US} / H_{US}} = \hat{v}_{II} \ln \frac{Q_c^{II} / H_c}{Q_{US}^{II} / H_{US}} + \hat{v}_L \ln \frac{Q_c^L / H_c}{Q_{US}^L / H_{US}} + \hat{v}_K \ln \frac{Q_c^K / H_c}{Q_{US}^K / H_{US}} + \ln MFP\_SO_c \quad (3.12)$$

with the weights as defined in (3.3).

The calculation of productivity measures and the decomposition are defined according to the formula's above at each level of industry aggregation. As such it follows the approach in the EU KLEMS Growth Accounts. The link between industry-level and aggregate productivity level differences can be of considerable importance if one is interested in the contribution of individual industries to overall productivity level differences. The precise form of the aggregation procedure depends on the productivity measure used. This is well-known in the context of growth accounting (see Schreyer, 2001 and Corrado et al., 2007 for a recent application). However, weighting schemes like Domar (1961) have not been extended to an open economy setting, yet, let alone in the context of multilateral level comparisons instead of growth comparisons. This is avenue for further research.

Comparisons of multi-factor productivity can be made using the so-called primal and dual approaches. In the primal approach relative MPF levels are based on comparisons of quantities as we do here. Alternatively, in the dual approach they are based on comparisons of prices. Usually, productivity measures are expressed in terms of relative quantities, as this is most closely related to the notion of production as a physical process in which quantities of inputs are converted into quantities of outputs. In theory, the two different estimates should be close, but in practice this is not always the case, in particular when production structures differ considerably between the two countries being compared. We opt for the primal approach as we are interested in a full and consistent decomposition of output quantities, rather than output prices.

3.2 PPPs for output and inputs

To calculate quantities of input and output, nominal values are deflated by relative prices (PPPs) as in formula's (3.5)-(3.9). The PPPs for outputs and inputs are derived on the basis of detailed

[10] Level accounting is also known as development accounting (see e.g. Caselli, 2005). We stick to the name level accounting as it most clearly indicates the difference and similarity with growth accounting.

sets of output and input prices. Prices are aggregated using the multilateral translog price indices introduced by Caves, Christensen and Diewert (1982) (CCD-index). Basically, in this methodology one creates an artificial country by averaging over all countries in the data set, and uses this constructed country as a bridge when making binary comparisons between two countries.[11] This creates so-called transitive PPPs (see 4.6 for more) which are base-country independent. For convenience, the PPPs are normalised with U.S. as 1 in the database.

Let i be the components of output, then the multilateral output price of country c (PPP_c^{SO}) is defined as follows:

$$\ln PPP_c^{SO} = \sum_i \hat{v}_{i,c} \left[\ln PPP_{i,c}^{SO} - \overline{\ln PPP_i^{SO}} \right] \qquad (3.13)$$

with $\hat{v}_{i,c} = \frac{1}{2}[v_{i,c} + \Sigma_q (v_{i,q} / N)]$ and $v_{i,c} = p_{i,c}^{SO} Q_{i,c}^{SO} / V_c^{SO}$ the share of component i in nominal sectoral output in country c. A bar indicates a geometric average over all countries indexed by q=1,..,N and N is the number of countries, in this case: $\overline{\ln PPP_i^{SO}} = \frac{1}{N} \sum_q \ln PPP_{i,q}^{SO}$.

Similarly the relative price of capital input (PPP_c^K) is derived as

$$\ln PPP_c^{K} = \sum_k \hat{v}_{k,c} \left[\ln PPP_{k,c}^{K} - \overline{\ln PPP_k^{K}} \right] \qquad (3.14)$$

with $\hat{v}_{k,c} = \frac{1}{2}[v_{k,c} + \Sigma_q (v_{k,q} / N)]$ and $v_{k,c} = p_{k,c}^{K} Q_{k,c}^{K} / \widetilde{V}_c^{K}$ the share of asset k in total ex ante nominal capital compensation in country c, with k the components of K. See section 5.1 for the measurement of capital service prices $p_{k,c}^K$.

Similarly for labour:

$$\ln PPP_c^{L} = \sum_l \hat{v}_{l,c} \left[\ln PPP_{l,c}^{L} - \overline{\ln PPP_l^{L}} \right] \qquad (3.15)$$

where $v_{l,c}$ is the share of labour type l in total labour compensation in country c, and for intermediate goods:

$$\ln PPP_c^{II} = \sum_m \hat{v}_{m,c} \left[\ln PPP_{m,c}^{II} - \overline{\ln PPP_m^{II}} \right] \qquad (3.16)$$

where $v_{m,c}$ is the share of intermediate input type m in total intermediate input compensation in country c.

The indices in (3.14)-(3.16) are referred to as the translog price indices of capital, labour and intermediates. In the datafile which accompanies this paper, the inputs are further subdivided into eight groups: two groups of labour (high skilled and others), two groups of capital (ICT-capital and non-ICT capital), and four intermediate inputs: energy (*E*), materials (*M*) and services (*S*) and

[11] In practice, this involves applying an EKS procedure to a matrix of all possible binary Törnqvist indices.

imports (IMP). Aggregation across the different inputs in each group also follows the CCD-methodology exposed above.[12]

For value added, two alternative PPPs are provided in the database: one based on the output and intermediate input PPPs (in a procedure known as double deflation) and one based on the output PPP only (single deflation). In the first case a CCD-like approach is followed by taking a geometric mean of all possible binary Tornqvist indices for a particular country c. First, calculate the binary PPP for each country pair (c,q) as follows:

$$\left[\ln PPP_c^{VA} - \ln PPP_q^{VA}\right] = \frac{1}{1-\hat{v}_{II,c,q}}\left[\left(\ln PPP_c^{Y} - \ln PPP_q^{Y}\right) - \hat{v}_{II,c,q}\left(\ln PPP_c^{II} - \ln PPP_q^{II}\right)\right] \quad (3.17)$$

The weight $\hat{v}_{II,c,q}$ is the share of intermediate inputs in output, averaged over the two countries. Next, an EKS procedure is applied. The advantages and disadvantages of double deflation are discussed in more detail in section 4.3.

4. IMPLEMENTATION ISSUES

Although the theory of measuring productivity levels is relatively straightforward there is a high degree of freedom in the actual implementation of the various measures. In this section we discuss a number of the most important choices to be made in implementing the productivity level methodology which was outlined in the previous section. For tractability, this discussion is organised on a topic-by-topic basis although some of the problems are clearly intertwined. By providing alternative productivity estimates we will show that the choices to be made are far from trivial in an empirical sense as differences can be rather large. The following issues will be discussed:

- Ex-ante versus ex-post approaches to capital and productivity measurement. In this study we opt for the hybrid approach advocated by Oulton (2007) as outlined in section 4.1.
- Unit value ratios versus specified PPPs. In this study we opt for a mix, but also provide an alternative data set of estimates based on specified prices only. Differences are discussed in Section 4.2.

[12] This creates a small inconsistency as CCD-aggregation is not consistent in aggregation: the value of the index calculated in two stages does not necessarily coincide with the value of the index calculated in a single stage. For example, one can derive the total intermediate input PPP by aggregating directly from the most detailed product level available, or in two steps: first from products to the groups of *E*, *M*, *S* and imports, and in a second stage to total. Fortunately, the differences are quantitatively minor as superlative index numbers are approximately consistent in aggregation (Diewert 1978).

- Single versus double deflated value added. Theoretically, double deflated measures of value added are to be preferred, but in some cases estimates can become unstable. We provide both alternatives in our data files. Differences are discussed in Section 4.3.
- Sectoral versus gross output measures. To correct for international differences in vertical integration we opt for the sectoral output approach advocated by Gollop (1979). This has also implications for the aggregation procedures as discussed in Section 4.4.
- Multilateral CCD versus bilateral Tornqvist models of productivity. Mainly for expositional reasons and tractability, we opt for bilateral Tornqvist MFP measures. However output and input PPPs are based on CCD indices, see section 4.5.
- Extrapolation over time of the 1997 benchmark estimates, see section 4.6.

4.1 Ex-ante versus ex-post approaches to capital and productivity measurement

In our approach we use the so-called hybrid approach to capital and productivity measurement advocated by Oulton (2007). Basically, in the hybrid approach ex-ante measures are used in the calculation of capital input, but in the measurement of the contribution of capital to output, and hence of MFP, ex-post measures are used as in equations (3.3) and (3.4). Traditionally, ex-post measures are used in both the measurement of capital and productivity (Nishimizu and Jorgenson, 1981). It is favoured by most analysts of economic growth due to its strong foundation in neo-classical theory. Also in the EU KLEMS growth accounts use is made of the ex-post rather than the ex-ante approach. However, the practical and methodological reasons to opt for the ex-ante approach are stronger in the context of level comparisons than in the case of growth comparisons.

Schreyer (2004) highlights the problems in measuring capital in the ex-post approach when the set of assets in the analysis is not complete and argues in favour of the ex-ante approach. Balk (2007) argues that the ex-post approach is based on stringent assumptions of perfect foresight, constant returns to scale and competitive markets which are most likely not to hold in reality. Inklaar (2008) provides an empirical discussion of some of the alternatives to capital measurement in the case of the US. While in an analysis of growth over time of one country one might argue that possible deviations from the assumptions of perfect markets and constant returns to scale only slowly change, this is much harder to argue in the case of comparisons across countries. Moreover, in level-comparisons one has to assume that countries are the same in terms of their production functions and only differ up to a scalar, indicating their technology level.

An important practical disadvantage of the ex-post approach is the high volatility of the user cost of capital due to its nature as a residual measure. Growth accounts are usually made for analyses of growth during a period of say 5 or 10 years in which these errors are smoothed. However, level comparisons are made for one benchmark year only and hence are highly sensitive to short-run fluctuations in the rental prices. This causes problems especially at a low industry and asset level as capital compensation frequently turns out to be low or even negative for some assets in some years. In addition, the ex-post approach is more sensitive to measurement errors, for example concerning the classification of investment by asset type.

Given this, we opt for a hybrid approach using the ex-ante approach to capital measurement, but the ex-post approach to MFP measurement. This means that the rate of return of capital is not measured as a residual as in the ex-post approach, but is based on an ex-ante required rate of return as can be found in financial market data. In the ex-ante approach a difference will appear between total input costs and total output, which can be called (supra-normal) profits, see section 5. The calculation of the profits is outlined in Section 5.1. The contribution of capital to output is measured by multiplying its weight in total output (ex-ante capital compensation plus profits) as in formula's (3.3) and (3.4).

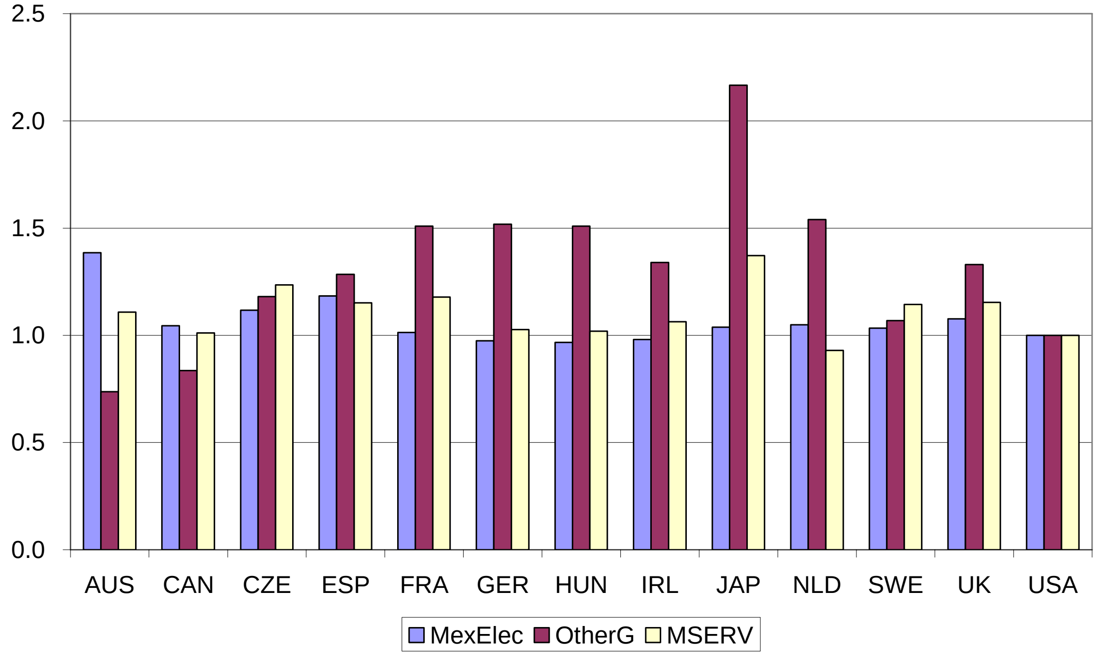
4.2 Unit value ratios versus specified PPPs.

Levels of outputs and inputs between countries can be compared by using relative prices to express these outputs and inputs in a common currency. It is well known that the use of exchange rates may be highly inaccurate, since relative prices and exchange rates may differ considerably. This will be particularly a problem when comparisons are made at the level of industries or sectors of the economy. Even in sectors which are open to international trade, and for which it may be assumed that relative price levels converge to one in the long run, different degrees of monopoly power, lags in response to exchange rate movements, etc., make this assumption unlikely to be fulfilled in practice. For non-traded sectors, there is in fact no reason at all to suppose price ratios will equal the exchange rate. Finally, it is well recognised that the exchange rate is also influenced by short-term capital movements which should not be reflected in comparative volume measures of output and productivity (Taylor and Taylor 2004).

To aggregate across countries use should be made of so-called Purchasing Power Parities (PPPs). A PPP is defined as the ratio of the price of a product or a bundle of products between two countries, with prices expressed in each country's own currency. The relative price level is defined as the (average) price of one country relative to the (average) price of the other country, with 50 prices expressed in a common currency. When countries have different currencies, the relative price level is obtained as the ratio of the PPP to the currency exchange rate. So the relative price level of a haircut in Poland compared to Germany is obtained by comparing the PPP of the haircut (for example, 30 Złoty in Poland to 15 euro in Germany) to the currency exchange rate (for example, 4 Złoty to one euro). The relative price level of Poland relative to Germany is then (30/15) / 4 = 50 per cent. When two countries have the same currency, for example, the euro, the relative price level can be directly derived from the PPP. For example, when the ex-factory price of a ton of flat steel of identical quality is 2,000 euro in Portugal against 2,500 euro in Germany, the Portuguese price level is 80 per cent of that in Germany.

For a long time, international comparisons of output and productivity have been based on price surveys from the International Comparisons Project which provide relative prices for a range of final demand products across countries (Kravis et al., 1982). Typically, PPPs for GDP were used, not only in studies of the aggregate economy but also at the industry level. Only a few attempts have been made to derive industry-specific PPPs. These studies have shown that large cross- sector differences in PPPs exist. By way of illustration, Fig 4.1 provides a comparison of the industry-specific PPPs used in this study and the overall GDP PPP from the OECD. It shows the ratio of PPPs for three major sectors and total GDP. The biggest differences can be found for the other goods sector (mainly agriculture and construction), for which PPPs can easily be 50% or higher than the GDP PPP (e.g. for Japan). But also for manufacturing and market services different relative prices can easily differ by more than 15% from the overall GDP PPP (see Timmer, Ypma and van Ark 2007 for more). In the past, industry studies were either based on underlying information from ICP, or based on producer price information. Both approaches have their advantages and disadvantages and we use a mix of both in this study, following Timmer, Ypma and van Ark (2007).[13]

Figure 4.1 Ratio of sectoral PPP and GDP PPP, 1997



Note: Ratio of sectoral PPP and GDP PPP for three sectors.
Source: GDP PPP from OECD. Sectoral PPPs from GGDC Productivity Level database.

For the derivation of industry output prices on the basis of expenditure prices a number of adjustments have to be made. First, the expenditure prices, which are based on a purchasers' price concept, must be transformed into basic prices as industry output in the National Accounts is measured at basic prices, not purchasers' prices. This cane be done by eliminating trade and transportation margins and net indirect taxes. Second, expenditure categories have to be mapped into industries. Jorgenson et al. (1987) were the first to do this for a US-Japan comparison. However, it is well known that this procedure has several drawbacks. First, the data to adjust PPPs from the expenditure side to a basic price concept is often not available. Second, PPPs from the expenditure side are not always a feasible option for all industries because no price data are

[13] See van Ark and Timmer (2008) for an elaborate survey.

available for products which are typically used as intermediates rather than for final consumption. Finally, PPPs from the expenditure side need to be adjusted for export and import prices. PPPs from the expenditure side reflect prices of final expenditure on products, which either have been produced domestically or have been imported. In addition, not all domestically produced goods are destined for final expenditure, as part is being used for intermediate demand or exported. Therefore expenditure prices include the prices of imports and exclude prices of exports, while basic prices should reflect the price of domestic production, including exports and excluding imports. This adjustment however is extremely difficult to make.

The other alternative is to use PPPs from the production side, based on producer price information. At the industry level, PPPs from the production approach are theoretically preferable as they refer to the correct price concept that is required at output level. Moreover, these PPPs will naturally fit the industry-classifications and cover all output, both final and intermediate goods. But they have one big disadvantage. PPPs from the expenditure side are derived from specified prices that are obtained from a specific survey set up for the purpose. Production PPPs are mostly only available through ratios of unit values derived from (national) production censuses and business statistics surveys, as basic prices for specified items at producer level are often not available. These unit value ratios have the disadvantage of introducing 'product matching' problems in international comparisons. Without precise specification of the products compared, chances are higher that differences in product quality will be reflected in the relative prices.[14] Also, this approach is only feasible for those industries for which unit value information is available.

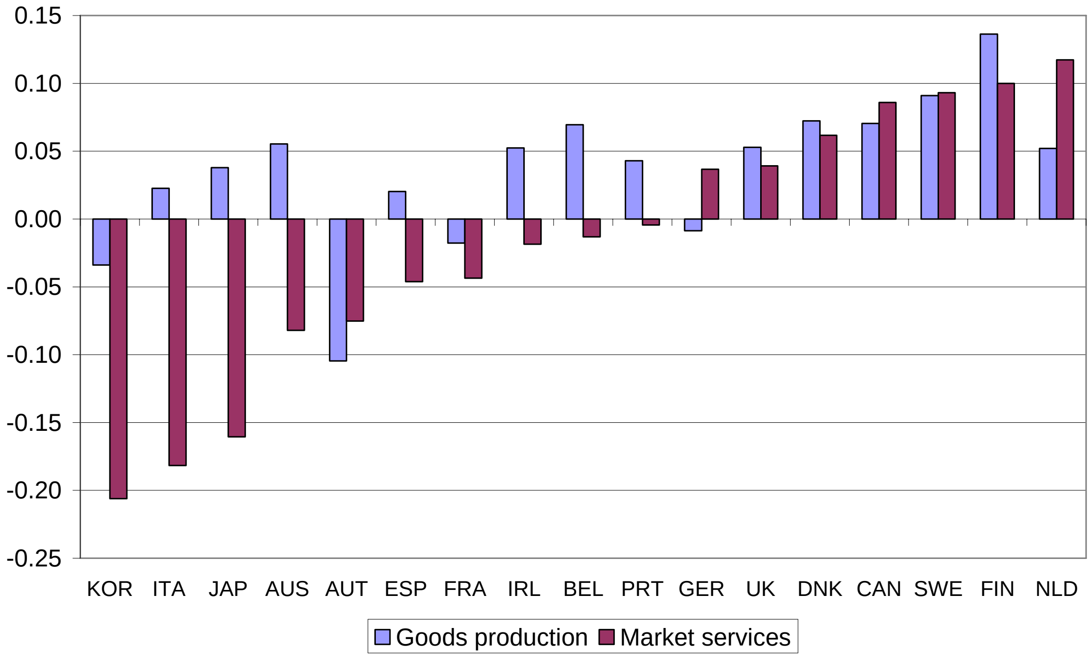
In a recent study Timmer, Ypma and van Ark (2007) provide two sets of PPPs: one based on unit value ratios for 1997 from the ICOP project at the University of Groningen and one based on specified expenditure prices side from OECD for the 1999 ICP-round, which were adjusted for trade and transportation margins and net taxes. They argue that the choice on whether to use PPPs from the expenditure or production side is an empirical one, and will differ by industry. They provide a framework to assess the strengths and weaknesses of PPPs from the expenditure side in different industries using a supply-use framework. PPPs from the expenditure side only approximate the industry level prices in case most of the expenditure is on domestically produced goods and the industry output being produced goes mostly to domestic final expenditure and not to intermediate consumption or exports. Ultimately, they present a mixture of PPPs from the production and expenditure side. The production PPPs are mainly based on unit value ratios and

[14] Due to the 'product matching' problem PPPs from the production side are often based on samples of products which are biased towards relatively homogeneous, less sophisticated goods. The underlying unit value ratios may not always be representative of the more upgraded, high-quality varities in the same industry. Another issue, linked to this, concerns the sampling error of expenditure PPPs vis-à-vis production PPPs. In principle one might expect a bigger sampling error for unit value ratios compared to specified expenditure PPPs. As more aggregate items are being matched, product mix problems and the quality problem may raise the sampling error of production PPPs. Lichtenberg and Griliches (1989) showed that in an intertemporal context producer price indices in the US based on specified product prices are superior to those based on census unit value ratios as price dispersions are much higher for the latter.

cover agriculture, mining, manufacturing (except high-tech), transport, communication and trade industries. PPPs for other industries are based on specified expenditure prices.

In this study we use the mix of UVRs and expenditure PPPs provided by Timmer, Ypma and van Ark (2007). As an alternative we also provide a file with results based on specified expenditure prices only.[15] Figure 4.2 shows the sensitivity of the comparisons to the choice of PPP set. It gives the log ratio of value added using mix of PPPs (our preferred choice) and using PPPs from expenditure side only.

Figure 4.2 Sensitivity to choice of PPPs, 1997.



Note: Log ratio of value added using mix of PPPs (our preferred choice) and using PPPs from expenditure side only. Value added is single deflated.
Source: Appendix Table 1.

Figure 4.2 shows that differences can go either way as mix PPPs are sometimes higher and sometimes lower than expenditure PPPs. For goods production differences are relatively minor and often within 5%-bounds. Differences for market services can be much larger though. For example, real value added in Italy, Korea and Japan compared to the U.S. is more than 15% higher when using the expenditure PPPs. A more detailed analysis at the industry level reveals that this is due to differences for the trade and transportation sector.[16] Expenditure PPPs for these

[15] This PPP set contains only expenditure PPPs, except for agriculture and mining for which no expenditure PPPs exist. All output of these industries consist of intermediate inputs, not final goods. For these industries UVR estimates are used. Similarly, for distributive trade no expenditure PPP is available (see Timmer and Ypma 2006 for an extensive discussion). The overall GDP PPP is used instead.

[16] For the other market service industires only expenditure PPPs are available and hence PPPs are tne same in the two alternative sets.

services are extremely low in various Asian and Eastern European countries (see Appendix Table 1). Arguably these expenditure PPPs refer to highly subsidised prices for public transportation which have little relevance for transport prices facing firms.[17] In contrast, estimates of distribution PPPs based on expenditure prices appear to be too high for Nordic countries. Appendix Table 1 further shows that the lower level of aggregation, the bigger differences can become. For some individual industry-by-country cells the two estimates diverge markedly.

4.3 Single versus double deflated value added

In theory, the price of value added should be based on the prices of output and the prices of intermediate inputs. As such, the data requirements for a value added based MFP measure is exactly the same as for a gross output based MFP measure. However, in practice, for reasons discussed below, one often opts to ignore the prices of intermediate inputs, and uses the PPP for gross output instead. The latter approach is called single deflation, as opposed to double deflation in which the prices of intermediate inputs are taken into account as in equation (3.17).

Single deflation has some important problems to it. It suffers from a so-called terms-of-trade bias[18] and a substitution bias. Firstly, the terms-of-trade bias arises when relative prices of output and intermediate inputs differ for a particular industry. For example, it might be the case that while the observed gross output prices in country A are the same as in country B, the unobserved intermediate input prices are lower in A. In that case value added in A is overestimated relative to B when using single deflation, because the price gain from the lower input prices is now reflected in A's volume measures of value added. Secondly, differences in relative prices of primary factor inputs and intermediate inputs can lead to differences in the use of intermediate inputs, leading to substitution effects. Relatively lower intermediate input prices will lead to a higher use of intermediate inputs compared to the use of capital and labour inputs in the production process. When using single deflation, this substitution effect between intermediate inputs and value added is not reflected in the relative volume measure of value added. In practice, the terms-of-trade and the substitution biases are difficult to disentangle. The main point here is that as long as relative intermediate input prices do not move in tandem with relative output prices across countries, measures of single deflated value added will be biased. The double deflation procedure does not suffer from this bias and therefore most European countries and the US recently adopted double deflation techniques in the compilation of value added time series in their National Accounts. We also apply double deflation techniques in this cross-country study.

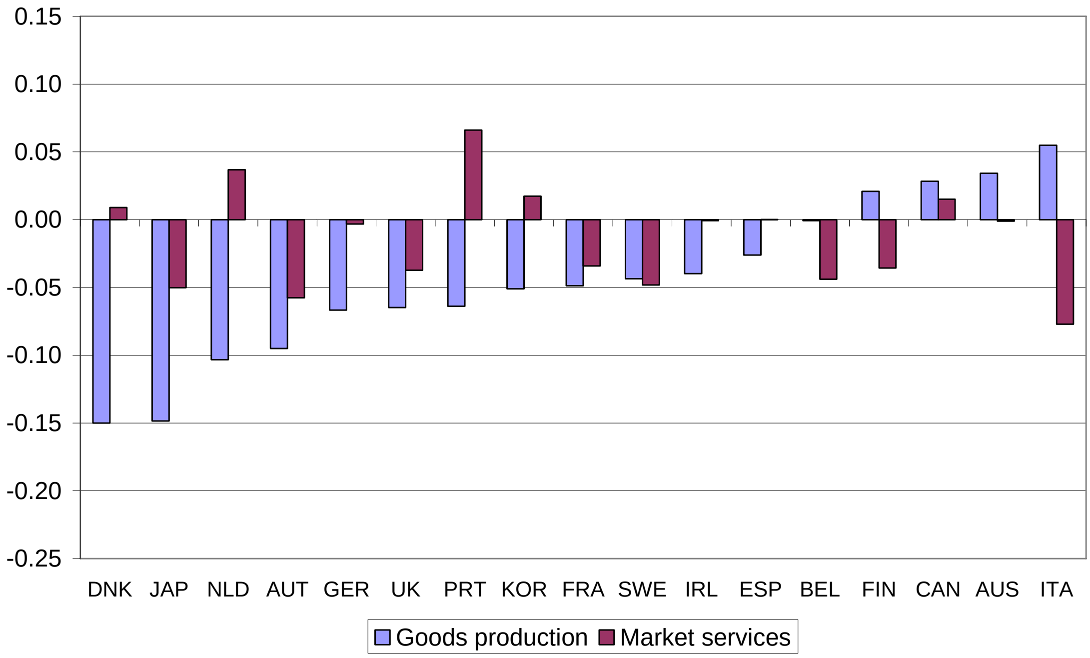
However, in practice double deflation also has a number of well-known problems to it. Firstly, double deflation puts larger requirements on data, as besides PPPs for gross output,

[17] Timmer et al. (2007) adjusted the expenditure PPPs for taxes and subsidies, but for transportation services this appeared to be nearly impossible due to the hugh amounts of direct and indirect subsidies which could not be derived on a product basis from published National Account statistics.

[18] Note that the concept "terms of trade" refers to relative prices of outputs and inputs in the domestic economy, and do not refer to "terms of trade" as used in international trade literature in which they refer to the differences in import and export prices.

intermediate input PPPs are also needed. These are not usually readily available and must be constructed on the basis of input prices for the various countries in combination with input shares derived from input-output tables (see section 5.3). Secondly, double deflation introduces a new possible source of error not present in single deflation measures, i.e. errors associated with the measurement of input prices. In many sectors, material input prices are either unavailable or crudely measured. Hill (1971) suggests that the use of single deflation may be less misleading than using double deflation when material input prices are measured with error. This problem is aggravated by the fact that double deflated value added is defined as the output volume minus the intermediate input volume. A small percentage measurement error in the volume of gross output appears as a much larger percentage error in the volume of double deflated value added than is the case for the volume of single deflated value added.[19]. Hence the trade-off is between an improved point estimate for value added, but with a larger standard error. Consequently, the choice for single or double deflation is ultimately an empirical issue. The bigger the differences between output and intermediate input prices and the bigger the share of intermediate inputs in output, the larger the possible error in the single deflated point estimate. This has to be weighted against the increasing variance due to measurement error in the intermediate input prices. The final choice between single and double deflation will ultimately depend on one's penalty function.[20]

Figure 4.3 Sensitivity to double deflation, 1997



Note: Log ratio of double deflated over single deflated value added, 1997
Source: Appendix Table 2

[19] See Hill (1971, p. 19).

[20] See Inklaar and Timmer, (2008, forthcoming) who provide a Monte Carlo simulation based on variances derived in a CPD-estimation of PPPs.

Figure 4.3 provides a test of the sensitivity of productivity level comparisons to the choice of single or double deflation techniques. It shows the log ratio of double deflated over single deflated value added for two major sectors: market services and goods production. Appendix Table 2 provides additional information. The following observations can be made. As before, differences increase with the level of industry detail. At market economy level differences are only large for countries with undervalued exchange rates, that is exchange rates which are much higher than the GDP PPP in 1997 (e.g. Eastern European countries, but also Denmark). For other countries, the differences are less than 5%. Also at major sector level differences are generally small and can go either way. Differences are smallest for market services, as is to be expected given the low share of intermediates in output. As such, measurement errors have only a minor impact. Differences can be larger for goods producing sectors as the intermediate input share is much larger (typically 60%, while only 30% in the case of services). At the lowest industry level differences can be sizeable, especially in Transportation services. In Finance all ratios are above 1, due to an extremely low output PPP for the US.

4.4 Sectoral output and aggregation over industries

4.4.1 Sectoral versus gross output measures

An important consideration when making cross-country comparisons is the effect of differences in the degree of integration of firms within an economy. In some countries, an industry may be made up of many small firms that only handle part of the production process, while in other countries, firms may be more integrated. In the former case, there will be more intra-industry trade of intermediate products, and the industry will use more of its own production. This has consequences for comparisons of output and input levels across countries. For example, ceteris paribus, countries with higher levels of integration will have higher MFP levels when based on gross output measures. This issue has been ignored in cross-country comparisons so far (except for Inklaar and Timmer, 2007). The standard approach is to use industry gross output defined as the summation of sales of all firms in the industry. In this study we make use of the so-called "sectoral" output and input concepts as introduced by Domar (1961) in which intra-industry deliveries are netted out.[21] Essentially, each industry is considered to be completely integrated, i.e. all individual production units in an industry are combined into a single unit. This assumption is made at all levels of aggregation. Sectoral output measures will be identical to gross output at the firm level, but as one moves up the hierarchy of industries, it moves closer and closer to value added. Similarly, sectoral intermediate input measures approach total imports at higher aggregation levels. Indeed, at the level of the total economy sectoral output is equal to gross domestic product (GDP) plus imports and sectoral intermediate input is equal to imports, as all

[21] See OECD (2001, section 3.1.3) and Corrado et al. (2007) for a discussion in the context of time-series and Inklaar and Timmer (2007) in a cross-country setting.

domestic inter-industry deliveries have been netted out.[22] Using the terminology of Durand (1996), this approach can be called aggregation with integration, as opposed to aggregation without integration. The main advantage of the aggregation with integration approach is that differences in integration across countries will not distort relative measures of inputs and productivity. A simple example can illustrate this point.

Suppose that we want to compare output, input and productivity in motor car manufacturing in two countries, *A* and *B*. Assume for simplicity that in both countries 10 cars are being produced, using 10 units of labour. The countries only differ in the number of firms: two in country *A* and only one in country *B*. The first firm in country *A* produces car components (engines, bodies, wheels etc.) using 5 units of labour. The second firm does the final assembly and produces 10 final cars, using 5 labour units to put together the car components produced by the other firm. In country *B* the two activities (car part production and assembly) are integrated in just one firm. So, by construction, the sectoral output (10 cars) and inputs (10 labour units) are the same in both countries, as the intra-industry trade of components between the two firms in country *A* is netted out (see Figure 4.4). Similarly, productivity levels are identical by definition.[23] However, when one is to aggregate outputs and inputs in country *A* without integration, differences will appear. Suppose that the output of car components of firm 1 is 5 units.[24] Then total output in country *A* of firms 1 and 2 will be 15 (=10+5), and total intermediate inputs will be 5. This would suggest that car manufacturing in country *A* uses more intermediates than in country *B*. Similarly, standard multi factor productivity (MFP) measures in *A* will be lower than in *B* as the input/output ratio of the aggregated sector in A is higher than the input/output ratio of the integrated sector in B.[25] In the extreme case of infinite fragmentation, MFP would tend to zero, intermediate input-output ratios to unity and labour- and capital-output ratios to zero. Hence comparisons of input and productivity across countries will be sensitive to differences in the degree of integration. This is clearly an undesirable characteristic of standard non-integrated measures.[26]

Although in a time-series perspective it might be expected that rates of growth of gross output and sectoral output do not differ greatly over short periods of time, there is less reason to expect such small differences for level comparisons, in particular between countries with different

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[22] To be more precise, sectoral output at the aggregate level equals GDP at basic prices plus imports at purchasers' prices, see Aulin-Ahmavaara and Pakarinen (2007) for a discussion. The term "sectoral" was suggested by Gollop (1979). This name is somewhat unfortunate, as the concept "sector" is used by statisticians to indicate institutional sectors. Nevertheless, we stick to the use of sectoral output and input concepts to indicate the outputs and inputs of a fully integrated industry.

[23] As productivity is defined as the ratio of output over inputs.

[24] For simplicity we abstract from incorporating prices in the example and assume unit prices for all goods.

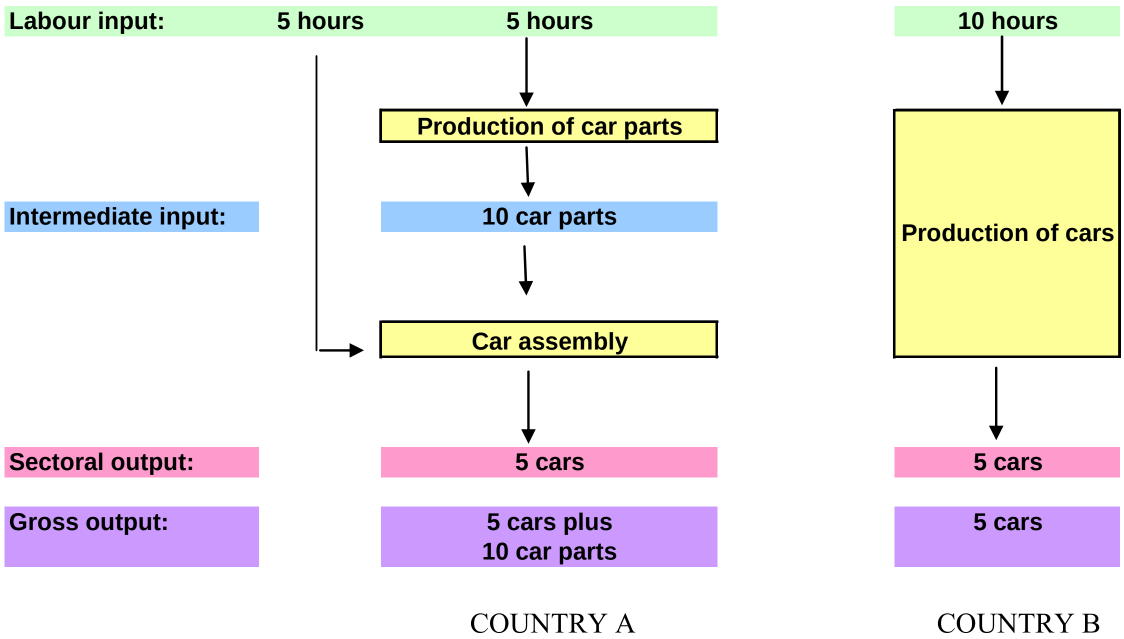
[25] This follows from the identity that nominal output is equal to the value of intermediate inputs and value added. With integration, output and intermediate input are reduced by the same amount, while value added remains the same. Hence, the ratio of intermediates over output will be lower.

[26] See Inklaar and Timmer (2007) for an empirical example which shows that the use of sectoral output measures is also empirically relevant, besides being conceptually preferable.

degrees of vertical integration. In practice, this problem can be exacerbated by differences in statistical practices between countries in measuring gross output. For example, in some countries output is measured at the level of a local unit or establishment (as in the U.S. Census of Manufactures), whereas in other countries (such as in France) a more integrated firm level or business unit concept is used. In the first case, the problem of double counting of output will be more severe. Hence, consistent sectoral output measures across countries require intra-industry flows of intermediate products.[27]

A thorny issue is the treatment of imports. In this study imports are treated as a separate input which can be justified for productivity measures as discussed above. However, as a consequence measures of output per unit of intermediate input become less insightful. For example, in case one is interested in the output per unit of energy used for example, both imported and domestically produced energy inputs should be taken into account. For this reason we have not included output per unit of intermediate input measures in the database.

Figure 4.4 Example of Aggregation with and without integration in car manufacturing



It is important to note that this sectoral output approach is not only important in making productivity comparisons based on output only, it also affects comparisons based on value added through the way in which PPPs are derived.

[27] When not all establishments of a firm belong to the same industry, this problem cannot be completely solved by using integrated measures.

4.4.2 Aggregation of PPPs over industries

Aggregation of PPPs over industries is done at the lowest level possible, that is at the level of individual input PPPs (29 for intermediate inputs, 30 for labour and 8 for capital, see Section 5). This is done by means of the CCD approach. The PPPs for capital and labour for a sector J are straightforwardly defined as :

$$\ln PPP_{c,J}^{K} = \sum_{j \varepsilon J} \hat{v}_{c,j}^{K} \left[\ln PPP_{j,c}^{K} - \overline{\ln PPP_{j}^{K}} \right] \quad (4.1)$$

$$\ln PPP_{c,J}^{L} = \sum_{j \varepsilon J} \hat{v}_{c,j}^{L} \left[\ln PPP_{j,c}^{L} - \overline{\ln PPP_{j}^{L}} \right] \quad (4.2)$$

With $\hat{v}_{c,j}^{K} = \frac{1}{2}\left[v_{c,j}^{K} + \sum_{q} v_{q,j}^{K} \Big/ N \right]$ and $v_{c,j}^{K}$ the share of industry j in total capital compensation in sector J, and similarly for labour. For output and intermediate inputs, use is made of the sectoral measures as outlined above. Consider sector J which consists of a group of industries j.

The output PPP for sectoral output of sector J ($PPP_{c,J}^{SO}$) is given by:

$$\ln PPP_{c,J}^{SO} = \sum_{j \varepsilon J} \hat{v}_{c,j}^{SO} \left[\ln PPP_{j,c}^{SO} - \overline{\ln PPP_{j}^{SO}} \right] \quad (4.3)$$

Where $\hat{v}_{c,j}^{SO} = \frac{1}{2}\left[v_{c,j}^{SO} + \sum_{q} v_{q,j}^{SO} \Big/ N \right]$ and $v_{c,j}^{SO}$ the share of industry j in sectoral output of the group of industries J. It is important to note that in this case the output PPP for sector J is not a weighted average of the sectoral output PPPs for each industry j in sector J. Instead, it is the weighted average of the PPPs over all outputs, weighted by their share in overall *sectoral* output in J. So for example, consider two industries in a sector in which one industry (A) delivers all output to the other industry (B), and B does not deliver to A. When this is the case for all countries, the output PPP for the sector as a whole will be the same as the output PPP for industry B as $v_{q,j}^{SO}$ is zero for A, and 1 for B.

In a similar vein, the PPP for intermediate inputs for sector J is defined as follows:

$$\ln PPP_{c,J}^{II} = \sum_{m} \hat{v}_{c,m}^{II} \left[\ln PPP_{m,c}^{II} - \overline{\ln PPP_{m}^{II}} \right] \quad (4.4)$$

Also here, the intermediate input PPP for sector J is not a weighted average of the intermediate input PPPs. In the example given above, the intermediate input PPP for the sector as a whole will depend on the PPPs of all intermediate inputs used in A and B, except the inputs in B originating from A.

4.5 Bilateral versus multilateral models

Our models of production are bilateral and involve comparisons of a country c with the US as base. We chose US as the base country as these comparisons generally generate the highest interest, the U.S. being the overall productivity and technology leader. Alternative bilateral comparisons with other countries as the base can be made using the same approach by simply replacing the US by another base country in the formula's given in Section 3. The disadvantage of bilateral comparisons is that the comparisons will not be transitive. An index I is transitive when a direct comparison between any pair of countries (A and B) gives the same result as indirect comparisons through any other country C, or $I^{AB} = I^{AC}/I^{BC}$. Bilateral comparisons do not satisfy transitivity. Alternatively, one can use the multilateral approach advocated by Caves, Christensen and Diewert (1982) who derive translog multilateral productivity indices which do satisfy the transitivity requirement. Our PPPs are based on this multilateral CCD-approach The multilateral price index is base-country invariant, which implies that output and inputs can be expressed as an index of any country s. This index sacrifices only a small amount of characteristicity and imposes no a priori restrictions on the structure of production. It has an intuitive interpretation: a comparison between two countries is obtained by first comparing each country with the "average" country and then comparing the differences in each country's productivity relative to this average country.[28] Note that the imposition of the transitivity condition is also a constraint: PPPs between two countries A and B are influenced by all other countries in the analysis, which implies that the results will change when new countries are added to the dataset. In our application this will not be a major issue as our set of countries already includes 30 countries. [29]

In our calculation of productivity measures we make use of a binary model. The main reason not to opt for a standard CCD approach is that this approach to productivity does not provide a consistent decomposition of relative output in terms of relative inputs and MFP levels. This is an important disadvantage given our interest in such decompositions, see Section 7 for a decomposition application.

4.6 Extrapolation of benchmark estimates

This study provides PPPs and productivity level comparisons for one particular benchmark year: 1997. This year was chosen because it was the most recent year for which PPPs from the production side were available. If one is interested in comparative levels for other years, say T, there are basically two options:

1. to derive a new benchmark for T

[28] This methodology has first been used by Christensen *et al.* (1981) in comparing productivity at the level of the total economy for a set of 9 countries, and was first used at the industry level by Conrad and Jorgenson (1985) in a comparison of Germany, Japan and the U.S.

[29] We aggregate over prices rather than over quantities. Surprisingly, the literature is rather silent on this issue. We find that aggregation over quantities leads often to non-plausible results and opt to aggregate over prices as variation in prices across countries is much less than variation in quantities. (see also Allen and Diewert, 1981). Differences can be large as indicated by Inklaar, Timmer and van Ark (2006, Appendix A).

2. to extrapolate the 1997 benchmark on the basis of relative price and volume growth rates between 1997 and T.

Unfortunately, the two approaches typically do not deliver the same result. The first option is theoretically preferable as it takes into account the prices and quantity structures of the year under consideration. It provides a snap-shot of the comparative performance in year T. This is also known as current-PPP comparisons, indicating that for the comparisons PPPs from the current year are used. The second alternative is widely used due to the heavy data requirements of the first approach. It is known as the constant PPP approach, indicating that PPPs from a fixed benchmark year are used to make comparisons outside the benchmark year. Constant and current PPP comparisons will differ due to standard substitution biases. This is discussed in detail in Appendix 2 of this paper. Typically, these biases will be bigger the further one moves away from the benchmark year.

Given the interest in up-to-date comparisons, we also provide comparisons for the year 2005, which is the latest year for which data is available in the EU KLEMS database (March 2008 release). In this section we outline the extrapolation approach used which is basically a constant PPP approach. To update a volume comparison to 2005, we simply apply the relative volume growth rates between the two countries in the period from 1997 to 2005. So for example in the case of a multi factor productivity comparison between country c and the US, the relative MFP level in 2005 ($MFP_{c,2005}$) is given by

$$MFP_{c,2005} = MFP_{c,1997}\left(\frac{MFP_{c,2005} / MFP_{c,1997}}{MFP_{US,2005} / MFP_{US,1997}}\right) \qquad (4.5)$$

And in the case of a labour productivity comparison between country c and the US, the relative labour productivity level in 2005 ($LP\_VA_{c,2005}$) is given by

$$LP\_VA_{c,2005} = LP\_VA_{c,1997}\left(\frac{Q^{VA}_{c,2005} / H_{c,2005}}{Q^{VA}_{c,1997} / H_{c,1997}}\right)\Bigg/\left(\frac{Q^{VA}_{US,2005} / H_{US,2005}}{Q^{VA}_{US,1997} / H_{US,1997}}\right) \qquad (4.6)$$

Similarly other volume comparisons can be made for 2005.

5. DATA

Basically, our level comparisons are based on deflating nominal inputs and output as given in national input-output tables by a set of relative prices. We use a new set of relative prices which is specifically developed for making cross-country, industry-level productivity comparisons provided by Timmer, Ypma and van Ark (2007). These are complemented by relative prices for capital and labour inputs.

In short, the following practical steps are taken for the construction of nominal tables:

1. Collect Supply and Use Tables (SUTs) for 1997
2. Split Use table into domestic and import tables
3. Transform SUT into domestic industry by industry Input-Output table (45 industries)
4. Benchmark labour compensation, value added and gross output to National Accounts figures
5. Calculate sectoral gross output and sectoral input measures at each level of aggregation
6. Breakdown of value added into labour compensation for 30 labour types, capital compensation for 8 capital types based on data on quantities (hours worked for labour and capital stocks for capital) and national wages and rental prices

This is described in more detail in section 5.1. The following practical steps are taken for the construction of PPPs:

1. Calculate multilateral PPPs for gross output based on expenditure and production approach (for 45 industries based on 213 sub-industries)
2. Calculate sectoral intermediate input PPPs for E, M and S using the domestic input-table in a CCD-approach plus exchange rate for imports (at the level of 29 industries)
3. Calculate relative prices for 30 labour types (wages) and 8 capital assets (rental prices) and aggregate into labour and capital PPPs using CCD-approach (at the level of 29 industries).[30]

This is described in more detail in section 4.2. Nominal values and PPPs are used to derive productivity levels as discussed in Section 3.

5.1 Nominal values of inputs and outputs

Sectoral output and intermediate inputs

Measures of sectoral output and input require industry-by-industry input-output tables (IOTs) with separate information on domestic and imported supplies of commodities. IOTs are not available for all countries in a common benchmark year and we used supply and use tables (see data description below) to construct comparable IOTs in the following way. Let S^D be the domestic supply matrix of a particular country (product×industry) of dimension n×m with n products and m industries, q^D the vector of total domestic supply by product (n×1), q^I a separate vector for imports (n×1) and q is total supply ($q = q^D + q^I$). Further, let U indicate the intermediate part of the Use table (product×industry) of dimension n×m, to be split into domestic (U^D) and imported (U^I) such that U

[30] Labour and capital PPPs can only be calculated for a set of 20 countries for which data is available. Output and intermediate inputs PPPs are based on a set of 30 countries.

= $U^D + U^I$. Similarly II^D and II^I indicate the domestic and imported intermediate part of the input-output table (industry×industry) of dimensions m×m with $II = II^D + II^I$.

The first step is to split the Use table into domestic and imported. For this, we assume that the import-share of a product used by an industry is constant over all using industries. This import-share is derived from the supply table by dividing imports by total supply for each product as follows:

$$\mathbf{U}^I = \hat{\mathbf{q}}^I \hat{\mathbf{q}}^{-1} \mathbf{U} \qquad (5.1)$$

Where $\hat{\mathbf{x}}$ is the diagonal matrix with the elements of vector x on its main diagonal and zeroes elsewhere. The domestic use table is then easily derived as the difference between U and U^I:

$$\mathbf{U}^D = \mathbf{U} - \mathbf{U}^I \qquad (5.2)$$

Next, one needs to transform supply and use-tables into input-output tables. There are various ways to do this, depending on the assumptions made (see e.g. Chapter 11 in Eurostat, 2002). We use the so-called fixed product-sales structure assumption where each product has its own specific sales structure, irrespective of the industry where it is produced. This assumption is more plausible than its alternative (fixed industry-sales structure).[31] Under this assumption, the intermediate part of the domestic input-output table is derived as follows:

$$II^{\mathrm{D}} = (S^{\mathrm{D}})'(\hat{q}^{\mathrm{D}})^{-1} U^{\mathrm{D}} \qquad (5.3)$$

where a prime is used for transposition. Similarly, imported intermediates are derived as follows, implicitly assuming a similar industry-origin of the imported intermediates as for domestically produced:

$$II^{\mathrm{I}} = (S^{\mathrm{D}})'(\hat{q}^{\mathrm{D}})^{-1} U^{\mathrm{I}} \qquad (5.4)$$

Using these matrices, sectoral intermediate input can be defined as follows. Let II_{ij}^D be elements of II^D, that is, domestic intermediate inputs from industry i used by industry j, and similarly for imports, then total sectoral intermediate input used by j (II_j) is given by:

$$II_j = \sum_i \left(II_{ij}^D + II_{ij}^I \right) - II_{jj}^D \qquad (5.5)$$

Similarly, sectoral output of industry j is defined as gross output minus the intra-industry deliveries (II_{jj}^D). In this study, intermediates are subdivided into energy inputs, material inputs and services inputs.

The starting point of our analysis is the national Supply and Use table for each country, valued in national currency for 1997.[32] For Canada, the U.S. and Australia these tables are obtained

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[31] Plausibility will depend on the nature of secondary production. Often, the structure of demand for the secondary products is rather different from the primary products. But if, for example, secondary products are mainly trade and transport services which are delivered together with the primary products, the fixed-industry sales structure assumption might also be a plausible assumption. We follow the recommendation by Eurostat (2002).

[32] Only for Australia do we have to rely on a set of tables for 1998 (more precisely, the tables are for fiscal year 1998-1999, but following OECD convention, the data for that fiscal year are allocated to 1998).

from the national statistical offices. Eurostat makes these tables available for the European countries on a common industry classification and at a sufficient level of industry detail for the purpose of this study. For Canada, the U.S. and Australia the classification for these tables had to be adjusted to the European industry classification.[33] For all countries, except the U.S. and Canada, the Supply table has a column for imported commodities. In the latter two cases, the Use table has a column (with negative entries) instead which is used to supplement the Supply table and make them comparable to the other countries.

An important decision to make is whether or not to treat trade and transport margins as separate inputs or not. As we are also interested in the output and productivity performance of trade and transportation industries, productivity analysis ideally should be based on intermediate inputs valued at basic prices plus net taxes on products, rather than at purchasers' prices, which include trade and transportation margins.[34] Net taxes on products include taxes less subsidies determined on the basis of the quantity purchased such as non-deductible value added taxes, sales taxes, taxes and duties on imports and other taxes. Therefore we compiled a set of comparable input-output tables in which intermediate energy and material inputs are at basic prices plus net taxes, while intermediate services (IIS) is at purchaser's prices. IIS thus includes the margins on energy and materials.

The Australian and the U.S. Use tables are at the required price concept. But the original European and Canadian Use tables are at purchasers' prices and the intermediate input block needed to be converted into basic prices plus net taxes. To do this, we estimated a margin matrix for the intermediate block in the Use table using total margins from the supply table and additional information from wholesale and retail trade survey material on margin rates by product. In addition, we assumed that all retail margins are generated in the delivery of goods to final demand.[35] We divide the wholesale margin between intermediate and final use by assuming that the wholesale margin rate is equal for each type of use, leaving us with an estimate of wholesale margins by commodity. For each industry, we assume an identical wholesale margin rate and attribute the resulting wholesale margins to the wholesale commodity use of each industry. After this conversion of the Use table, all SUTs are turned into an industry-by-industry input-output tables as described above.

We use data on value added at current prices from the EU KLEMS database to adjust the 1998 table to 1997. This adjustment leaves all input proportions unaffected and only changes the overall sum of inputs and outputs by the difference between value added from the 1998 table and the 1997 data.

[33] For Canada we had access to the worksheet level tables, which cover 713 commodities and 284 industries, and for the U.S. we used the benchmark level of detail, which covers 508 commodities and industries. In both cases, the detail is fine-grained enough to make a fairly good concordance to the European classification. The Australian tables 'only' cover 106 commodities and industries, so in some cases data from industrial surveys had to be used to distinguish the necessary industries.

[34] See e.g. Jorgenson *et al.* (1987), Aulin-Ahmavaara (2003) and Aulin-Ahmavaara and Pakarinen (2007).

[35] This is confirmed by data for Australia, where margins are split by commodity, type of margin and type of use as only a small fraction of retail margins is attributed to intermediate use.

Labour input

The value added block of the Use table only distinguishes two primary factors, namely capital and labour, so further disaggregation of these factor inputs is required.[36] The value of labour input should include all costs incurred by the producers in employment of labour such as taxes levied, payments for health and other types of insurance and contributions to retirement paid by the employer, and the value of payments in kind and allowances (such as housing and rent). The value of capital input should include all taxes levied on the ownership and the utilisation of capital. The SUTs do not readily conform to these definitions and divide gross value added into gross operating surplus, net taxes on production and compensation of employees. Operating surplus includes the labour compensation for self-employed workers. Hence we use the labour and capital compensation as given in the EU KLEMS database in which a correction is made for the labour income of self-employed. Total hours worked and wages for each of the 18 labour types is taken from the EU KLEMS database (March 2008 release) and extended to 30 types by incorporating more detailed educational attainment data (see 5.2.3).

Capital input: ex-ante approach

The next step is splitting capital compensation of each industry into compensation of eight capital assets. These are three ICT assets (computers, communication equipment and software) and five non-ICT assets (residential structures, non-residential structures, transport equipment, other non-ICT equipment and other assets). The share of each asset in total compensation is based on capital rental prices using the ex-ante approach (see section 4.1). In the absence of taxation the familiar cost-of-capital equation for asset type k is given by (Jorgenson and Griliches, 1967):

$$p_{k,t}^{K} = p_{k,t-1}^{I} r_t + \delta_k p_{k,t}^{I} - [p_{k,t}^{I} - p_{k,t-1}^{I}] \qquad (5.6)$$

This formula shows that the rental price is determined by the nominal rate of return (r) , the rate of economic depreciation (δ) and the asset specific capital gains. The asset revaluation term can be derived from investment price indices. To minimize the impact of sometimes volatile annual changes, annual averages over the period 1992-1997 are used. The rates of depreciation are geometric rates which vary across asset, but assumed identical across countries as in the EU KLEMS growth accounts. The nominal rate of return is the 10-year government bond yield for 1997 taken from IMF, *Financial Statistics*. It indicates the opportunity cost of using the investment fund in a risk-free alternative.[37] The realised rate of return on an asset will only by chance be equal to this bond-rate, and might be lower or higher depending on the performance of the industry. User costs

[36] Capital compensation includes operating surplus and taxes less subsidies on production. Hence the output valuation concept is basic prices. In the case of the U.S., the distinction between taxes on products and taxes on production can only be made at the aggregate level, so here the valuation concept is factor cost. At the aggregate level, net taxes on products and net taxes on production accounted for around three percent of GDP each. At the industry level, these ratios can be higher.

[37] Whether one should use a risk-premium in the calculation of ex-ante rental prices is still debated.

are constrained to be non-negative, as is usually done to avoid negative rental prices.[38] Finally, we multiply the asset- and industry-specific rental prices with the capital stock taken from the capital input files from the EU KLEMS database (March 2008 release) to derive the ex-ante capital compensation. This will typically differ from the (ex-post) capital compensation as given in the National Accounts. We normalise the compensation by asset to the National Accounts figure by proportionality.

After combining all the different data sources, we have derived a set of production accounts for each industry which conforms to the following value-identity. Let V denote nominal values in national currencies, then the sectoral output of industry j is given by the sum of the nominal value of all inputs: domestically produced intermediate inputs energy (E), materials (M) and services (S); imports (IMP); hours worked by 30 labour types (L) and capital stocks of 8 assets (K):

$$V_j^{SO} = V_j^E + V_j^M + V_j^S + V_j^{IMP} + V_j^L + V_j^K \qquad (5.7)$$

where output and intermediate inputs are all sectoral measures, excluding intra-industry deliveries. As discussed above, output is valued at basic prices, intermediate inputs at basic prices plus net taxes, and capital and labour input at purchasers' prices.[39] Equation (5.7) is the basis of the level comparisons of output, input and productivity made in the remainder of this paper.

5.2 Relative prices of inputs and outputs

Comparisons of levels of outputs and inputs between countries need relative prices to express these outputs and inputs in a common currency. Jorgenson and Nishimizu (1978) introduced the methodology to derive PPPs for output, labour and capital input; the latter based on relative wages and investment prices. This system was extended by Jorgenson et al. (1987) to include PPPs for intermediate inputs. In this section we describe the derivation of our output and input PPPs. We use the basic methodology as outlined by Jorgenson et al. (1987) but deviate in the practical implementation. First, we use a mix of expenditure and production-side price estimates to derive output PPPs. Second, we derive capital PPPs based on the ex-ante rather than the ex-post approach. Thirdly, we derive PPPs for sectoral output and sectoral input and provide these at all levels of aggregation.

5.2.1 Output PPPs

Timmer, Ypma and van Ark (2007) presented a new and comprehensive dataset of industry output PPPs. Output PPPs are defined from the producer's point of view and are at basic prices. These PPPs have partly been constructed using unit value ratios for agricultural, mining, and manufacturing products and transport and communication services. For the other market industries, PPPs are based on specified expenditure prices from Eurostat and the OECD, which were adjusted

[38] This was only necessary in a limited amount of cases.

[39] This identity does not hold when net taxes on intra-industry deliveries are non-zero. We have no information on this type of taxes and subsidies, and assume they are zero.

to industry level by using relative transport and distribution margins and adjusting for differences in relative tax rates. PPPs have been made transitive by applying the multilateral EKS-procedure for a set of 30 countries.[40] This set of gross output PPPs for 1997 covering 45 industries at (roughly) 2-digit industry level is the basic starting point for our current study. The gross output PPPs are allocated to the industries in the input-output tables.[41]

For non-market industries a special adjustment has been made. In almost all countries, output in the non-market sector is measured by means of inputs.[42] By implication, productivity levels should be the same across all countries. Put otherwise, output PPPs should be a weighted sum of the input PPPs with weights indicating the share of each input in total output. However, when we compared our input PPPs with the output PPPs as given by the OECD for non-market industries, large differences were found. In particular, the labour PPPs used by the OECD are rather different from our labour PPPs. Therefore we decided to define the output PPPs for non-market services (industries L, M, N and P) as a weighted sum of our inputs. Consequently, comparative productivity levels in these industries are all one (see section 7 for further discussion).

5.2.2 PPPs for intermediate input

Intermediate input PPPs should reflect the costs of acquiring intermediate deliveries and match the price concept used in the input-output tables, hence at basic prices plus net taxes. The data problems to obtain input PPPs for individual industries are larger than for output. There is often no input price parallel to the output PPPs. Business statistics surveys and productivity censuses provide little, or no, information on quantities and values of inputs in manufacturing, and for non-manufacturing industries the information is largely absent. Moreover, PPPs from the expenditure side by definition do not reflect prices of intermediate inputs as they cover only final expenditure categories. In this study we use output PPPs as a proxy for relative intermediate input prices under the assumption that the basic price of a good is independent of its use. That is, we use the same gross output PPP of an industry to deflate all intermediate delivers from this industry to other industries. Unfortunately, (net) tax matrices are not available for most countries, so PPPs for intermediate input could not be adjusted for differences in product tax rates across countries. As net taxes on products are minor for most market industries, this will probably not greatly affect our level estimates, but further investigation is needed to substantiate this claim, especially for comparisons at a detailed level.[43] The aggregate intermediate input PPP for a particular industry can

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[40] One is referred to Timmer *et al.* (2007) for further details about the construction and data sources underlying these PPPs.

[41] Some minor changes have been made as for some manufacturing industries in Italy and Spain expenditure PPPs have been used instead of unit value ratios.

[42] There is a recent tendency in some countries to come up with genuine output measures. However, by and large our assumption that output is measured by inputs holds true, in particular for our benchmark year, which is 1997.

[43] We assume net taxes on intermediates to be zero. Aulin-Ahmavaara and Pakarinen (2007) provide a discussion of sectoral measures which explicitly account for differences in net tax rates of intermediates.

be derived by weighting intermediate inputs at the output PPP from the delivering industries. Imported goods are separately identified and exchange rates are used as conversion factors for imports. Ideally, one would like to have separate estimates of import PPPs based on trade data as there is little evidence that the law of one price holds for all goods even when internationally traded. However, so far this data is not readily available.

5.2.3 PPPs for labour input

Comparisons which use a homogenous (or 'raw') labour concept in the denominator of the productivity equation, such as number of workers or total hours worked do not need currency converters for labour input, as the comparison is already given in terms of volume. In the case of a heterogeneous labour concept, for example workers of different skill types, labour input PPPs are needed to correct total labour compensation for differences in relative prices of different categories of workers as in equation (3.15). Ideally, this labour input PPP should be based on labour costs including all costs incurred by the producers in employment of labour such as taxes levied, health cost payments, other types of insurance and contributions to retirement paid by the employer, financial benefits such as stocks options and the value of payments in kind and allowances (such as housing and rent).

The PPP for labour represents the relative price of one unit of labour between two countries. For each type of labour, relative wages can be calculated. In the EU KLEMS Growth Accounts a distinction is made between 18 different labour types: 2 gender categories, 3 age categories and 3 educational attainment categories: low skilled (pre-primary, primary and lower secondary education, ISCED 0-2), medium skilled (upper secondary education, 3) and high skilled labour (total tertiary education, 5-7). However, in particular for level comparisons, this classification is rough and might be misleading as educational systems within Europe and the US are very different. In particular the different role of vocational schooling systems cause problems of comparability across countries. For example, in Germany vocational training is important to enter many occupations, but this is unknown in the US. Based on the work by the NIESR (see Mason, O'Leary and Vecchi, 2007) and O'Mahony (2008), we made a more detailed comparison and further decomposed the medium skill level into 3 categories to a total of 5. O'Mahony (2008) shows that this further decomposition has a large impact on relative levels of labour and productivity.

5.2.4 PPPs for capital input

To convert capital input measured in national prices into common prices, capital input PPPs need to be developed. Capital PPPs give the relative price of the use of a unit of capital in two countries from the purchasers' perspective. The calculation of the capital input PPP is less straightforward than for output, intermediate input or labour input PPPs. This is due to the conceptualisation of capital input as capital services rather than capital stocks (see section 3). To obtain relative prices for capital input, we follow Jorgenson and Nishimizu (1978). Under the assumption that the relative efficiency of new capital goods is the same in both countries, the relative rental price of asset k between country C and the base country US ($PPP^K_{k,t}$) is calculated as:

$$PPP^K_{k,t} = PPP^I_{k,t} \frac{p^K_{k,t,C} / p^I_{k,t,C}}{p^K_{k,t,US} / p^I_{k,t,US}} \qquad (5.8)$$

with lower-case p indicating prices, $PPP^I_{k,t}$ the relative current investment price of asset k between country C and the US, and $p^K_{k,t}$ the cost of capital as defined in (5.6). This definition indicates that the relative rental price of a unit of capital between two countries depends on the relative investment price and the user cost of capital input. The latter depends on the rate of return to capital, the depreciation rate and the investment price change, as in equation (5.6).

Investment PPPs are available for 35 capital assets from OECD (2002) for 1999. The PPPs for the 35 assets are aggregated to the eight assets in this study using a CCD aggregation procedure. Investment deflators by asset and industry from the EU KLEMS database are used to move these PPP to the benchmark year, which is 1997.

5.2.5 PPPs for EU- and Euro-region aggregates

In the database, also comparisons between various groups of European countries (EU10, EU15, EU25 and euro zone) and the US are being made. A similar methodology is followed as for individual countries as outlined in section 3. PPPs for output and inputs for these regional aggregates are straightforwardly defined as weighted averages of the PPPs of the countries involved. More specifically, nominal values are expressed in Euros based on exchange rate conversions. For example, in the case of input L, let q index the countries belonging to the regional aggregate EU and X_q the euro exchange rate of country q, then

$$V^L_{EU} = \sum_q \frac{V^L_q}{X_q} \qquad (5.9)$$

with V^L_{EU} labour compensation for the EU expressed in Euros and V^L_q labour compensation for country q in national currency. The PPP for the EU region (in euro per US$) is derived by a Paasche-type expression as follows:

$$PPP^L_{EU} = \frac{V^L_{EU}}{\sum_q \frac{V^L_q}{PPP^L_q}} \qquad (5.10)$$

with PPP^L_q in national currency of q per US$ as before. The same methodology is used for other inputs and output.[44]

[44] Note however that in the case of sectoral output we have not been able to exclude intra-regional trade of products in the same industry. Sectoral measures still include intra-industry international trade. To be consistent with the approach for individual countries a symmetric input-ouput table for the region should be used which is not available.

6. COVERAGE AND CONTENTS OF THE DATABASE

The database described in this paper consist of 3 files. The first two files contain the basic data and provide productivity comparisons for the benchmark year 1997. The only difference between the two files is the PPP-set used as discussed in Section 4.2. The first file (name *Benchmark 1997*) is based on a mix of PPPs from both the production and expenditure side. The second file (name *Alternative Benchmark, 1997*) is based on PPPs from the expenditure side only. The first file is our preferred option as overall it provides the most accurate estimates. But as discussed in Section 4.2 in some cases it can generate implausible results. In those cases one is advised to also take into account the alternative estimates. The third file (name *2005 Extrapolation*) contains updates of the productivity comparisons to the year 2005 which is the latest year for which data is available in the EU KLEMS database as yet (March 2008 release; see O'Mahony and Timmer, 2008). Extrapolation is done as explained in section 4.6. In this section we discuss the contents of the files.

Tables 6.1 to 6.3 provide an overview of the contents and coverage of the Productivity Level database: the set of variables included (Table 6.1), the set of countries and regions included (Table 6.2) and the industries and industry aggregates (Tables 6.3). The Productivity Level database has been developed to closely match the EU KLEMS Growth and Productivity Accounts. As such, the industry detail and classification is the same and the same set of countries is being covered. Also variable names have been harmonised. This allows one to easily extrapolate the level comparisons which are for 1997 in the database to other years (see section 7 for a discussion).

Table 6.1 shows the set of variables which are included. This set can be subdivided into three sub-sets: nominal values of inputs and output; relative prices of inputs and outputs; and relative levels of productivity and input-intensity. Below we will indicate for each variable how it is related to other variables in the database, and how they are derived in terms of the basic methodology outlined in section 3.

Nominal values

The nominal values obey the accounting identity that output value equals the sum of input values as in equation (5.7). In particular this means that the following identities hold, all in national currencies:

$$\begin{aligned} SO &= II + VA \\ II &= IIE + IIM + IIS \\ VA &= LAB + CAP \qquad (6.1) \\ LAB &= LABHS + LABNHS \\ CAP &= CAPIT + CAPNIT \end{aligned}$$

LABHS is the compensation for high-skilled workers defined as college educated and above. LABNHS is the compensation for the remaining workers. CAPIT is the capital compensation for ICT capital (computing and communication equipment and software, as in the EU KLEMS database) while CAPNIT is the compensation for non-ICT capital. Intermediate inputs include both domestically and imported goods and are sub-divided into energy, materials and services inputs as in the EU KLEMS database.

Relative prices

The PPPs in the database are all given in local currency per US$. They indicate the relative price of an output or input in a country relative to the US. So a PPP higher than 1 indicates a higher price in that country than in the U.S. For example the PPP for sectoral output for a country c is given by:

$$PPP\_SO = \frac{PPP_c^{SO}}{PPP_{US}^{SO}} \qquad (6.2)$$

PPP_c^{SO} is defined by equation (3.13), and similarly for all other PPPs.

Comparative levels

Comparative productivity levels are provided on a value added and sectoral output basis, both for labour- and multifactor productivity. In addition, we provide levels of skill- and capital intensity. All levels are relative to the U.S. (US=1). Labour productivity on a value added basis in country c is derived as:

$$LP\_VADD = \frac{\left(VA_c / PPP\_VA_c\right) / HOURS_c}{VA_{US} / HOURS_{US}} \qquad (6.3)$$

when value added is double deflated, and as

$$LP\_VASD = \frac{\left(VA_c / PPP\_SO_c\right) / HOURS_c}{VA_{US} / HOURS_{US}} \qquad (6.4)$$

when value added is single deflated, as in equation (3.2). Sectoral output per hour worked is defined in a similar way as, as in equation (3.1):

$$LP\_SO = \frac{\left(SO_c / PPP\_SO_c\right) / HOURS_c}{SO_{US} / HOURS_{US}} \qquad (6.5)$$

Multifactor productivity measures are defined in equations (3.3) and (3.4) as follows. For double deflated value added:

$$\ln MFP\_VADD_c = \ln \frac{\left(VA_c / PPP\_VA_c\right)}{VA_{US}} - \hat{w}_L \ln \frac{\left(LAB_c / PPP\_LAB_c\right)}{LAB_{US}} - \left(1 - \hat{w}_L\right) \ln \frac{\left(CAP_c / PPP\_CAP_c\right)}{CAP_{US}} \qquad (6.6)$$

where $\hat{w}_L = \frac{1}{2}\left(\frac{LAB_C}{VA_C} + \frac{LAB_{US}}{VA_{US}}\right)$, the average share of labour compensation in value added.

For single deflated value added:

$$\ln MFP\_VASD_c = \ln\frac{\left(VA_c / PPP\_SO_c\right)}{VA_{US}} - \hat{w}_L \ln\frac{\left(LAB_c / PPP\_LAB_c\right)}{LAB_{US}} - \left(1-\hat{w}_L\right)\ln\frac{\left(CAP_c / PPP\_CAP_c\right)}{CAP_{US}} \qquad (6.7)$$

For sectoral output based MFP:

$$\ln MFP\_SO_c = \ln\frac{\left(SO_c / PPP\_SO_c\right)}{SO_{US}} - \hat{v}_L \ln\frac{\left(LAB_c / PPP\_LAB_c\right)}{LAB_{US}} - \hat{v}_K \ln\frac{\left(CAP_c / PPP\_CAP_c\right)}{CAP_{US}} - \left(1-\hat{v}_L-\hat{v}_K\right)\ln\frac{\left(II_c / PPP\_II_c\right)}{II_{US}} \qquad (6.8)$$

where $\hat{v}_L = \frac{1}{2}\left(\frac{LAB_C}{SO_C} + \frac{LAB_{US}}{SO_{US}}\right)$, the average share of labour compensation in sectoral output,

and similarly for capital: $\hat{v}_K = \frac{1}{2}\left(\frac{CAP_C}{SO_C} + \frac{CAP_{US}}{SO_{US}}\right)$

In addition there are indicators of relative skill- and capital intensity. LAB_QPH indicates the amount of labour services per hour worked. If it is bigger than 1, it indicates that the quality of labour in country c is higher than in the US, that is, the work force in c has on average higher qualifications. It is defined as follows:

$$LAB\_QPH = \frac{\left(LAB_c / PPP\_LAB_c\right) / HOURS_c}{LAB_{US} / HOURS_{US}} \qquad (6.9)$$

Similarly CAP_QPH indicates the amount of capital services in use per hour worked:

$$CAP\_QPH = \frac{\left(CAP_c / PPP\_CAP_c\right) / HOURS_c}{CAP_{US} / HOURS_{US}} \qquad (6.10)$$

This can be further subdivided into the amount of ICT and non-ICT capital per hour worked as follows:

$$ITCAP\_QPH = \frac{\left(CAPIT_c / PPP\_IT_c\right) / HOURS_c}{CAPIT_{US} / HOURS_{US}} \qquad (6.11)$$

$$NITCAP\_QPH = \frac{\left(CAPNIT_c / PPP\_NIT_c\right) / HOURS_c}{CAPNIT_{US} / HOURS_{US}} \qquad (6.12)$$

Finally, using all these variables a breakdown of labour productivity can be given as follows:

$$\begin{aligned} \ln LP\_VADD \quad = \quad & \hat{w}_L \ln LAB\_QPH + \hat{w}_{KIT} \ln ITCAP\_QPH + \\ & \hat{w}_{KNIT} \ln NITCAP\_QPH + \ln MFP\_VADD \end{aligned} \qquad (6.13)$$

where $\hat{w}_L = \frac{1}{2}\left(\frac{LAB_C}{VA_C} + \frac{LAB_{US}}{VA_{US}}\right)$, the average share of labour compensation in value added, and with $\hat{w}_{KIT}$ the average compensation share of ICT assets in value added given by $\hat{w}_{KIT} = \frac{1}{2}\left(\frac{CAPIT}{VA} + \frac{CAPIT_{US}}{VA_{US}}\right)$ and similarly for non-ICT assets. In section 7 we provide the results of this decomposition.

Table 6.1 Variables in the Productivity Level Database

Variables	
Nominals (in millions of local currency)	
SO	Sectoral output at current basic prices
II	Sectoral intermediate inputs at current purchase prices
IIE	Sectoral energy inputs at current prices
IIM	Sectoral material inputs at current prices
IIS	Sectoral services inputs at current prices
VA	Gross value added at current basic prices
LAB	Labour compensation
LABHS	High-skilled labour compensation
LABNHS	Non-High-skilled labour compensation
CAP	Capital compensation
CAPIT	ICT capital compensation
CAPNIT	Non-ICT capital compensation
HOURS	Total hours worked
Relative prices (PPP, in local currency per US$)	
PPP_SO	PPP for sectoral output
PPP_II	PPP for sectoral intermediate inputs
PPP_IIE	PPP for sectoral intermediate energy input
PPP_IIM	PPP for sectoral intermediate material input
PPP_IIS	PPP for sectoral intermediate service input
PPP_VA	PPP for value added (double deflated)
PPP_LAB	PPP for labour
PPP_HS	PPP for high-skilled labour
PPP_NHS	PPP for non-high-skilled labour
PPP_CAP	PPP for capital
PPP_IT	PPP for ICT capital
PPP_NIT	PPP for Non-ICT capital
Levels relative to the United States (US=1)	
LP_VADD	Gross value added per hour worked (double deflated)
LP_VASD	Gross value added per hour worked (single deflated)
LP_SO	Sectoral output per hour worked
MFP_VADD	Multifactor productivity (value added based, double deflated)
MFP_VASD	Multifactor productivity (value added based, single deflated)
MFP_SO	Multifactor productivity (sectoral output based)
LAB_QPH	Labour input per hour worked
CAP_QPH	Capital input per hour worked
ITCAP_QPH	ICT capital input per hour worked
NITCAP_QPH	Non-ICT capital input per hour worked

Table 6.2 Countries included in the Productivity Level Database

Code	*Country name*
AUS	Australia
AUT	Austria
BEL	Belgium
CAN	Canada
CYP	Cyprus
CZE	Czech Republic
DNK	Denmark
ESP	Spain
EST	Estonia
FIN	Finland
FRA	France
GER	Germany
GRC	Greece
HUN	Hungary
IRL	Ireland
ITA	Italy
JAP	Japan
KOR	South Korea
LTU	Lithuania
LUX	Luxembourg
LVA	Latvia
MLT	Malta
NLD	Netherlands
POL	Poland
PRT	Portugal
SVK	Slovakia
SVN	Slovenia
SWE	Sweden
UK	United Kingdom
USA	United States
EA	Euro area (AUT, BEL, ESP, FIN, FRA, GER, GRC, IRL, ITA, LUX, NLD, PRT)
EU15	EU-15 (AUT, BEL, DNK, ESP, FIN, FRA, GER, GRC, IRL, ITA, LUX, NLD, PRT, SWE, UK)
EU25	EU-25, (AUT, BEL, CYP, CZE, DNK, ESP, EST, FIN, FRA, GER, GRC, HUN, IRL, ITA, LTU, LUX, LVA, MLT, NLD, POL, PRT, SVK, SVN, SWE, UK)
EAex	Euro area, excluding GRC
EU15ex	EU-15, excluding GRC
EU25ex	EU-25, excluding, CYP, EST, GRC, LVA, LTU, MLT, POL, SVK

Table 6.3 Industries included in Productivity Level Database

Description	NACE-Code
TOTAL INDUSTRIES	**TOT**
MARKET ECONOMY	**MARKT**
ELECTRICAL MACHINERY, POST AND COMMUNICATION SERVICES	**ELECOM**
Electrical and optical equipment	30t33
Post and telecommunications	64
GOODS PRODUCING, EXCLUDING ELECTRICAL MACHINERY	**GOODS**
TOTAL MANUFACTURING, EXCLUDING ELECTRICAL	**MexElec**
Consumer manufacturing	Mcons
Food products, beverages and tobacco	*15t16*
Textiles, textile products, leather and footwear	*17t19*
Manufacturing nec; recycling	*36t37*
Intermediate manufacturing	Minter
Wood and products of wood and cork	*20*
Pulp, paper, paper products, printing and publishing	*21t22*
Coke, refined petroleum products and nuclear fuel	*23*
Chemicals and chemical products	*24*
Rubber and plastics products	*25*
Other non-metallic mineral products	*26*
Basic metals and fabricated metal products	*27t28*
Investment goods, excluding hightech	Minves
Machinery, nec	*29*
Transport equipment	*34t35*
OTHER PRODUCTION	**OtherG**
Mining and quarrying	C
Electricity, gas and water supply	E
Construction	F
Agriculture, hunting, forestry and fishing	AtB
MARKET SERVICES, EXCLUDING POST AND TELECOMMUNICATIONS	**MSERV**
DISTRIBUTION	**DISTR**
Trade	50t52
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel	*50*
Wholesale trade and commission trade, except of motor vehicles and motorcycles	*51*
Retail trade, except of motor vehicles and motorcycles; repair of household goods	*52*
Transport and storage	60t63
FINANCE AND BUSINESS, EXCEPT REAL ESTATE	**FINBU**
Financial intermediation	J
Renting of m&eq and other business activities	71t74
PERSONAL SERVICES	**PERS**
Hotels and restaurants	H
Other community, social and personal services	O
Private households with employed persons	P
NON-MARKET SERVICES	**NONMAR**
Public admin, education and health	LtN
Public admin and defence; compulsory social security	*L*
Education	*M*
Health and social work	*N*
Real estate activities	70

7. SOME EMPIRICAL RESULTS

In this section we provide some of our main results for the year 2005. These results are based on our preferred set of estimates for 1997 (using a mix of PPPs), extrapolated to 2005 as described in section 4.6 based on the EU KLEMS Growth Accounts (O'Mahony and Timmer, 2008). We provide a set of relative levels of labour productivity, capital intensity, skill intensity and MFP in section 7.1. Detailed results can be found in the Appendix Tables to this paper at www.ggdc.net/databases/levels.htm. In section 7.2 a decomposition of gaps in labour productivity is made.

7.1 Relative levels

Labour productivity

In Figure 7.1 we provide comparative labour productivity levels for the year 2005 for our set of 30 countries in the market economy (variable *LP_VADD*). The countries are sorted according to levels of labour productivity. More detailed estimates for nine major sectors and higher aggregates are given in Table 7.1 Figure 7.2 provides a graphical representation of relative levels in the EU-15 compared to the U.S. in major sectors.

Table 7.1 Value added per hour worked, 2005, US=1
Figure 7.1 Value added per hour worked in market economy, 2005, US=1
Figure 7.2 Value added per hour worked in EU-15, major sectors 2005, US=1

The following broad patterns for labour productivity levels can be seen for European countries:

- Table 7.1 shows that in most European countries, market economy labour productivity levels compared to the US are lower than levels for the total economy. This is because the relative labour productivity level in non-market services are generally close to 1, while in the market economy it is (much) lower. As discussed in section 5.2.1 relative productivity levels in non-market services are close to one as output is typically measured by inputs.[45] As such, comparisons of the market economy (that is excluding public administration, health, education and real estate) can be considered to be more meaningful than comparisons for the total economy.
- In 2005, the labour productivity level in the EU15 relative to the US was only 69 %. The gap is smallest in Manufacturing and biggest in Other goods and Finance and business services (Figure 7.2).

[45] 1997 PPPs for non-market services have been constructed under the assumption that relative MPF levels (sectoral output based) are one. Hence, labour productivity are not necessarily one, depending on the maount of other inputs. Also, the figures in this table refer to 2005 so include any relative changes over the period 1997-2005.

- Within the EU large differences can be found. Belgian labour productivity levels are equal to the US but all other countries are lagging behind. Relative levels in France, Germany and the U.K. are around 70-80 %, while less than 60 % in Italy and Spain. Levels in Greece and Portugal are even below 40% of the US level (see Figure 7.1).
- In almost all European countries comparative levels are highest non-electrical manufacturing, while gaps are much bigger for market services.
- Labour productivity levels in various market services industries differ much more across countries than levels in manufacturing. Comparative performance to US in Finance is high in many countries, while it is (very) low in Business services
- For the new member states (EU-10) comparative levels in Market services are generally higher than in Goods production. This mainly due to very low labour productivity levels in Other goods production (Agriculture, Mining, Construction, Utilities).

Capital intensity

In Table 7.2 we provide comparative levels of capital services per hour worked in the year 2005 for our set of 20 countries for which capital data is available. Estimates are given for nine major sectors and higher aggregates. Figure 7.3 provides a graphical representation of relative levels in the market economy, while Figure 7.4 levels in the EU-15ex are provided. Comparisons are made for total capital (variable *CAP_QPH)* as well as for ICT-capital (computers, telecommunication equipment and software, variable *ITCAP_QPH*) and non-ICT capital only (variable *NITCAP_QPH*).

Table 7.2 Capital services per hour worked, 2005, US=1
Table 7.3 ICT capital services per hour worked, 2005, US=1
Table 7.4 Non-ICT capital services per hour worked, 2005, US=1
Figure 7.3 Capital services per hour worked, market economy, 2005, US=1
Figure 7.4 Capital services per hour worked in EU-15, major sectors, 2005, US=1
Figure 7.5 ICT capital services per hour worked, market economy, 2005, US=1
Figure 7.6 ICT Capital services per hour worked in EU-15, major sectors, 2005, US=1
Figure 7.7 Non-ICT capital services per hour worked, market economy, 2005, US=1
Figure 7.8 Non-ICT capital services per hour worked, EU-15, major sectors, 2005, US=1

The main results are as follows:

- In 2005, relative levels of capital per hour worked in the EU market economy were 86% of the U.S. The EU was leading the US in terms of non-ICT capital (107%) but severely lagging behind in ICT-capital (52%). In all sectors, relative levels of non-ICT are much higher than of ICT.
- Some sectors in Europe have a much higher relative level than others. In particular comparative capital levels in European manufacturing are relatively high, while they are much lower in other goods production.

- Across Europe, large differences in capital intensity can be found. Most European countries have higher non-ICT levels than the U.S., but all countries except Belgium and Sweden are severely lagging behind in ICT investments.[46]
- Comparative non-ICT capital levels in Europe appear to be particularly high in manufacturing and all market services. This is especially true for Personal services, Transport services and Business services, which might partly be due to differences in statistical practice across various countries. For example, the allocation and classification of investment between public and private (e.g. infrastructure) sectors and between leaser and lessee in the case of rental is not yet fully internationally harmonised.

Skill intensity

In Table 7.5 we provide comparative levels of labour services per hour worked in the year 2005 for our set of 20 countries (variable *LAB_QPH)*. Estimates are given for nine major sectors and higher aggregates. Figure 7.9 provides a graphical representation of relative levels in the market economy compared to the U.S.. The countries are sorted according to levels in the market economy. Figure 7.10 provides relative levels for the EU. Differences in labour services per hour work indicate differences in the composition of the labour force. If a country has a higher level, this indicates that the country has larger shares of workers in labour categories which have higher productivity than other workers. Typically these are workers in higher skill categories (as measured by educational attainment) hence this measure is often called the skill intensity.[47]

For the EU-15 the gap in skill intensity with the US is somewhat smaller than the physical capital level, at 89% in the market economy. The gap is biggest in Finance and business services, but much more uniform across sectors than physical capital gaps. Also, differences in skill intensity appear to be much smaller across countries than differences in capital intensity. While there are some sectoral idiosyncrasies, relative skill levels in an industry are mainly determined by the economy-wide supply of skills. Almost all European countries have levels above 80% of the U.S. and most levels are higher than 90%. It must be noted however that international comparisons of educational attainment across countries is still fraught with difficulties (see O'Mahony 2008). In this study 5 different educational types are distinguished, but problems of comparability remain as indicated by the rather high level in Hungary, while the level in Denmark appears to be particularly low.

Table 7.5 Labour services per hour worked, 2005, US=1

[46] This might partly be a problem of international differences in the measurement of software investments, in particular own-account software (e.g. in Germany this part of software investment is barely covered). Nevertheless, this cannot explain away the wide gaps observed in ICT investment.

[47] Nevertheless it might also be because of other labour characteristics such as higher age. Older (more experienced) workers typically earn higher wages and hence, by assumption, have a higher productivity than younger workers. Mostly though, it is skill differences which drive relative levels of labour services per hour worked.

Figure 7.9 Labour services per hour worked, market economy, 2005, US=1
Figure 7.10 Labour services per hour worked in EU-15, major sectors, 2005, US=1

Multi factor productivity

Finally, we present comparative levels of MFP (value added based, variable *MFP_VADD*). In Table 7.6 we provide levels for the year 2005 for our set of 20 countries. Estimates are given for nine major sectors and higher aggregates. Market economy levels are depicted in Figure 7.11 in which countries are sorted according to levels of productivity. Figure 7.12 provides a graphical representation of relative levels in the EU-15 compared to the U.S. for major sectors

Table 7.6 Multi factor productivity, 2005, US=1
Figure 7.11 Multi-factor productivity levels, market economy, 2005, US=1
Figure 7.12 Multi-factor productivity levels in EU-15, major sectors, 2005, US=1

The following observations can be made:

- European MFP gaps are smaller than labour productivity gaps due to higher inputs in the US compared to most European countries. This higher input of capital and skills in the U.S. was shown in the tables above.
- In 2005, EU15 MFP level in the market economy was 81% of the US
- In most countries, the MFP gap is smallest in Manufacturing, while biggest in Market Services
- Within market services, MFP levels are generally high in Trade and Financial services, but low in Transport and Business Services

7.2 Explaining Gaps in Labour Productivity

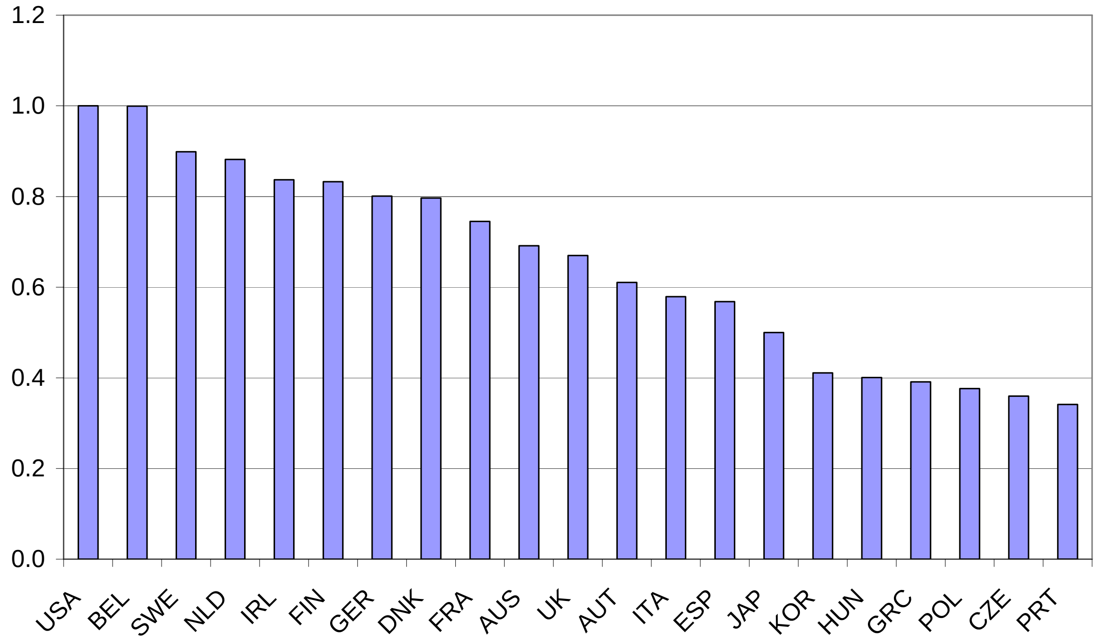
In this section we provide decompositions of gaps in labour productivity as in equation (7.13). Differences in labour productivity are decomposed into differences in ICT and non-ICT capital intensity, skill intensity and MFP. This is done for 1997, which is the benchmark year for the database. Decompositions are provided for our set of 20 countries for which this is possible. Table 7.7 provides figures for the market economy, while the other two tables provide decompositions for Goods production and Market Services.

Table 7.7 Breakdown of labour productivity gaps with the U.S., 1997, Market economy
Table 7.8 Breakdown of labour productivity gaps with the U.S., 1997, Goods production and Market Services

The tables read as follows. For example, the first row in Table 7.7 indicates that in 1997 the (log) labour productivity gap in Australian market economy with the US was 30%. Of this 10% was due to lower skill levels. Differences in capital intensity played no significant role. Although ICT intensity was much lower, non-ICT levels were much higher. The remaining gap of 21 % is explained by differences in MFP. In contrast, Belgium led the US in labour productivity levels by 5%. This was completely due to higher levels of non-ICT capital, as Belgium was lagging in terms of skills and MFP. Spain is different again. Although its labour productivity gap with the US is as big as in Australia, this is due to gaps in skills, capital and MFP alike, each accounting for at least 10 percentage points of the overall gap.

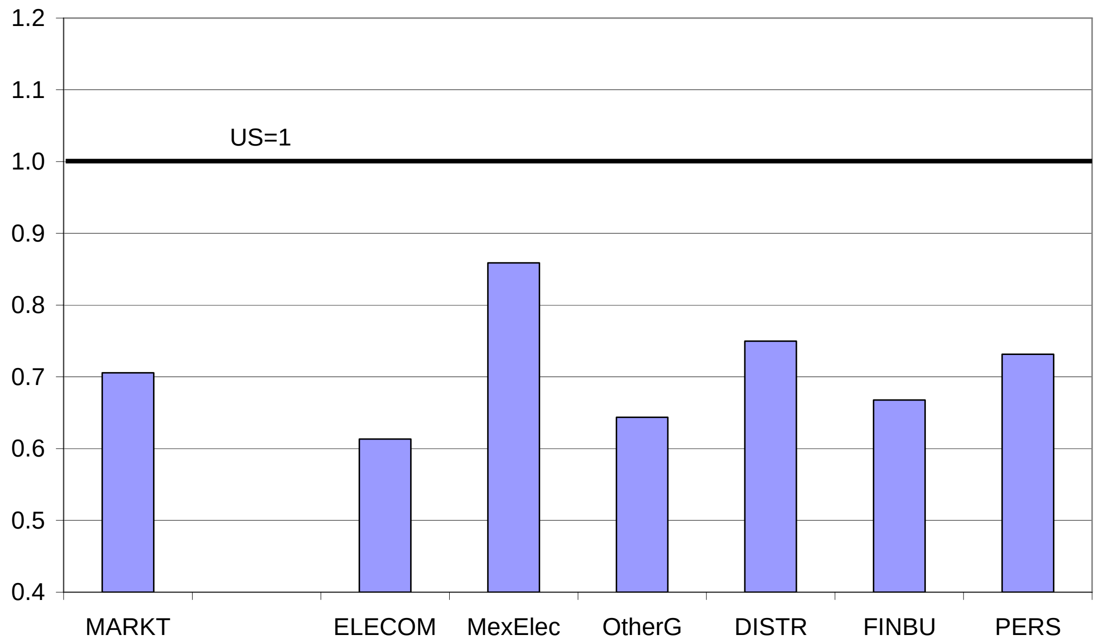
For the EU15, the gap is 26%, mainly due to a skills gap (8%) and MFP gap (16%). Capital accounted only for 2%, due to a large ICT gap, partly compensated for by higher non-ICT levels. At lower sector levels, patterns are different. In Goods production skill and capital gaps contribute each 8% to the overall gap of 29 %. In Market services, the contribution of capital differences is nil and MFP gaps explain 2/3 of the overall labour productivity gap. Given the superior MFP growth in US market services after the mid 1990s, this pattern will be even stronger for decompositions for more recent years.

Figure 7.1 Value added per hour worked in market economy, 2005, US=1



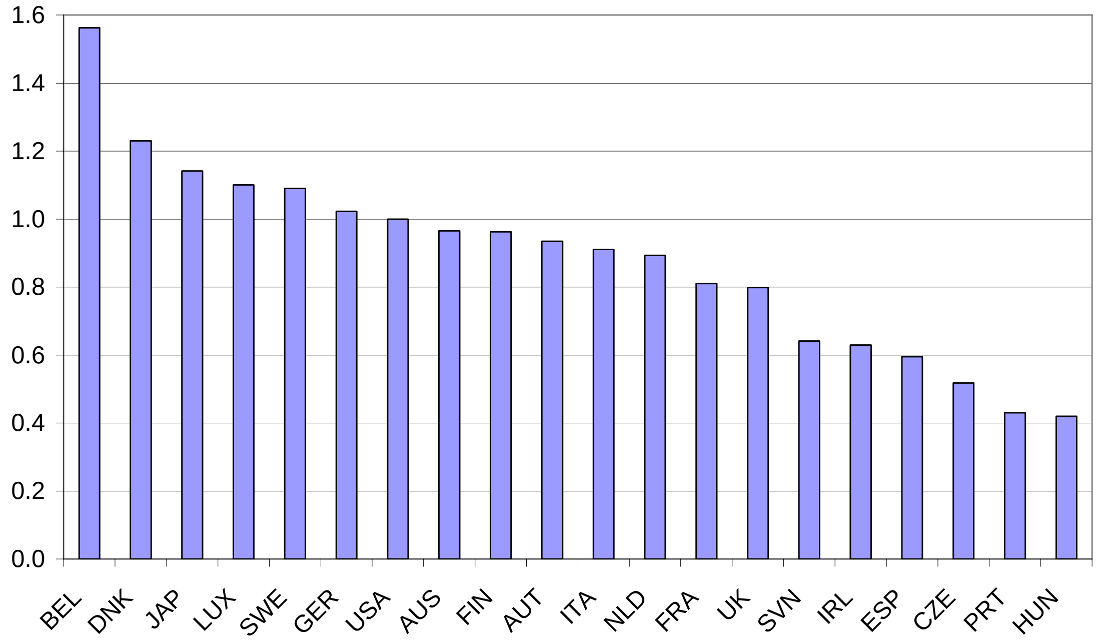
Source: Author's calculations on GGDC Productivity Level database

Figure 7.2 Value added per hour worked in EU-15, major sectors 2005, US=1



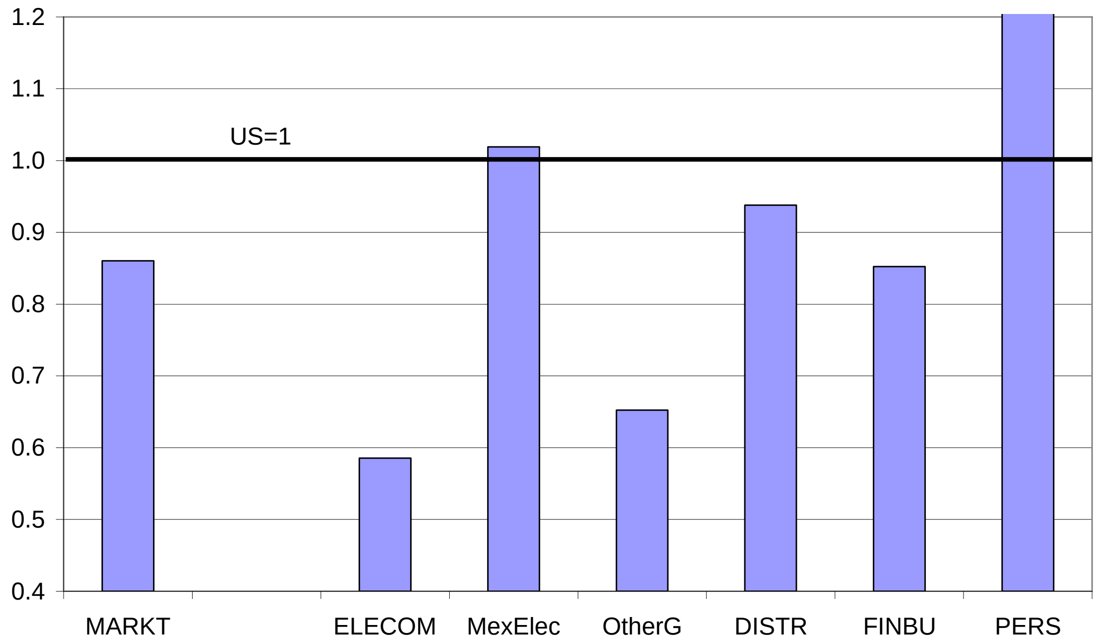
Source: Author's calculations on GGDC Productivity Level database

Figure 7.3 Capital services per hour worked, market economy, 2005, US=1



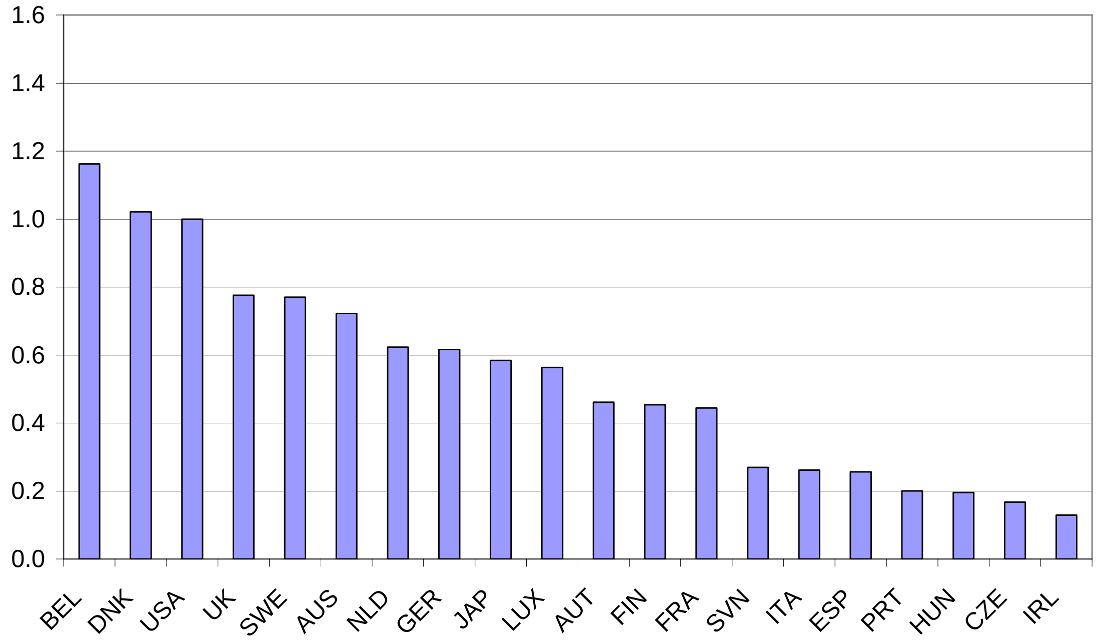
Source: Author's calculations on GGDC Productivity Level database.

Figure 7.4 Capital services per hour worked in EU-15, major sectors, 2005, US=1



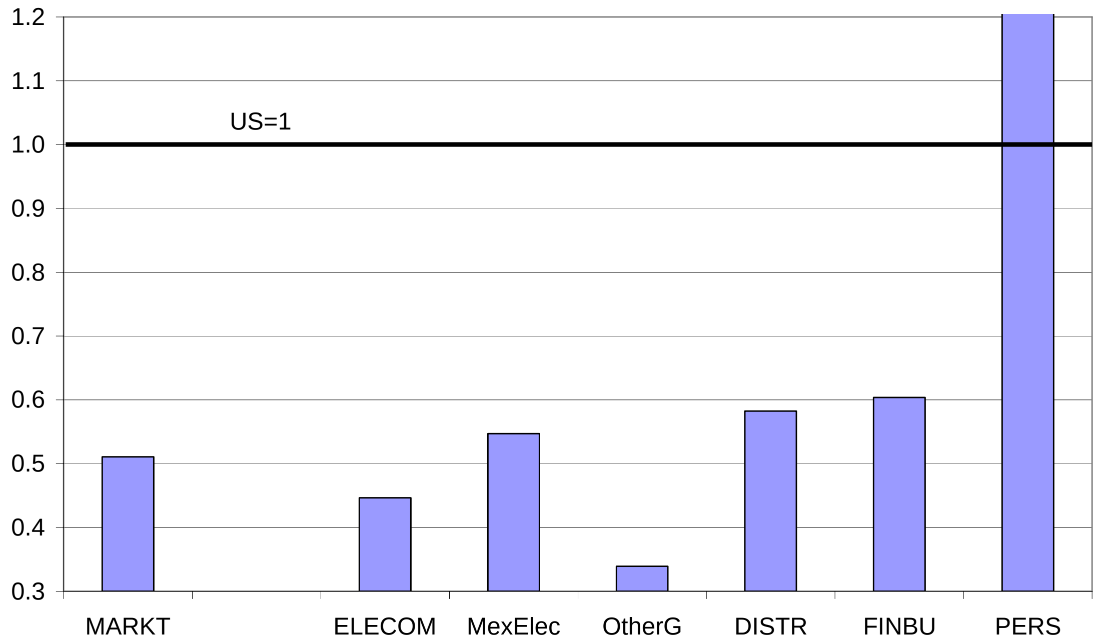
Source: Author's calculations on GGDC Productivity Level database. EU refers to EU15ex. First column is market economy. Other columns are major sectors.

Figure 7.5 ICT-capital services per hour worked, market economy, 2005, US=1



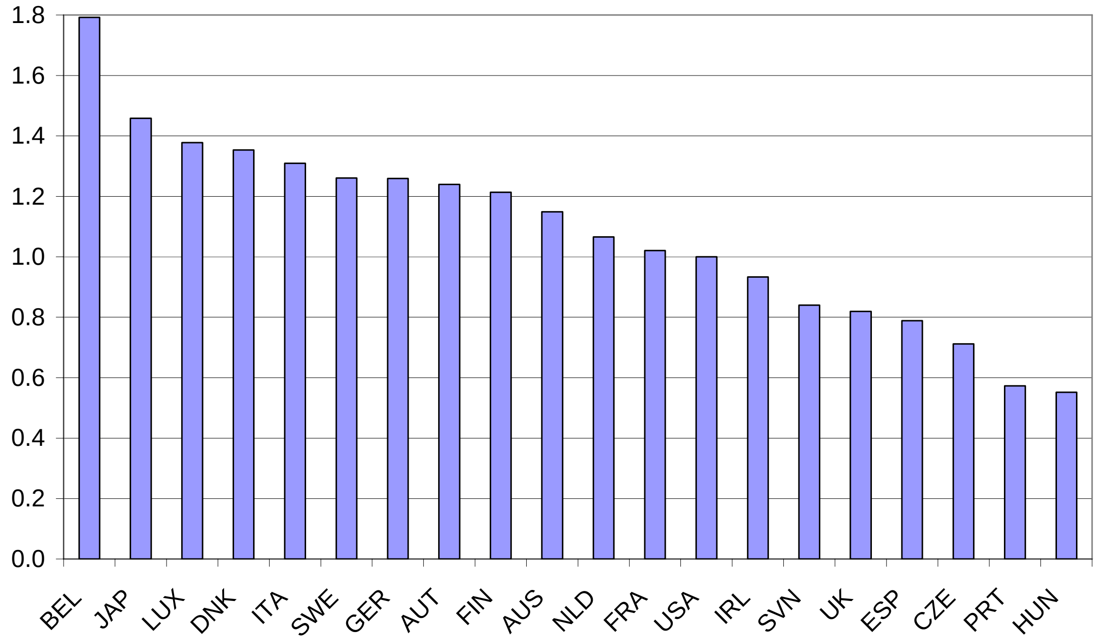
Source: Author's calculations on GGDC Productivity Level database.

Figure 7.6 ICT-capital services per hour worked in EU-15, major sectors, 2005, US=1



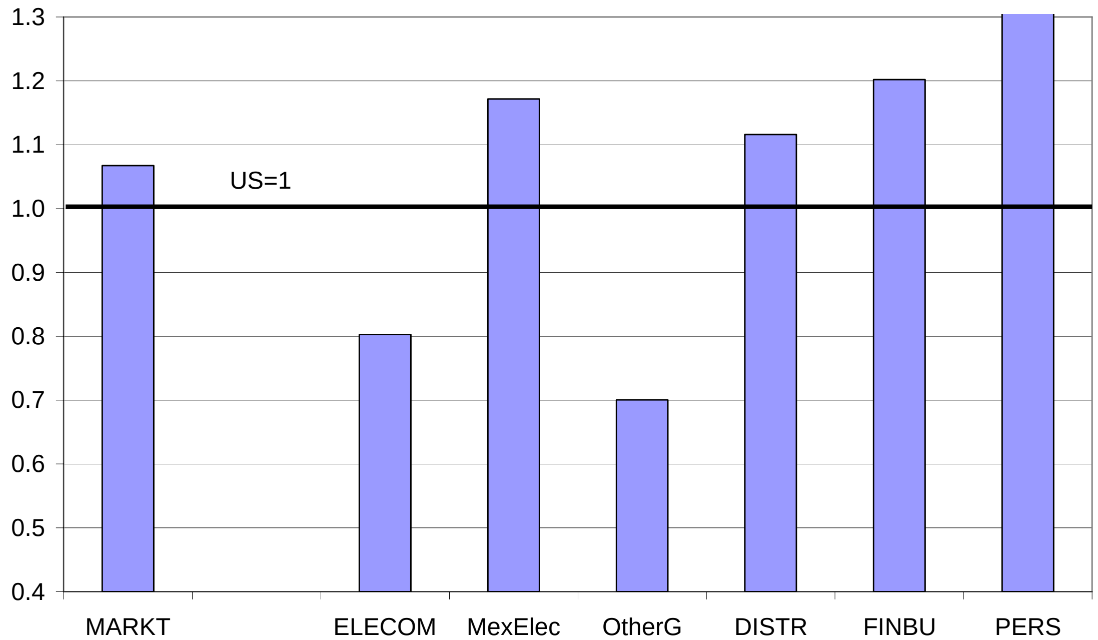
Source: Author's calculations on GGDC Productivity Level database. EU refers to EU15ex. First column is market economy. Other columns are major sectors.

Figure 7.7 Non-ICT capital services per hour worked, market economy, 2005, US=1



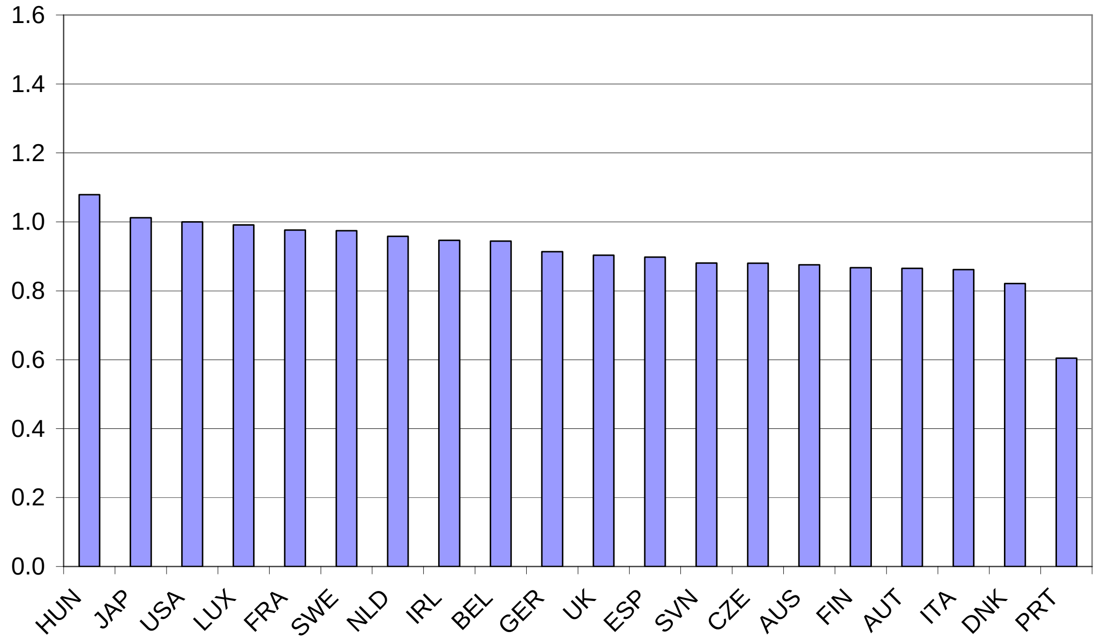
Source: Author's calculations on GGDC Productivity Level database.

Figure 7.8 Non-ICT capital services per hour worked in EU-15, major sectors, 2005, US=1



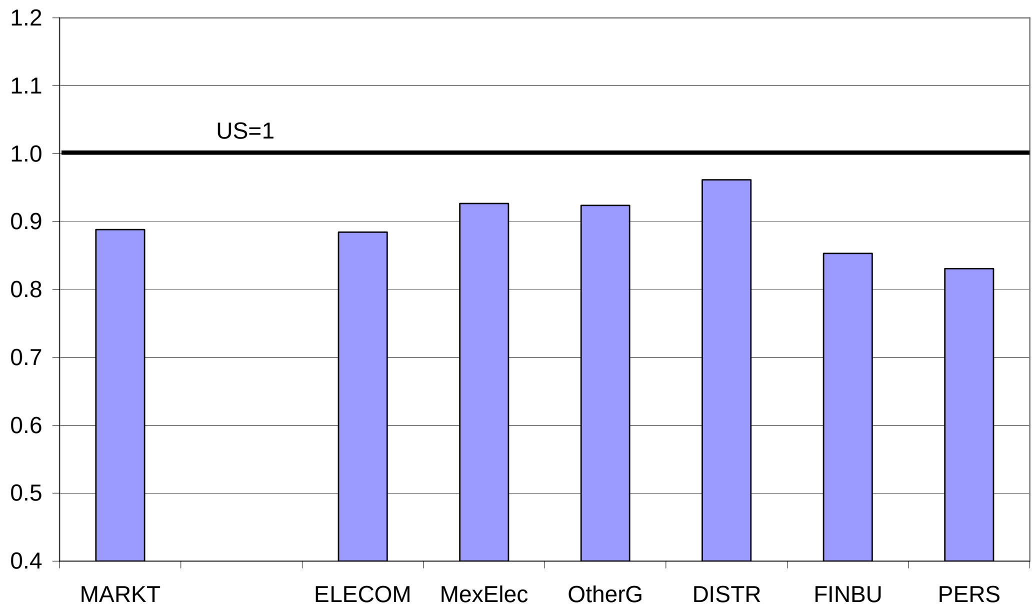
Source: Author's calculations on GGDC Productivity Level database. EU refers to EU15ex. First column is market economy. Other columns are major sectors.

Figure 7.9 Labour services per hour worked, market economy, 2005, US=1



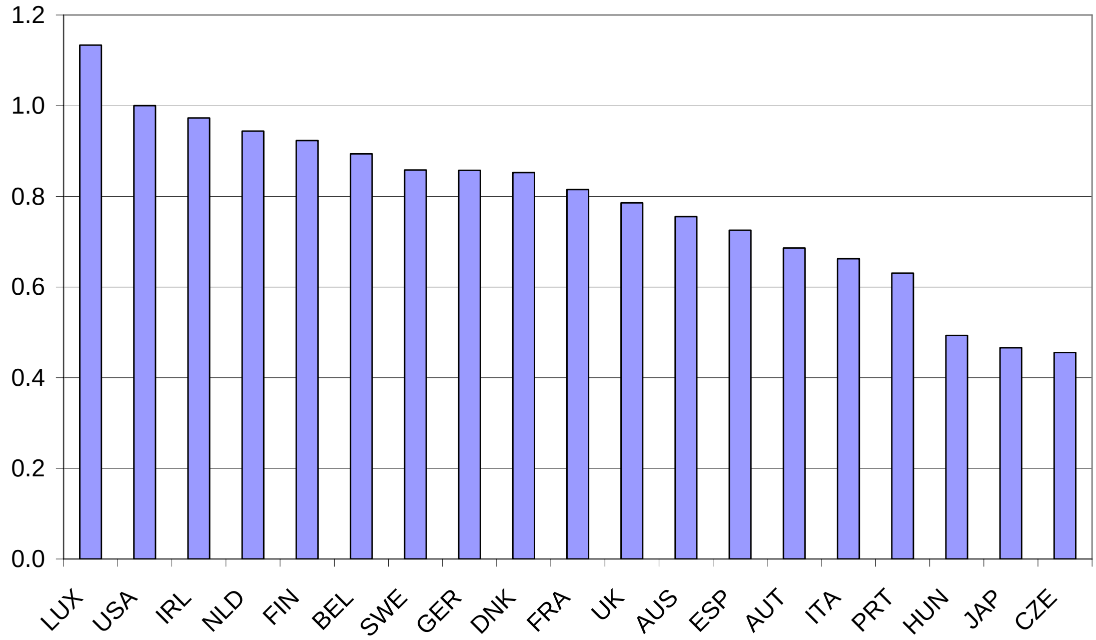
Source: Author's calculations on GGDC Productivity Level database.

Figure 7.10 Labour services per hour worked in EU-15, major sectors, 2005, US=1



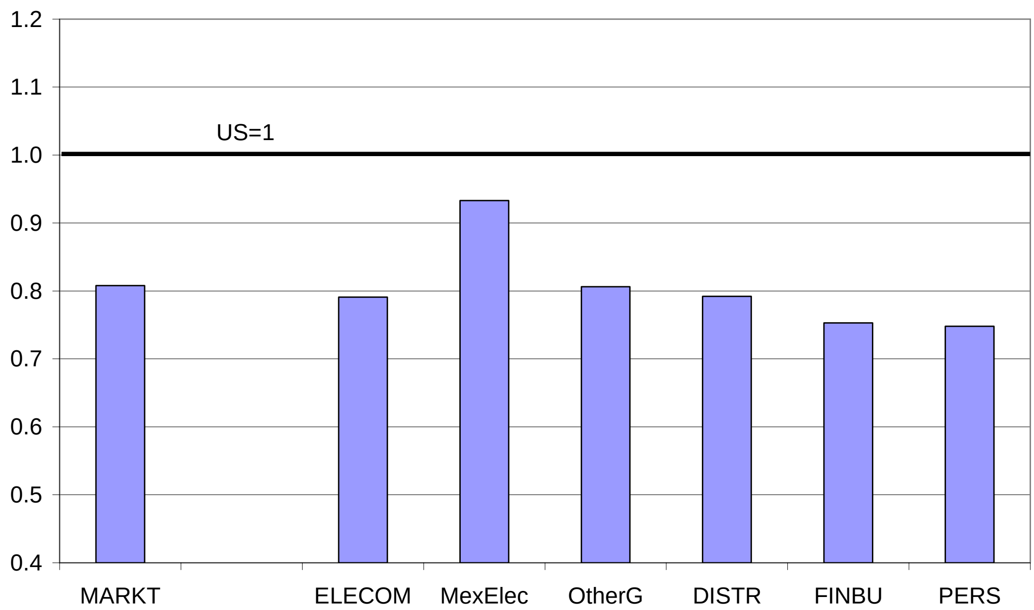
Source: Author's calculations on GGDC Productivity Level database. EU refers to EU15ex. First column is market economy. Other columns are major sectors.

Figure 7.11 Multi-factor productivity levels, market economy, 2005, US=1



Note: Multi-factor productivity is value added based (double deflated)
Source: Author's calculations on GGDC Productivity Level database.

Figure 7.12 Multi-factor productivity levels in EU-15, major sectors, 2005, US=1



Note: Multi-factor productivity is value added based (double deflated)
Source: Author's calculations on GGDC Productivity Level database. EU refers to EU15ex. First column is market economy. Other columns are major sectors.

Table 7.1 Value added per hour worked, 2005, US=1

	TOT														
		MARKT													NONMAR
			ELECOM	GOODS			MSERV								
					MexElec	OtherG		DISTR			FINBU			PERS	
									G	60t63		J	71t74		
AUS	0.71	0.68	0.38	0.82	0.52	1.38	0.67	0.63	0.48	1.15	0.68	1.48	0.40	0.74	0.82
AUT	0.67	0.60	0.36	0.71	0.69	0.79	0.57	0.60	0.70	0.40	0.47	0.87	0.33	0.93	0.92
BEL	0.97	0.96	0.52	1.20	1.27	1.13	0.89	0.95	1.39	0.41	0.83	1.55	0.64	0.80	0.95
CAN															
CYP	0.68	0.48	0.60	0.38	0.28	0.60	0.58	0.58	0.46	0.98	1.13	0.87	1.72	0.57	1.86
CZE	0.43	0.35	0.10	0.37	0.37	0.41	0.35	0.47	0.49	0.45	0.25	0.75	0.16	0.54	0.79
DNK	0.78	0.78	0.36	0.71	0.63	0.85	0.92	1.08	1.33	0.69	0.78	1.31	0.60	0.97	0.80
ESP	0.65	0.56	0.35	0.55	0.58	0.56	0.60	0.61	0.66	0.53	0.70	1.39	0.49	0.74	1.07
EST	0.34	0.22	0.04	0.18	0.09	0.37	0.29	0.23	0.28	0.15	0.85	0.39	1.28	0.51	1.45
FIN	0.77	0.81	0.90	0.82	1.06	0.69	0.68	1.09	1.26	0.82	0.40	0.64	0.37	0.58	0.63
FRA	0.80	0.73	0.68	0.75	0.92	0.58	0.76	0.88	1.00	0.65	0.57	1.08	0.44	1.00	1.02
GER	0.86	0.79	0.58	0.82	0.91	0.62	0.81	0.88	1.13	0.44	0.70	0.62	0.73	1.00	1.08
GRC	0.55	0.39	0.35	0.34	0.35	0.36	0.44	0.36	0.34	0.39	0.49	0.91	0.28	0.79	1.62
HUN	0.48	0.39	0.26	0.33	0.35	0.34	0.42	0.28	0.24	0.34	0.56	0.67	0.52	1.03	0.92
IRL	0.81	0.80	0.39	0.86	1.66	0.42	0.73	0.63	0.95	0.23	1.04	1.52	0.67	0.65	0.76
ITA	0.71	0.57	0.48	0.72	0.79	0.66	0.50	0.46	0.49	0.39	0.68	0.97	0.63	0.45	1.39
JAP	0.58	0.50	0.66	0.47	0.70	0.30	0.49	0.47	0.45	0.51	0.63	1.00	0.50	0.48	1.05
KOR	0.48	0.41	0.59	0.52	0.74	0.37	0.25	0.21	0.13	0.46	0.45	0.72	0.28	0.23	0.87
LTU	0.35	0.23	0.05	0.21	0.16	0.28	0.29	0.33	0.31	0.38	0.29	0.42	0.23	0.55	1.43
LUX	1.22	1.17	2.32	0.74	0.93	0.56	1.50	1.38	1.35	1.36	1.51	1.86	0.98	0.74	1.37
LVA	0.43	0.30	0.14	0.22	0.12	0.49	0.39	0.38	0.38	0.37	0.62	0.43	0.73	0.50	1.59
MLT	0.45	0.36	0.14	0.30	0.23	0.44	0.40	0.42	0.39	0.46	0.37	0.30	0.42	0.84	1.00
NLD	0.89	0.86	0.50	0.85	0.98	0.74	0.95	1.52	1.34	2.03	0.64	1.33	0.46	0.90	0.99
POL	0.50	0.37	0.09	0.27	0.34	0.26	0.55	0.65	0.64	0.66	0.61	1.17	0.40	0.63	1.43
PRT	0.42	0.33	0.31	0.22	0.25	0.24	0.49	0.50	0.39	1.07	0.89	1.80	0.56	0.39	0.86
SVK	0.42	0.30	0.11	0.24	0.19	0.41	0.41	0.31	0.24	0.50	0.49	0.64	0.48	0.95	1.35
SVN	0.48	0.40	0.21	0.38	0.49	0.25	0.46	0.36	0.41	0.25	0.49	0.91	0.35	0.87	0.86
SWE	0.82	0.88	2.43	0.91	0.90	0.86	0.81	0.79	0.99	0.50	0.73	1.23	0.63	0.51	0.68
UK	0.68	0.66	0.73	0.72	0.79	0.66	0.65	0.58	0.60	0.55	0.64	0.99	0.54	0.57	0.69
USA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EA	0.75	0.67	0.54	0.70	0.81	0.59	0.68	0.74	0.83	0.58	0.66	0.99	0.57	0.76	1.08
EU15	0.75	0.68	0.61	0.71	0.81	0.61	0.69	0.72	0.80	0.57	0.66	1.00	0.56	0.73	0.99
EU25	0.70	0.62	0.53	0.62	0.72	0.54	0.65	0.68	0.75	0.56	0.64	0.98	0.54	0.72	1.02
EAex	0.77	0.69	0.54	0.73	0.83	0.62	0.70	0.77	0.86	0.60	0.66	0.97	0.58	0.76	1.07
EU15ex	0.76	0.69	0.60	0.73	0.83	0.63	0.70	0.74	0.82	0.59	0.66	0.99	0.57	0.72	0.98

Table 7.2 Capital services per hour worked, 2005, US=1

	TOT														
		MARKT													NONMAR
			ELECOM	GOODS			MSERV								
					MexElec	OtherG		DISTR			FINBU			PERS	
									G	*60t63*		*J*	*71t74*		
AUS	**1.00**	**0.97**	**0.60**	**1.12**	0.99	1.32	**0.91**	1.18	*0.80*	*1.37*	0.68	*0.66*	*0.75*	1.68	
AUT	**0.99**	**0.93**	**0.59**	**0.93**	1.03	0.87	**0.95**	1.03	*0.81*	*1.06*	0.77	*0.70*	*0.87*	2.24	
BEL	**1.40**	**1.56**	**1.28**	**1.45**	1.59	1.59	**1.65**	2.23	*1.85*	*1.81*	1.18	*1.22*	*1.19*	2.48	
CZE	**0.58**	**0.52**	**0.22**	**0.43**	0.45	0.41	**0.59**	0.78	*0.51*	*0.71*	0.38	*0.51*	*0.34*	1.38	
DNK	**1.21**	**1.23**	**0.56**	**1.26**	1.23	1.27	**1.21**	1.54	*1.21*	*1.47*	0.79	*0.55*	*1.17*	3.32	
ESP	**0.78**	**0.59**	**0.55**	**0.55**	0.83	0.36	**0.59**	0.90	*0.71*	*1.03*	0.46	*0.59*	*0.41*	0.91	
FIN	**1.00**	**0.96**	**0.44**	**0.89**	1.16	0.69	**0.88**	1.27	*0.85*	*1.21*	0.40	*0.61*	*0.43*	2.42	
FRA	**1.03**	**0.81**	**0.45**	**0.76**	0.96	0.59	**0.83**	0.78	*0.71*	*0.71*	0.90	*0.70*	*0.93*	1.77	
GER	**1.15**	**1.02**	**0.48**	**0.85**	1.01	0.68	**1.16**	0.88	*0.71*	*0.92*	1.25	*0.63*	*1.42*	2.52	
HUN	**0.46**	**0.42**	**0.23**	**0.40**	0.44	0.35	**0.41**	0.46	*0.34*	*0.31*	0.31	*0.35*	*0.24*	0.90	
IRL	**0.72**	**0.63**	**0.37**	**0.72**	0.90	0.54	**0.53**	0.57	*0.62*	*0.52*	0.35	*0.17*	*0.47*	2.02	
ITA	**0.85**	**0.91**	**0.58**	**1.08**	1.33	0.84	**0.76**	1.05	*0.87*	*0.91*	0.82	*0.95*	*0.74*	0.94	
JAP	**1.13**	**1.14**	**0.89**	**1.12**	1.52	0.76	**1.07**	1.04	*0.90*	*0.92*	1.52	*0.84*	*1.91*	1.59	
LUX	**1.12**	**1.10**	**1.89**	**1.02**	1.56	0.62	**1.16**	1.37	*0.99*	*1.22*	0.59	*0.58*	*0.53*	2.50	
NLD	**1.02**	**0.89**	**0.88**	**0.98**	1.12	0.84	**0.84**	0.99	*0.93*	*0.86*	0.73	*1.02*	*0.65*	1.47	
PRT	**0.52**	**0.43**	**0.59**	**0.30**	0.47	0.19	**0.52**	0.56	*0.34*	*0.97*	0.74	*0.94*	*0.60*	0.85	
SVN	**0.55**	**0.64**	**0.32**	**0.54**	0.62	0.43	**0.68**	0.80	*0.83*	*0.56*	0.50	*0.64*	*0.33*	1.53	
SWE	**0.79**	**1.09**	**0.73**	**1.03**	1.16	0.84	**1.14**	1.47	*1.28*	*1.19*	0.96	*0.93*	*1.03*	1.35	
UK	**0.77**	**0.80**	**0.70**	**0.76**	0.85	0.66	**0.84**	0.84	*0.82*	*0.72*	0.69	*0.85*	*0.58*	1.99	
USA	**1.00**	**1.00**	**1.00**	**1.00**	1.00	1.00	**1.00**	1.00	*1.00*	*1.00*	1.00	*1.00*	*1.00*	1.00	
EAex	**0.95**	**0.86**	**0.54**	**0.82**	1.04	0.63	**0.87**	0.94	*0.76*	*0.94*	0.91	*0.75*	*0.93*	1.60	
EU15ex	**0.92**	**0.86**	**0.59**	**0.83**	1.02	0.65	**0.87**	0.94	*0.79*	*0.90*	0.85	*0.76*	*0.85*	1.66	

Table 7.3 ICT capital services per hour worked, 2005, US=1

	TOT														
		MARKT													**NONMAR**
			ELECOM	**GOODS**			**MSERV**								
					MexElec	OtherG		DISTR			FINBU			PERS	
									G	*60t63*		*J*	*71t74*		
AUS	**0.86**	**0.72**	**0.45**	**1.03**	1.05	1.31	**0.68**	0.94	*1.01*	*0.69*	0.69	*0.93*	*0.53*	2.54	
AUT	**0.47**	**0.46**	**0.54**	**0.40**	0.55	0.24	**0.74**	0.59	*0.86*	*0.19*	0.50	*0.41*	*0.65*	1.69	
BEL	**1.13**	**1.16**	**0.56**	**1.14**	1.08	1.03	**1.17**	2.27	*1.97*	*1.53*	0.93	*0.86*	*1.18*	3.53	
CZE	**0.19**	**0.17**	**0.17**	**0.15**	0.12	0.20	**0.20**	0.21	*0.29*	*0.08*	0.21	*0.37*	*0.18*	0.78	
DNK	**1.00**	**1.02**	**0.48**	**0.88**	0.87	0.85	**0.93**	1.07	*1.34*	*0.56*	1.17	*1.10*	*1.04*	6.60	
ESP	**0.30**	**0.26**	**0.29**	**0.25**	0.34	0.17	**0.25**	0.46	*0.25*	*0.65*	0.29	*0.58*	*0.18*	1.10	
FIN	**0.47**	**0.45**	**0.32**	**0.47**	0.63	0.29	**0.43**	0.63	*0.74*	*0.37*	0.42	*1.01*	*0.35*	3.20	
FRA	**0.46**	**0.44**	**0.28**	**0.49**	0.56	0.41	**0.38**	0.33	*0.37*	*0.22*	0.55	*0.62*	*0.53*	1.29	
GER	**0.64**	**0.62**	**0.28**	**0.54**	0.54	0.44	**0.68**	0.55	*0.71*	*0.30*	0.86	*0.55*	*0.96*	1.95	
HUN	**0.21**	**0.20**	**0.17**	**0.17**	0.17	0.16	**0.26**	0.21	*0.24*	*0.12*	0.27	*0.39*	*0.19*	1.07	
IRL	**0.17**	**0.13**	**0.06**	**0.13**	0.21	0.14	**0.14**	0.25	*0.25*	*0.32*	0.08	*0.04*	*0.12*	2.17	
ITA	**0.31**	**0.26**	**0.23**	**0.28**	0.32	0.17	**0.26**	0.47	*0.26*	*0.54*	0.27	*0.52*	*0.21*	0.57	
JAP	**0.66**	**0.58**	**0.50**	**0.45**	0.53	0.34	**0.60**	0.38	*0.54*	*0.13*	1.21	*0.97*	*1.31*	1.08	
LUX	**0.61**	**0.56**	**1.12**	**0.32**	0.37	0.40	**0.54**	0.44	*0.49*	*0.32*	0.48	*0.55*	*0.39*	1.28	
NLD	**0.73**	**0.62**	**0.64**	**0.53**	0.54	0.61	**0.65**	0.69	*0.80*	*0.42*	0.61	*1.25*	*0.40*	2.87	
PRT	**0.29**	**0.20**	**0.51**	**0.06**	0.11	0.02	**0.27**	0.18	*0.23*	*0.08*	0.51	*0.38*	*0.58*	2.00	
SVN	**0.31**	**0.27**	**0.26**	**0.28**	0.30	0.24	**0.30**	0.26	*0.37*	*0.10*	0.34	*0.64*	*0.14*	1.55	
SWE	**0.68**	**0.77**	**0.44**	**1.14**	1.17	0.45	**0.67**	0.99	*1.25*	*0.53*	0.84	*1.08*	*0.78*	2.16	
UK	**0.80**	**0.78**	**0.91**	**0.76**	0.91	0.49	**0.69**	0.81	*1.01*	*0.47*	0.63	*0.88*	*0.54*	2.35	
USA	**1.00**	**1.00**	**1.00**	**1.00**	1.00	1.00	**1.00**	1.00	*1.00*	*1.00*	1.00	*1.00*	*1.00*	1.00	
EAex	**0.47**	**0.42**	**0.31**	**0.40**	0.45	0.30	**0.44**	0.50	*0.49*	*0.43*	0.56	*0.60*	*0.57*	1.33	
EU15ex	**0.55**	**0.51**	**0.45**	**0.48**	0.55	0.34	**0.51**	0.58	*0.64*	*0.43*	0.60	*0.69*	*0.59*	1.56	

Table 7.4 Non-ICT capital services per hour worked, 2005, US=1

	TOT													
		MARKT												**NONMAR**
			ELECOM	**GOODS**			**MSERV**							
					MexElec	OtherG		DISTR			FINBU			PERS
									G	*60t63*		*J*	*71t74*	
AUS	**1.06**	**1.15**	**0.89**	**1.17**	1.02	1.06	**1.09**	1.29	*0.73*	*1.98*	0.76	*0.60*	*1.11*	1.50
AUT	**1.16**	**1.24**	**0.58**	**1.08**	1.23	0.83	**1.35**	1.33	*0.93*	*1.81*	1.21	*1.02*	*1.57*	2.30
BEL	**1.48**	**1.79**	**1.76**	**1.53**	1.75	1.36	**2.06**	2.40	*1.90*	*2.38*	1.50	*1.43*	*1.71*	2.18
CZE	**0.69**	**0.71**	**0.30**	**0.50**	0.55	0.43	**0.91**	1.06	*0.59*	*1.23*	0.54	*0.52*	*0.63*	1.44
DNK	**1.26**	**1.35**	**0.81**	**1.35**	1.31	1.35	**1.30**	1.72	*1.07*	*2.26*	0.41	*0.32*	*0.98*	2.58
ESP	**0.94**	**0.79**	**0.91**	**0.63**	0.99	0.39	**0.84**	1.10	*0.93*	*1.37*	0.60	*0.48*	*0.84*	0.82
FIN	**1.14**	**1.21**	**0.72**	**0.98**	1.34	0.73	**1.16**	1.60	*0.88*	*2.01*	0.21	*0.10*	*0.54*	2.01
FRA	**1.23**	**1.02**	**0.73**	**0.82**	1.07	0.62	**1.19**	1.03	*0.86*	*1.16*	1.26	*0.71*	*1.72*	1.80
GER	**1.32**	**1.26**	**0.78**	**0.92**	1.15	0.72	**1.57**	1.04	*0.70*	*1.46*	1.81	*0.71*	*2.69*	2.59
HUN	**0.53**	**0.55**	**0.32**	**0.46**	0.53	0.38	**0.56**	0.60	*0.40*	*0.46*	0.39	*0.24*	*0.49*	0.86
IRL	**0.90**	**0.93**	**0.84**	**0.85**	1.12	0.58	**0.89**	0.74	*0.78*	*0.73*	0.71	*0.29*	*1.21*	1.87
ITA	**1.04**	**1.31**	**1.09**	**1.27**	1.67	0.94	**1.22**	1.29	*1.16*	*1.23*	1.70	*1.33*	*2.09*	0.99
JAP	**1.29**	**1.46**	**1.44**	**1.28**	1.85	0.82	**1.43**	1.40	*1.04*	*1.60*	1.74	*0.67*	*2.90*	1.62
LUX	**1.27**	**1.38**	**3.21**	**1.17**	1.97	0.65	**1.64**	1.90	*1.24*	*2.01*	0.77	*0.62*	*0.82*	2.66
NLD	**1.11**	**1.07**	**1.22**	**1.08**	1.30	0.89	**1.03**	1.18	*1.02*	*1.29*	0.92	*0.89*	*1.20*	1.22
PRT	**0.59**	**0.57**	**0.71**	**0.36**	0.61	0.21	**0.77**	0.78	*0.42*	*1.71*	1.12	*1.33*	*0.97*	0.69
SVN	**0.63**	**0.84**	**0.39**	**0.62**	0.72	0.46	**0.99**	1.07	*1.01*	*0.95*	0.70	*0.67*	*0.71*	1.40
SWE	**0.84**	**1.26**	**1.16**	**1.03**	1.15	0.90	**1.43**	1.71	*1.23*	*1.86*	0.98	*0.69*	*1.53*	1.15
UK	**0.76**	**0.82**	**0.49**	**0.77**	0.83	0.69	**0.92**	0.87	*0.74*	*0.95*	0.69	*0.59*	*0.77*	1.82
USA	**1.00**	**1.00**	**1.00**	**1.00**	1.00	1.00	**1.00**	1.00	*1.00*	*1.00*	1.00	*1.00*	*1.00*	1.00
EAex	**1.12**	**1.12**	**0.87**	**0.92**	1.23	0.69	**1.24**	1.15	*0.89*	*1.39*	1.40	*0.86*	*1.89*	1.60
EU15ex	**1.05**	**1.07**	**0.80**	**0.91**	1.17	0.70	**1.18**	1.12	*0.87*	*1.33*	1.20	*0.78*	*1.59*	1.63

Table 7.5 Labour services per hour worked, 2005, US=1

	TOT														
		MARKT													NONMAR
			ELECOM	GOODS			MSERV								
					MexElec	OtherG		DISTR			FINBU			PERS	
									G	*60t63*		*J*	*71t74*		
AUS	**0.87**	**0.88**	**0.77**	**0.89**	0.87	0.89	**0.86**	0.84	*0.85*	*0.80*	0.82	*0.93*	*0.78*	1.09	
AUT	**0.88**	**0.87**	**0.83**	**0.86**	0.89	0.84	**0.86**	0.94	*0.94*	*0.90*	0.81	*0.92*	*0.82*	0.93	
BEL	**0.93**	**0.94**	**0.86**	**1.03**	1.01	1.03	**0.90**	1.00	*0.98*	*0.97*	0.82	*1.00*	*0.80*	0.73	
CZE	**0.88**	**0.88**	**0.77**	**0.89**	0.83	0.97	**0.88**	0.95	*0.94*	*0.91*	0.84	*0.94*	*0.86*	0.95	
DNK	**0.82**	**0.82**	**0.76**	**0.85**	0.83	0.86	**0.80**	0.84	*0.80*	*0.88*	0.76	*0.85*	*0.74*	0.85	
ESP	**0.92**	**0.90**	**1.01**	**0.94**	0.97	0.95	**0.87**	1.03	*1.01*	*1.04*	0.87	*1.03*	*0.86*	0.84	
FIN	**0.87**	**0.87**	**0.86**	**0.89**	0.92	0.90	**0.84**	0.91	*0.87*	*0.89*	0.75	*0.88*	*0.74*	1.00	
FRA	**0.98**	**0.98**	**0.93**	**0.95**	0.99	0.93	**0.99**	1.06	*1.07*	*0.96*	0.94	*1.07*	*0.92*	0.90	
GER	**0.91**	**0.91**	**0.87**	**1.01**	0.97	0.97	**0.86**	0.94	*0.93*	*0.89*	0.80	*0.89*	*0.80*	0.91	
HUN	**1.03**	**1.08**	**0.82**	**0.88**	0.84	0.93	**1.26**	1.09	*1.13*	*0.94*	0.94	*1.01*	*0.89*	3.76	
IRL	**0.94**	**0.95**	**0.89**	**0.95**	0.97	0.94	**0.95**	1.03	*1.06*	*0.96*	0.94	*1.00*	*0.86*	0.99	
ITA	**0.87**	**0.86**	**0.87**	**0.87**	0.86	0.87	**0.86**	1.03	*1.04*	*0.96*	0.90	*1.10*	*0.93*	0.69	
JAP	**0.97**	**1.01**	**0.91**	**0.99**	0.95	1.03	**1.02**	1.10	*1.14*	*0.95*	0.96	*1.09*	*0.93*	1.37	
LUX	**0.95**	**0.99**	**0.90**	**0.93**	0.93	0.96	**1.00**	1.02	*1.01*	*0.90*	0.93	*0.98*	*0.83*	0.85	
NLD	**0.96**	**0.96**	**0.89**	**0.99**	1.00	0.98	**0.95**	0.99	*1.04*	*0.83*	0.85	*1.00*	*0.84*	1.10	
PRT	**0.65**	**0.60**	**0.65**	**0.56**	0.49	0.70	**0.65**	0.80	*0.81*	*0.88*	0.78	*0.96*	*0.77*	0.54	
SVN	**0.89**	**0.88**	**0.82**	**0.83**	0.81	0.87	**0.97**	1.02	*1.02*	*0.96*	0.88	*0.94*	*0.88*	1.11	
SWE	**0.95**	**0.97**	**0.92**	**1.00**	0.98	0.98	**0.96**	1.01	*0.99*	*0.95*	0.89	*1.05*	*0.87*	1.08	
UK	**0.90**	**0.90**	**0.90**	**0.99**	0.96	1.03	**0.86**	0.90	*0.87*	*0.92*	0.84	*0.91*	*0.85*	0.86	
USA	**1.00**	**1.00**	**1.00**	**1.00**	1.00	1.00	**1.00**	1.00	*1.00*	*1.00*	1.00	*1.00*	*1.00*	1.00	
EAex	**0.90**	**0.88**	**0.87**	**0.91**	0.92	0.90	**0.87**	0.98	*0.97*	*0.93*	0.86	*0.99*	*0.86*	0.82	
EU15ex	**0.90**	**0.89**	**0.88**	**0.92**	0.93	0.92	**0.87**	0.96	*0.95*	*0.93*	0.85	*0.97*	*0.86*	0.83	

Table 7.6 Multi factor productivity, 2005, US=1

	TOT	MARKT	ELECOM	GOODS	MexElec	OtherG	MSERV	DISTR	G	60t63	FINBU	J	71t74	PERS
AUS	0.77	0.75	0.50	0.84	0.58	1.36	0.76	0.68	0.58	1.16	0.87	1.89	0.51	0.63
AUT	0.74	0.67	0.48	0.82	0.75	0.97	0.63	0.61	0.77	0.42	0.57	1.09	0.37	0.82
BEL	0.91	0.86	0.50	1.05	1.09	1.03	0.80	0.72	1.14	0.34	0.90	1.48	0.68	0.83
CZE	0.54	0.44	0.18	0.52	0.54	0.57	0.42	0.47	0.51	0.52	0.37	1.09	0.20	0.54
DNK	0.84	0.84	0.51	0.74	0.70	0.84	1.01	1.10	1.53	0.63	0.99	1.91	0.69	0.78
ESP	0.76	0.71	0.41	0.73	0.65	0.90	0.77	0.61	0.72	0.48	0.94	1.74	0.63	0.87
FIN	0.85	0.90	1.24	0.95	1.07	0.86	0.78	1.06	1.47	0.78	0.64	0.85	0.55	0.49
FRA	0.81	0.80	0.93	0.88	0.97	0.75	0.80	0.91	1.05	0.72	0.60	1.28	0.43	0.95
GER	0.88	0.85	0.80	0.90	0.97	0.75	0.84	0.98	1.33	0.49	0.68	0.85	0.58	0.85
HUN	0.62	0.47	0.45	0.50	0.51	0.54	0.45	0.32	0.30	0.46	0.80	0.95	0.74	0.43
IRL	0.93	0.93	0.52	1.02	1.54	0.56	0.87	0.68	1.00	0.27	1.51	3.49	0.82	0.52
ITA	0.83	0.65	0.61	0.79	0.82	0.78	0.60	0.44	0.50	0.40	0.76	0.98	0.64	0.60
JAP	0.56	0.47	0.66	0.46	0.60	0.33	0.46	0.44	0.42	0.55	0.52	1.02	0.41	0.34
LUX	1.17	1.08	1.37	0.80	0.88	0.69	1.30	1.15	1.27	1.27	1.72	2.31	1.16	0.68
NLD	0.92	0.92	0.53	0.88	0.96	0.81	1.03	1.53	1.33	2.37	0.79	1.36	0.56	0.78
PRT	0.71	0.61	0.43	0.51	0.54	0.56	0.78	0.69	0.62	1.22	1.06	1.88	0.65	0.63
SVN	0.62	0.46	0.33	0.48	0.66	0.27	0.51	0.35	0.40	0.29	0.63	1.12	0.44	0.74
SWE	0.90	0.84	2.58	0.90	0.85	0.95	0.76	0.69	0.96	0.43	0.73	1.18	0.61	0.45
UK	0.82	0.77	0.90	0.83	0.91	0.78	0.77	0.66	0.70	0.64	0.81	1.27	0.63	0.55
USA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EAex	0.85	0.79	0.72	0.86	0.90	0.79	0.78	0.80	0.96	0.63	0.72	1.14	0.57	0.79
EU15ex	0.84	0.79	0.77	0.85	0.90	0.79	0.79	0.78	0.92	0.63	0.75	1.18	0.58	0.74

Note: MFP is value added based (double deflated)

Table 7.7 Breakdown of labour productivity gaps with the U.S., 1997, market economy

	Labour-productivity	Contributions by				
		Labour composition	Capital	*of which ICT-capital*	*Non-ICT-capital*	MFP
	(1) = (2)+(3)+(6)	(2)	(3) = (4)+(5)	*(4)*	*(5)*	(6)
AUS	-0.30	-0.10	0.01	-0.04	0.05	-0.21
AUT	-0.48	-0.10	0.04	-0.06	0.09	-0.42
BEL	0.05	-0.04	0.15	0.00	0.16	-0.07
CZE	-1.10	-0.09	-0.29	-0.11	-0.18	-0.72
DNK	-0.16	-0.14	0.07	-0.02	0.09	-0.09
ESP	-0.33	-0.10	-0.13	-0.06	-0.07	-0.11
FIN	-0.24	-0.10	0.05	-0.05	0.10	-0.20
FRA	-0.27	-0.03	-0.03	-0.03	0.00	-0.20
GER	-0.13	-0.05	0.02	-0.03	0.04	-0.09
HUN	-1.03	-0.01	-0.27	-0.10	-0.17	-0.74
IRL	-0.33	-0.07	-0.21	-0.12	-0.09	-0.05
ITA	-0.32	-0.11	0.02	-0.05	0.07	-0.23
LUX	0.26	-0.03	0.10	-0.03	0.13	0.18
NLD	-0.12	-0.05	0.01	-0.02	0.03	-0.08
PRT	-0.96	-0.34	-0.31	-0.13	-0.18	-0.31
SVN	-1.04	-0.14	-0.18	-0.07	-0.11	-0.71
SWE	-0.20	-0.03	0.03	0.02	0.01	-0.20
UK	-0.41	-0.09	-0.09	-0.03	-0.06	-0.23
EU15ex	-0.26	-0.08	-0.02	-0.04	0.01	-0.16
JAP	-0.64	-0.02	0.06	-0.01	0.07	-0.68

Table 7.8 Breakdown of labour productivity gaps with the U.S., 1997,

(A) Goods production

	Labour-productivity		Contributions by				
			Labour composition	Capital	*of which* *ICT-capital*	*Non-ICT-capital*	MFP
	(1) = (2)+(3)+(6)		(2)	(3) = (4)+(5)	*(4)*	*(5)*	(6)
AUS	-0.22		-0.10	0.03	-0.02	0.05	-0.15
AUT	-0.61		-0.13	-0.01	-0.05	0.04	-0.47
BEL	0.13		-0.01	0.11	-0.01	0.12	0.03
CZE	-1.20		-0.10	-0.46	-0.07	-0.38	-0.65
DNK	-0.38		-0.13	0.04	-0.02	0.06	-0.29
ESP	-0.30		-0.09	-0.19	-0.05	-0.15	-0.02
FIN	-0.29		-0.11	-0.01	-0.03	0.02	-0.16
FRA	-0.42		-0.08	-0.10	-0.01	-0.08	-0.24
GER	-0.29		-0.03	-0.06	-0.01	-0.05	-0.19
HUN	-1.28		-0.12	-0.38	-0.07	-0.31	-0.78
IRL	-0.33		-0.10	-0.25	-0.09	-0.16	0.01
ITA	-0.09		-0.12	0.01	-0.04	0.05	0.02
LUX	-0.41		-0.07	0.02	-0.03	0.05	-0.36
NLD	-0.27		-0.06	0.02	-0.02	0.04	-0.23
PRT	-1.48		-0.41	-0.46	-0.12	-0.34	-0.60
SVN	-1.23		-0.20	-0.21	-0.03	-0.19	-0.80
SWE	-0.24		-0.04	-0.01	0.03	-0.04	-0.19
UK	-0.41		-0.05	-0.14	-0.02	-0.12	-0.23
EU15ex	-0.29		-0.08	-0.08	-0.02	-0.05	-0.13
JAP	-0.79		-0.06	-0.01	-0.02	0.01	-0.72

(B) Market Services

	Labour-productivity		Contributions by				
			Labour composition	Capital	*of which* *ICT-capital*	*Non-ICT-capital*	MFP
	(1) = (2)+(3)+(6)		(2)	(3) = (4)+(5)	*(4)*	*(5)*	(6)
AUS	-0.34		-0.10	0.00	-0.05	0.04	-0.24
AUT	-0.38		-0.08	0.06	-0.05	0.11	-0.36
BEL	0.00		-0.06	0.18	0.00	0.18	-0.13
CZE	-1.02		-0.08	-0.17	-0.12	-0.05	-0.78
DNK	0.04		-0.14	0.09	-0.01	0.10	0.09
ESP	-0.36		-0.10	-0.10	-0.06	-0.04	-0.16
FIN	-0.24		-0.09	0.09	-0.04	0.13	-0.24
FRA	-0.16		0.00	0.00	-0.03	0.03	-0.15
GER	-0.01		-0.07	0.07	-0.02	0.10	-0.02
HUN	-0.85		0.07	-0.21	-0.10	-0.10	-0.72
IRL	-0.34		-0.05	-0.21	-0.12	-0.08	-0.08
ITA	-0.46		-0.10	0.01	-0.05	0.06	-0.37
LUX	0.66		0.00	0.16	-0.03	0.18	0.51
NLD	0.03		-0.04	0.00	-0.03	0.02	0.07
PRT	-0.51		-0.26	-0.20	-0.12	-0.08	-0.05
SVN	-0.79		-0.04	-0.16	-0.09	-0.07	-0.59
SWE	-0.21		-0.02	0.05	0.03	0.02	-0.23
UK	-0.42		-0.11	-0.07	-0.03	-0.03	-0.25
EU15ex	-0.22		-0.08	0.00	-0.04	0.04	-0.15
JAP	-0.59		0.01	0.09	0.01	0.08	-0.69

8. CONCLUDING REMARKS

In this paper we presented the GGDC Productivity Level database and its construction. This database provide comparisons of output, inputs and productivity at a detailed industry level for a set of thirty countries. This is the first attempt to provide level estimates for a wide range of countries and industries. It complements the EU KLEMS growth and productivity accounts, in terms of countries, variable definition, industry-detail and basic data. As such, the level and growth accounts can be used together in comparative analyses of productivity trends. In the construction of the database, the neo-classical theory of production by Jorgenson and associates has been used (Jorgenson and Nishimizu, 1985; Jorgenson, 1995). A number of improvements and refinements to the theory have been made: the use of sectoral output and input measures that exclude intra-industry flows; the application of multilateral indices at the industry-level; use of relative output prices from the production side and the use of the exogenous approach to capital measurement. The GGDC Productivity Level database is publicly available at www.ggdc.nl.

The GGDC Productivity Level database should be used with care. Compared to growth accounts, level accounts are subject to a wider range of possible measurement errors, and their impact is often larger. For example, the level of output or employment in an industry can be mismeasured while its growth rate is not. Measurement errors due to misclassifications in terms of industry, labour category or asset type will generally have a much larger impact on level accounts than growth accounts. As a general rule, the higher the level of industry detail, the lower the reliability of the level estimates will be. The main issue here is the consistency of output and input measures, in particular labour and capital. Meaningful comparisons of productivity across countries demand first that the output (and relevant inputs) for a particular activity in one country will correspond to that in another country and, secondly, that each country measures both inputs and outputs in comparable ways. In this study we relied on the measures provided in the EU KLEMS database which was designed to track changes over time, not necessarily differences across countries. Within Europe, gross output and intermediate input measures are increasingly comparable across countries, due to the use of the SUT-framework. Also, capital flows are increasingly incorporated in this system (although less information is available about investment cross-classified by asset and industry). The biggest obstacle to reliable international comparisons of productivity levels is the conversion from simple job (or person) counts to estimates of total hours actually worked. A major worry is the comparability of hours worked measures. The available evidence suggests that cross-country differences in the number of average hours worked per person are quite large. Even within the OECD, economy wide measures of annual working hours range between just over 1,300 hours per year for countries like the Netherlands and Norway up to over 2,400 hours for Korea. Eurostat provides estimates of hours actually worked which are (partly) harmonized across countries. Cross-country comparability can thus be improved as compared to the use of original national sources for some countries, but there remains a margin of uncertainty. Also as yet it is unclear how these estimates match to the output measures in the National Accounts, particularly at the industry-level. This margin can only be addressed by further methodological and statistical work to enhance international comparability, preferably within the System of National Accounts.

The sophistication of the methodology followed in the construction of this database adds to the vulnerability of the estimates as it makes use of detailed measures of capital and labour services, and separate industry-level PPPs for output and various types of inputs. Our point estimates will be more accurate than crude estimates derived on the basis of capital stocks, hours worked and GDP PPPs only. But the variance of our estimates will be higher as well. The choice between an estimate which is precisely wrong or approximately correct ultimately depends on its use. If one is interested in specific estimates for a country at a detailed industry level, one would do well to consider alternative estimates as well. We provide alternative measures by providing single deflated value-added based comparisons and comparisons based on expenditure PPP only. Detailed industry estimates should never be interpreted without additional, more qualitative, evidence from careful industry case studies.[48] On the other hand, if one needs a set of level estimates for econometric cross-country analyses, this database provides a unique opportunity to improve estimation models.[49]

[48] E.g. studies by Global McKinsey Institute such as MGI (2002).

[49] See e.g. Inklaar, Timmer and van Ark (2008).

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Appendix 1 Comparison of Expenditure and Production Approach to GDP

The main aim of this study is to provide comparative labour and multi factor productivity estimates at the industry level across a wide set of countries. However, one might be interested in the consistency of industry-level results with the well-known estimates of relative labour productivity levels regularly produced by the OECD and Eurostat. The main reason to do so would be have a cross-check on our methodology and industry-level data sources. To this end, one can compare the labour productivity results presented in this paper for the total economy with estimates by the OECD and Eurostat.

The estimates will differ for various reasons, both methodological and practical. First of all, the measures will differ as they refer to two different concepts of GDP. In our study we measure GDP from the production side, while OECD/Eurostat measures GDP from the expenditure side. The former explicitly accounts for differences in domestic, import and export prices, while the latter does not adjust for differences in terms-of-trade across countries (see Feenstra et al, 2008). As such, the former measures the production capacity of a country, while the latter measures the consumption possibilities. For example, when a country has to pay relatively high prices for its imports, while receiving low prices for its exports, GDP measured from the production side will be higher than measured from the expenditure side. For productivity comparisons it is the former we are interested in.

Secondly, there are differences in the underlying data. The differences for GDP and persons engaged will be relatively small, but the differences in estimates of hours worked per person can be sizeable for some countries. Moreover, our estimates are built up in a SUT-framework, deflating outputs and intermediate inputs with PPPs. The OECD/Eurostat estimates are made from the expenditure side, deflating expenditure with expenditure PPPs. As is well known, there are discrepancies between output, intermediate input and expenditure prices in a SUT. Finally, we adjust the treatment of non-market services, by setting its relative productivity to 1 by definition, as it should. The expenditure PPPs for non-market services used by OECD/Eurostat do not imply this and suggest higher productivity in Europe compared to the US in non-market services. As non-market services typically make up 20 to 30% of total GDP this has a major impact on comparative GDP per hour levels.

By way of example, our estimates for GDP per hour worked in France relative to the US are 22% lower than made by the OECD. Actually, our estimates for hours worked in the US are 5% higher, leaving 27%-points differences for real GDP measure. Nine %-points are due to our treatment of non-market services. The remaining 18%-points are due to terms-of-trade and inconsistencies between production and expenditure PPPs. Unfortunately, the latter two cannot be disentangled and one can only guess after its relative importance. In the case of France, the exchange rate, which is used as PPP for imports, is much lower than the GDP-PPP, while the output PPP is much higher. This indicates that the volume of imports is underestimated in the OECD estimates, while the volume of exports are overestimated. The impact of this mismeasurement depends on the size of the trade balance compared to GDP. For small open economies, this will be bigger.

Appendix 2 Why benchmarks and time-series PPPs are not consistent

PPPs are normally not made on an annual basis, but only for a given benchmark year. For example, expenditure PPPs are currently available for OECD countries every 3 years. Also production PPPs are not systematically collected. The most regular effort is done within the framework of the ICOP project at the University of Groningen, which has produced production PPPs for manufacturing for the years 1975, 1987 and 1992 for different sets of countries and for all sectors and all OECD countries for 1997 (Timmer, Ypma and van Ark, 2006). Benchmark year PPPs provide a snapshot of relative prices in that particular year. PPPs for other years can be estimated by extrapolations with national price series. For example, the expenditure PPP in a country for year t can be obtained on the basis of extrapolation of the expenditure PPP from benchmark year 0 with the movement in the relevant consumer price index (CPI) in the country relative to the CPI in the reference country during [0, T]. Similarly, PPPs from the production side can be updated using producer price indices. Typically, updated PPPs for year t and original benchmark estimates for the same year do not match. There are both methodological and practical reasons why this is the case. This will be explained below.

Let PPP_T^{BA} be the benchmark PPP for year T defined by:[50]

$$PPP_T^{BA} = \sum_i w_{T,i}^{BA} PPP_{T,i}^{BA} \qquad \text{(A.1)}$$

with $PPP_{T,i}^{BA}$ the PPP for category *i* in year *T* and $w_{T,i}^{BA}$ the weight of category i in year T based on a common weighting scheme (industry output or expenditure at basic heading level) which will not be defined any further. The benchmark for T can also be proxied by updating the PPP for year 0, using national price indices

$$P\tilde{P}P_T^{BA} = PPP_0^{BA} \frac{P_T^A / P_0^A}{P_T^B / P_0^B} \qquad \text{(A.2)}$$

with *P* the national price level. The PPP for T is estimated by extrapolating the benchmark PPP for 0 on the basis of relative changes in price levels in countries A and B. $P\tilde{P}P_T^{BA}$ and PPP_T^{BA} are normally not the same. Equation (A.1) can be rewritten in terms of prices of individual categories which are aggregated with weights for the year 0, assuming Laspeyres-type national price indices for simplicity:

[50]. Here we make no distinction between PPPs from the expenditure or production side as the issues are the same for both PPP concepts.

$$P\widetilde{P}P_T^{BA} = \left[\sum_i w_{0,i}^{BA} PPP_{0,i}^{BA}\right]\left[\frac{\sum_i w_{0,i}^{A}(P_{T,i}^{A}/P_{0,i}^{A})}{\sum_i w_{0,i}^{B}(P_{T,i}^{B}/P_{0,i}^{B})}\right] \qquad (A.3)$$

The procedure above may be described as the 'constant' PPP method. Although PPPs change over time, the weights are kept constant, in this example, to those of year 0.[51] In reality, an extrapolated PPP to year T is rarely equal to the benchmark year T PPP (when available). This is both for theoretical and practical reasons. The impact of practical implementation is probably more important but we start with the former.

When comparing (A.1) and (A.3) it can be easily seen that two index number problems plague the extrapolation procedure (Szilagyi, 1984). The first element is that the weights for the base year are preserved as the weighting system for the time series (fixed weight bias) in the extrapolated benchmark. The second element is that each of the time series are based on national weights of each individual country, whereas benchmark estimates are based on a common weighting system for both countries (weight inconsistency). Both weighting problems are well-known in the price-index number literature. They are related and, in an international context, they are referred to as the tableau effect.[52] The "tableau effect" can be significant in case relative price and quantity structures between countries and over time differ considerably, for example in case there is a wide gap between successive benchmark comparisons. However, when the period considered is relatively short and the levels of development across countries not too different, the procedure would itself only lead to relatively minor inconsistencies, as price and quantity structures may be assumed constant over time and across countries.

The inconsistency due to the tableau effect can be reduced to a minimum when the extrapolation is not done at the aggregate level but at the lowest level of detail possible. In that case the updated PPP for category *i* ($P\widetilde{P}P_{T,i}^{BA}$) is defined by

$$P\widetilde{P}P_{T,i}^{BA} = PPP_{0,i}^{BA}\frac{P_{T,i}^{A}/P_{0,i}^{A}}{P_{T,i}^{B}/P_{0,i}^{B}} \qquad (A.4)$$

51 In essence the procedure is the same as extrapolating a comparison of real output or productivity between two countries from year 0 (using that year's PPP) by using time series of output or productivity growth. In principle these two methods would give the same result if PPPs and GDP levels use are consistent with GDP price and volume series applied.

52 As called by Summers and Heston (1991, p. 340). Various smoothing methods can be used to straighten out these differences (see e.g. Krijnse Locker and Faerber 1984), but this implies that in the process benchmark PPPs and/or national CPIs are modified compared to the original estimates. See Prasada Rao (2008) for an original attempt based on econometric smoothing techniques.

The updated PPP for category *i* in year *T* ($\widetilde{PPP}^{BA}_{T,i}$) is equal to the PPP for category i in year 0 ($PPP^{BA}_{0,i}$), using relative changes in national prices of i (P_i) in country A and B over the period [0,T]. In case that the basic price and quantity data for the benchmark PPPs and time series are consistent, the updated benchmark PPP for T will be equal to the original benchmark PPP for T when weights for T are used in the aggregation procedure as in (A.1). This method approaches the alternative to a constant PPP method, namely redoing the PPP calculation every year and weighting the categories at each year's expenditure. This is called the 'current' PPP method. However, as the weights differ for every year compared to the previous year, the current PPP method cannot be used for comparisons of relative price levels over time and it therefore only provides a 'snapshot' for each individual year. Eurostat uses a mix of the current PPP method and the annual extrapolation of PPPs at basic heading level.[53]

In practice consistency between basic price data and weights for the benchmark PPPs vis-à-vis the time series of national prices is never achieved. There are a host of problems which can be categorised into two groups:

1. differences in methodology and procedures between the national accounts and PPP programmes, and

2. inconsistency between PPP benchmarks and national price indices due to changes in methods and procedures.

Ad 1. The price methodology for PPPs differs from that for national price indices because of the different aims of both exercises. These include differences in the price index formulae used (for example, a multilateral index or Fisher index for the PPP and a Paasche index for the price series) but also a difference in the actual weights entering into the country's intertemporal price indexes. In addition, there are differences between the specifications and pricing of products in both pricing exercises. For a PPP comparison, items are priced which are comparable between countries. For domestic time series, items are priced which are representative in both periods 0 and T. These item baskets are by no means identical. The product selection and definition for spatial comparisons often has to take into account large differences in output or expenditure structure whereas structures only change gradually over time for a single country.

53 Eurostat estimates PPPs on an annual basis using the rolling benchmark method which relies on the assumption that basic price and quantity data for the benchmark PPPs and time series are consistent. The starting point of the rolling benchmark approach is the complete matrix of basic heading PPPs from the latest benchmark year calculation. In each year following the benchmark year, about a third of the basic heading PPPs are replaced by new PPPs calculated using prices collected during the year, while the basic heading PPPs that are not replaced are extrapolated using price indices specific to these basic headings. Expenditure weights are updated every year for each basic heading. Eurostat constructs current PPPs for EU Member States, Iceland, Norway, Poland and Switzerland on an annual basis.

Other methodological differences between PPPs and price series over time are related to the treatment of foreign trade which differs between ICP and national accounting practice. Also pricing procedures differ between ICP and national accounts, as for ICP one compares products and service prices irrespective of location and type of outlet is not taking into account.[54] The practical problems may be somewhat different between production PPPs and expenditure PPPs, but they are of a similar nature. For example, whereas the PPPs for manufacturing products are based on unit values from production statistics, the national price indices are either survey-based producer price indices or national accounts-based deflators by industry.

Ad 2. In practice the product specifications, the expenditure and industry classifications, and the data collection and pricing procedures evolve over time, in both price index and PPP work. For example, price methodologies, especially for rents, high-tech goods and (non-market) services might differ between countries and affect the intertemporal consistency of CPIs. Initiatives such as the Harmonised Consumer Price Index by Eurostat are aimed at minimizing these inconsistencies between countries. Revisions such as those which came with the introduction of the 1993 System of National Accounts and the introduction of NACE rev. 1 and NAICS brought with it changes in product, industry and expenditure classifications, which affect the weights for price index and PPP computations. Especially the PPP methodologies and quality of the underlying price data and weights are changing over time. For example, multilateral PPP results are sensitive to the number of countries which participate in the ICP and ICOP programmes.[55] Finally, there is the problem that PPPs cannot be extrapolated at the item level as they should ideally, but at best at the basic heading or industry level which introduces a fixed weighting problem below the basic heading.

The discussion above suggests that there is no unique way of obtaining a set of PPPs and national price indices which are internally consistent both in the interspatial and intertemporal dimension. At the moment we only have a set of PPPs for 1997, and hence we provide a benchmark for the year 1997, extrapolated with relative productivity growth rates for each country from the EU KLEMS Growth and Productivity Accounts. In future work, we would like to derive new benchmarks for other years as well. This might be achieved by extrapolating the PPPs at a detailed level and use current year weights to aggregate, or by constructing a new benchmark. Preliminary analysis suggests that volume comparisons for 1980 based on proxy current PPPs are not far off from estimates based on the constant 1997 PPPs, except for industries with large international differences in price movements, such as computer manufacturing.

54. This is the so-called “a potato is a potato” rule.

55. See Heston, Summers and Aten (2001). This can be remedied by imposing “bloc fixity” for a particular group of countries (for example, EU member states) as done by Eurostat and OECD.

Appendix Table 1 **Sensitivity to choice of PPPs, 1997.**

	TOT														
		MARKT													NONMAR
			ELECOM	GOODS			MSERV								
					MexElec	OtherG		DISTR			FINBU			PERS	
									G	*60t63*		*J*	*71t74*		
AUS	0.99	0.98	0.80	1.06	1.05	1.06	0.92	0.87	0.82	0.98	1.00	1.00	1.00	1.00	1.00
AUT	0.93	0.91	0.92	0.90	0.86	0.99	0.93	0.83	0.87	0.75	1.00	1.00	1.00	1.00	1.00
BEL	1.02	1.03	1.20	1.07	1.09	1.03	0.99	0.92	1.11	0.60	1.00	1.00	1.00	1.00	1.00
CAN	1.06	1.08	1.24	1.07	1.04	1.11	1.09	1.14	0.97	1.63	1.00	1.00	1.00	1.00	1.00
CYP	0.94	0.93	0.51	0.97	0.98	0.96	0.90	0.89	0.92	0.81	1.00	1.00	1.00	1.00	1.00
CZE	0.91	0.89	0.86	0.97	0.94	1.02	0.80	0.65	0.82	0.40	1.00	1.00	1.00	1.00	1.00
DNK	1.04	1.06	0.88	1.08	1.11	1.04	1.06	1.12	1.28	0.82	1.00	1.00	1.00	1.00	1.00
ESP	0.99	0.99	0.91	1.02	1.01	1.04	0.95	0.92	1.03	0.70	1.00	1.00	1.00	1.00	0.99
EST	0.86	0.82	0.71	0.97	0.93	1.05	0.69	0.51	0.74	0.28	1.00	1.00	1.00	1.00	1.00
FIN	1.08	1.11	1.04	1.15	1.21	1.03	1.11	1.18	1.27	0.98	1.00	1.00	1.00	1.00	1.00
FRA	0.98	0.97	0.89	0.98	0.96	1.02	0.96	0.94	1.04	0.73	1.00	1.00	1.00	1.00	1.00
GER	1.01	1.01	0.97	0.99	0.98	1.02	1.04	1.08	1.20	0.84	1.00	1.00	1.00	1.00	1.00
GRC	0.89	0.85	0.67	0.99	0.98	0.97	0.73	0.55	0.64	0.37	1.00	1.00	1.00	1.00	1.00
HUN	0.96	0.94	1.08	1.01	1.02	1.00	0.89	0.72	0.70	0.76	1.00	1.00	1.00	1.00	1.00
IRL	1.00	1.00	0.82	1.05	1.11	1.00	0.98	0.97	1.14	0.70	1.00	1.00	1.00	1.00	0.99
ITA	0.94	0.92	1.00	1.02	1.01	1.04	0.83	0.68	0.77	0.48	1.00	1.00	1.00	1.00	1.00
JAP	0.96	0.94	0.87	1.04	1.04	1.01	0.85	0.75	0.70	0.85	1.00	1.00	1.00	1.00	1.00
KOR	0.92	0.89	0.69	0.97	0.92	1.02	0.81	0.71	0.70	0.70	1.00	1.00	1.00	1.00	1.00
LTU	0.84	0.80	0.53	0.94	0.91	0.97	0.66	0.54	0.62	0.38	1.00	1.00	1.00	1.00	1.00
LUX	1.02	1.03	0.98	1.03	1.05	0.99	1.02	1.10	1.24	0.85	1.00	1.00	1.00	1.00	1.00
LVA	0.92	0.90	1.45	0.93	0.88	1.01	0.87	0.69	0.69	0.65	1.00	1.00	1.00	1.00	1.00
MLT	0.96	0.94	0.69	0.96	0.99	0.94	0.92	0.94	0.74	1.31	1.00	1.00	1.00	1.00	1.00
NLD	1.06	1.08	0.98	1.05	1.03	1.09	1.12	1.28	1.18	1.51	1.00	1.00	1.00	1.00	1.00
POL	1.01	1.01	0.82	1.06	1.05	1.05	0.97	0.96	0.95	1.00	1.00	1.00	1.00	1.00	1.00
PRT	1.01	1.01	0.82	1.04	1.07	0.99	1.00	1.03	1.04	1.00	1.00	1.00	1.00	1.00	1.00
SVK	0.85	0.81	0.90	0.89	0.89	0.93	0.72	0.53	0.67	0.32	1.00	1.00	1.00	1.00	1.00
SVN	0.97	0.90	0.77	1.00	0.99	1.04	0.80	0.65	0.73	0.50	1.00	1.00	1.00	1.00	1.30
SWE	1.06	1.08	1.45	1.10	1.13	1.04	1.10	1.03	1.00	1.02	1.00	1.00	1.00	1.00	1.00
UK	1.03	1.04	1.37	1.05	1.08	1.01	1.04	0.97	0.90	1.08	1.00	1.00	1.00	1.00	1.00
USA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Note: Log ratio of value added using mix of PPPs (our preferred choice) and using PPPs from expenditure side only. Value added is single deflated.
Source: Author's calculations on GGDC Productivity Level database

Appendix Table 2 Sensitivity to double deflation, 1997

	TOT														
		MARKT													NONMAR
			ELECOM	GOODS			MSERV								
					MexElec	OtherG		DISTR			FINBU			PERS	
									G	*60t63*		*J*	*71t74*		
AUS	0.99	1.00	0.94	1.03	0.85	1.26	1.00	1.00	0.92	1.17	1.01	1.27	0.82	0.98	1.00
AUT	0.96	0.92	0.95	0.91	0.89	0.95	0.94	0.94	1.01	0.79	0.92	1.09	0.81	1.01	1.07
BEL	0.97	0.97	0.97	1.00	1.15	0.87	0.96	0.96	1.19	0.59	0.95	1.09	0.86	0.92	1.01
CAN	1.02	1.02	1.03	1.03	1.00	1.10	1.02	1.04	1.02	1.05	0.98	1.08	0.92	1.01	1.08
CYP	1.04	0.99	0.99	0.94	0.84	1.07	1.03	1.04	0.99	1.13	1.02	1.18	0.92	0.95	1.22
CZE	1.22	1.14	0.87	1.20	1.35	1.15	1.07	1.17	1.16	1.16	1.00	1.47	0.79	1.37	1.38
DNK	0.96	0.94	0.87	0.86	0.88	0.84	1.01	1.05	1.18	0.79	0.98	1.07	0.92	0.97	1.02
ESP	1.02	0.99	0.97	0.97	1.02	0.94	1.00	1.05	1.13	0.87	1.01	1.12	0.94	0.92	1.10
EST	1.26	1.15	0.82	1.17	1.07	1.19	1.09	0.97	1.08	0.77	1.20	1.18	1.19	1.35	1.68
FIN	0.98	0.98	0.88	1.02	1.09	1.05	0.97	1.08	1.21	0.89	0.89	0.99	0.83	0.84	0.97
FRA	0.96	0.95	1.06	0.95	1.05	0.84	0.97	1.03	1.11	0.84	0.90	1.12	0.79	0.99	1.03
GER	0.97	0.97	0.98	0.94	1.02	0.81	1.00	1.05	1.16	0.77	0.97	1.05	0.91	0.99	1.02
GRC	1.03	0.97	0.82	0.99	1.23	0.89	0.95	0.86	0.85	0.85	1.06	1.07	1.07	1.00	1.22
HUN	1.23	1.16	1.14	1.16	1.40	0.98	1.10	0.97	0.86	1.21	1.10	1.12	1.07	1.59	1.33
IRL	0.98	0.97	0.77	0.96	1.06	0.87	1.00	0.98	1.15	0.61	1.05	1.17	0.96	0.99	1.01
ITA	1.00	0.97	1.06	1.06	1.23	0.90	0.93	0.81	0.84	0.72	1.02	1.08	0.97	0.86	1.07
JAP	0.93	0.92	1.05	0.86	1.08	0.71	0.95	0.91	0.89	0.95	0.98	1.07	0.92	0.95	1.02
KOR	1.03	0.99	0.94	0.95	1.12	0.87	1.02	0.98	0.92	1.05	1.05	1.13	1.01	1.07	1.23
LTU	1.22	1.08	0.73	1.11	0.91	1.27	1.06	1.06	1.02	1.12	1.04	1.29	0.90	1.46	1.89
LUX	1.00	1.01	0.99	0.84	0.96	0.71	1.09	1.07	1.07	1.05	1.13	1.14	1.09	0.85	1.01
LVA	1.24	1.07	0.82	1.01	0.77	1.41	1.09	1.08	1.02	1.13	1.14	1.19	1.11	1.22	1.94
MLT	1.08	1.05	0.92	1.02	0.93	1.21	1.03	1.08	1.03	1.13	1.05	1.03	1.05	1.10	1.22
NLD	0.99	0.98	0.86	0.90	1.00	0.81	1.04	1.24	1.17	1.41	0.97	1.16	0.86	0.97	1.04
POL	1.17	1.09	0.62	1.11	1.18	1.09	1.06	1.13	1.08	1.30	1.12	1.21	1.07	0.96	1.46
PRT	1.05	1.02	0.77	0.94	1.02	0.96	1.07	1.16	1.05	1.47	1.05	1.05	1.08	1.05	1.11
SVK	1.29	1.15	0.98	1.12	1.13	1.28	1.12	0.97	0.84	1.21	1.17	1.08	1.24	1.68	1.68
SVN	0.26	0.18	0.16	0.08	0.05	0.17	0.42	0.30	0.41	0.16	0.54	0.73	0.45	0.51	0.86
SWE	0.96	0.95	1.47	0.96	0.96	0.94	0.95	0.92	1.01	0.73	0.90	0.95	0.88	0.74	0.97
UK	0.98	0.96	1.18	0.94	1.01	0.89	0.96	0.90	0.96	0.77	0.95	1.08	0.89	0.82	1.00
USA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Note: Log ratio of double deflated over single deflated value added, 1997
Source: Author's calculations on GGDC Productivity Level database