Using Expenditure PPPs for Sectoral Output and Productivity Comparisons

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Purchasing power parities (PPPs) have a wide range of analytical and policy applications.[1] Traditionally, PPPs have been used for international comparisons of income, expenditure, and output. Most well known are the comparisons of levels of gross domestic product (GDP) per capita as published by the World Bank (e.g., World Bank 2008). Differences in GDP per capita across countries are mainly determined by levels of labor productivity at the aggregate economy level. Today, comparative series of output per worker and per hour worked are being produced routinely by various statistical organizations and in academia, such as the Penn World Table and the series produced by the Organisation for Economic Co-operation and Development (OECD), Conference Board, and Groningen Growth and Development Centre (GGDC) at the University of Groningen.

Various useful analytical applications of productivity levels, however, are also found at the more detailed level of individual industries. Because of the large differences in economic structure across countries, international comparisons of output and productivity at the sector level (agriculture, manufacturing, and services) provide useful complements to comparisons of GDP by expenditure categories. Previous research has shown that a low overall level of productivity is not necessarily indicative of large gaps in all sectors. Generally, it is assumed that productivity gaps in manufacturing can be large, and that gaps in services productivity across countries are much smaller. This well-known finding is at the heart of the Harrod-Balassa-Samuelson effect and often invoked to explain the lower relative prices of services in low-income countries compared with high-income countries. Also, studies of convergence and divergence in the world economy are increasingly being made at the industry level. Tests of international trade theories and endogenous growth models require measures relative to the world productivity frontier by sector.

By definition, a major part of the research in these areas requires PPPs from the production side rather than from the expenditure side—that is, PPPs should reflect the differences in the output prices of goods and services rather than the expenditure prices. In the remainder of this chapter, we call these production PPPs. Comparisons of productivity, loosely defined as output per unit of inputs, also require the relative prices of capital inputs, labor inputs, and intermediate inputs. This so-called industry of origin approach was pioneered by Paige and Bombach (1959) in a comparison of the United Kingdom and the United States. The earlier work was then conveniently summarized by Kravis (1976). Over the last two decades, this method was further developed and used in the International Comparisons of Output and Productivity (ICOP) project at the University of Groningen and at the National Institute of Economic and Social Research in London (O'Mahony 1999). Van Ark and Maddison (1994) and Maddison and van Ark (2002) provide an overview of the progress made in the early phase of this project through the research input of a dozen scholars and work on about 30 countries. More recently, sectoral output and productivity trends for a large set of countries were provided by the EU KLEMS database (available at http://www.euklems.net and discussed by Timmer et al. 2010). However, it appears that production PPPs were scarce and empirically difficult to obtain, which mainly related to the lack of readily available producer price surveys.

An alternative to the industry of origin approach is to use data from internationally coordinated surveys on expenditure prices such as those collected for the International Comparison Program (ICP) under the auspices of the United Nations and the World Bank (Kravis, Heston, and Summers 1982; Summers and Heston 1991). Since the early 1980s, OECD has regularly published estimates of expenditure PPPs derived from its joint program with Eurostat. Expenditure-based PPP comparisons are based on purchasers' prices of final goods and services with a detailed product specification. Hence, to apply them to output and productivity comparisons by industry, the PPPs have to be mapped from expenditure categories to industry groups.

The expenditure approach to sectoral PPPs was pioneered by Jorgenson, Kuroda, and Nishimizu (1987) and most recently applied by Sørensen and Schjerning (2008) and van Biesebroeck (2009). In general, PPPs based on expenditure price surveys suffer less from quality problems than unit values because product comparisons are based on detailed specifications. However, the approach also has some drawbacks for comparisons of output and productivity at the industry level because it requires detailed adjustments for margins, taxes, and international trade. Furthermore, by definition these PPPs only cover prices for final expenditure and do not reflect the relative prices of intermediate goods. Following Pilat (1996), van Ark and Timmer (2009) argue that a mixture of PPPs derived from the expenditure and industry of origin approaches should be used for productivity comparisons at the industry level. Building on this idea, Inklaar and Timmer (2009) have constructed the GGDC Productivity Level database. This database provides comparisons of output, inputs, and productivity at a detailed industry level for a set of 30 OECD countries for 1997, and it is publicly available at http://www.ggdc.net/databases/levels.htm. The PPPs used for this database are a combination of production- and expenditure-side PPPs. This study also provides price comparisons of capital, labor, and intermediate inputs, alongside output price comparisons, so that large-scale comparisons of multifactor productivity at the sector level became feasible.

This chapter begins by outlining what types of PPPs are needed for sectoral, single-, and multifactor productivity comparisons by industry. We argue in the first section that, given the limited availability of production PPPs, expenditure PPPs from the ICP are indispensable in facilitating these comparisons. However, until now the literature has not clearly described what adjustments are needed to convert PPPs by expenditure category into output PPPs by industry and under which conditions expenditure PPPs would provide a good proxy for production PPPs. The main contribution of this chapter is to derive these adjustments and conditions based on a system of supply-use tables (SUTs). SUTs are a major building block of the national accounts in many countries. They provide a systematic framework of the flows of goods and services from production and imports to final expenditure.

The second section of this chapter shows the usefulness of the derivation and confrontation of various types of prices (basic and purchasers' prices) in a SUT system. For example, this system provides clear guidance on how the prices of consumption goods and intermediate inputs are related to the output prices of industries. These relationships can be used to generate cross-checks in case different data sources (from the production and expenditure sides) exist or to illustrate the adjustments to be made to the expenditure PPPs to be used in sectoral productivity comparisons. Using a supply-use framework, we show that final expenditure prices need to be adjusted for trade and transportation margins, for taxes and subsidies, for the prices of exports and imports, and finally for the prices of intermediate use in order to provide a good proxy for output prices.

Because of these adjustments, the usefulness of expenditure PPPs in sectoral productivity comparisons differs across sectors. This difference is illustrated with some results from the GGDC Productivity Level database for OECD countries in the third section of this chapter. The fourth section presents some productivity comparisons, and the final section some concluding remarks. In those remarks, we stress the mutual dependence and potential spillovers from sectoral productivity comparisons and expenditure results from the ICP.

Methodology for Productivity Comparisons

In this section, we present the methodology for comparing levels of output, input, and productivity across countries that we used in constructing the GGDC Productivity Level database (Inklaar and Timmer 2009). Because we were trying to construct a comparable set of productivity measures for a large number of countries and industries at the same time, various choices had to be made, not only about the use of particular index number formulas, but also about their actual implementation. This section lays out the basic methodology (for a more detailed discussion of methodology and empirics, see Inklaar and Timmer 2009).

The main aim of the GGDC Productivity Level database is to compare productivity between countries. The accounts provide so-called binary comparisons—that is, comparisons between a country *c* and a base country that is the same in all comparisons. Because the greatest interest lies in comparing the performance of countries to the world productivity and technology leader, it is natural that we choose the United States as our base country in the productivity comparisons.[2] The most commonly used single productivity measure for international comparisons of levels is *labor productivity*. This term is generally defined as an output measure divided by a labor input measure. The labor input measure can be the number of persons employed, number of employees, or number of hours worked. The output measure can be either the volume of gross output or the volume of value added. If Q^{VA} is value added and H is hours worked, then value added–based labor productivity (LP_VA) is given by

$$LP\_VA_c = \frac{\dfrac{Q_c^{VA}}{H_c}}{\dfrac{Q_{US}^{VA}}{H_{US}}}. \tag{24.1}$$

Alternatively, more than one input can be accounted for—the so-called multifactor productivity (MFP) measures. MFP measures are well rooted in economic theory, but because of their heavy data requirements they are used much less than single productivity measures such as labor productivity. MFP and labor productivity measures are not independent of each other. Multifactor productivity measures can be used to explain single-factor productivity differences. For example, differences in labor productivity levels can be explained by differences in the ratio of capital to labor and differences in multifactor productivity. These and other links have been established with the help of the economic theory of production.

The GGDC Productivity Level accounts provide estimates for both value added–based MFP, taking into account both labor and capital services, and gross output–based MFP, taking into account labor, capital, and intermediate inputs. In this chapter, we outline only the methodology for value added–based measures. Following Jorgenson and Nishimizu (1978), we define the translog quantity index of difference in multifactor productivity based on value added (*MFP_VA*). This index is defined as

$$\ln MFP\_VA_c = \ln \frac{Q_c^{VA}}{Q_{US}^{VA}} - \hat{w}_K \ln \frac{Q_c^K}{Q_{US}^K} - \hat{w}_L \ln \frac{Q_c^L}{Q_{US}^L} \tag{24.2}$$

where Q^K is the quantity of capital services, Q^L is the quantity of labor services, and $\hat{w}_K$ is the share of capital services in value added averaged over the two countries—that is, $\hat{w}_K = \frac{1}{2}(w_c^K + w_{US}^K)$, where $w_c^K = \frac{V_c^K}{(V_c^K + V_c^L)}$, with V_c^K the nominal value of capital services compensation in country *c* in national currency and similarly for labor, so that $\hat{w}_K + \hat{w}_L = 1$. Under the standard neoclassical assumptions, this measure indicates the difference in the level of technology between the two countries (see Jorgenson and Nishimizu 1978).

Formulas (24.1) and (24.2) 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 terms of real values. In that case, a correction for differences in relative price levels between countries is needed. This is usually done with a purchasing power parity (*PPP*) that indicates the ratio of the price of output in one country relative to that in another country, each given in local currencies.

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

$$Q_c^{VA} = \frac{V_c^{VA}}{PPP_c^{VA}}. \tag{24.3}$$

For labor input, one can use number of workers or total hours worked as a volume measure. However, for multifactor productivity comparisons one would also like to include the composition of labor in terms of various labor types with different productivities—for example, low- and high-skilled labor. This can be done by choosing an appropriate PPP based on relative wages so that

$$Q_c^L = \frac{V_c^L}{PPP_c^L} \tag{24.4}$$

where V_c^L is the nominal value of labor compensation in country *c* (in national currency), and PPP_c^L is the relative price of labor services in country *c*. Similarly, for aggregate capital input in country *c*

$$Q_c^K = \frac{\tilde{V}_c^K}{PPP_c^K} \tag{24.5}$$

where $\tilde{V}_c^K$ is the nominal value of ex ante capital compensation in country c, and PPP_c^K is the relative price of capital services in country c.[3]

One of the main applications in productivity comparisons is so-called level accounting. Level accounts provide a decomposition of differences in value added per hour worked into differences in capital per hour worked (capital intensity), in labor composition (skill intensity), and in MFP. This decomposition is carried out as

$$\ln \frac{\frac{VA_c}{H_c}}{\frac{VA_{US}}{H_{US}}} = \hat{w}_L \ln \frac{\frac{Q_c^L}{H_c}}{\frac{Q_{US}^L}{H_{US}}} + \hat{w}_K \ln \frac{\frac{Q_c^K}{H_c}}{\frac{Q_{US}^K}{H_{US}}} + \ln MFP\_VA_c \tag{24.6}$$

where $\hat{w}_L$ and $\hat{w}_K$ are defined as in equation (24.2).

The PPPs for outputs and inputs required in (24.3)–(24.5) are derived on the basis of detailed sets of output and input prices.[4] Prices are aggregated using the multilateral translog price indexes (CCD index) introduced by Caves, Christensen, and Diewert (1982). Basically, in this methodology an artificial country is created by averaging over all countries in the data set. This constructed country is then used as a bridge when making binary comparisons between two countries. This method creates so-called transitive PPPs that are base country–independent (see chapters 1, 4, and 5 in this volume for further discussion). As with our MFP indexes, the PPPs are normalized with the United States equal to one. Labor and capital volume indexes grounded in production theory should take into account the composition of each factor input such as different levels of skills or types of capital goods, in particular information and communication technology (ICT) assets versus non-ICT assets. For labor, this can be achieved by deflation with an appropriate PPP (PPP_c^L) based on the relative wages of each labor type l as follows:

$$\ln PPP_c^L = \sum_l \overline{w}_l^L \left[\ln PPP_{l,c}^L - \overline{\ln PPP_l^L} \right] \tag{24.7}$$

where the bar in the last term indicates a geometric average over all countries indexed by c running from 1 to N, and N is the number of countries. It follows that $\overline{\ln PPP_l^L} = 1/N \sum_c \ln PPP_{l,c}^L$ and $\overline{w}_l^L$ is the average weight of labor type l defined as $\overline{w}_l^L = \frac{1}{2}[w_{l,c}^L + \sum_c (w_{l,c}^L / N)]$ with $w_{l,c}^L$ the share of labor type l in total labor compensation in country c: $w_{l,c}^L = V_{l,c}^L / V_c^L$. The PPP for each labor type is derived on the basis of relative wages. A similar procedure is applied for the derivation of PPPs for capital PPP_c^K, output PPP_c^Y, and intermediate inputs PPP_c^X.

For the deflation of value added, a double deflation procedure is used based on separate PPPs for gross output and intermediate inputs as required (Jorgenson, Kuroda, and Nishimizu 1987). We follow a CCD-like approach by taking a geometric mean of all possible binary Törnqvist indexes for a particular country c. First, we calculate the binary value added PPP for each country pair (c,d) as follows:

$$\left[\ln PPP_c^Z - \ln PPP_d^Z \right] = \frac{1}{1 - \overline{w}_X^Y} \left[(\ln PPP_C^Y - \ln PPP_d^Y) - \overline{w}_X^Y (\ln PPP_c^X - \ln PPP_d^X) \right]. \tag{24.8}$$

The weight $\overline{w}_X^Y$ is the share of intermediate inputs in gross output, averaged over the two countries.

Second, a GEKS (Gini-Éltetö-Köves-Szulc) procedure is applied to multilateralize the set of value added PPP binaries given in (24.8), as in Caves, Christensen, and Diewert (1982). Together, these equations provide the system used to derive MFP measures consistent with neoclassical production theory.

Output and Expenditure Prices within a Supply-Use Table Framework

The theoretically most appropriate approach for international comparisons of output and productivity levels is to apply PPPs that are based on the industry of origin approach. Various alternative ways can be used to obtain PPPs for gross output, partly depending on the data availability for individual industries. One way is to make use of producer prices for specified products, but these are scarce because large-scale international surveys of production prices are not conducted. The most widely used approach to obtain production PPPs is the unit value ratio (UVR) method. This method makes use of production statistics such as censuses or business statistics surveys that record the output values and quantities for product items. By dividing the output value by the corresponding quantities, one obtains unit values, which can then be used for calculating unit value ratios for matched items between countries. Because of lack of data, this approach can be used only for a limited set of industries and countries. In addition, unit value ratios can suffer from quality adjustment problems in international comparisons. Detailed product characteristics are difficult to observe directly from production statistics because those statistics report quantity and values for product groups rather than for specified products, and product descriptions are often brief.[5]

An alternative to the industry of origin approach is to use data from internationally coordinated surveys on expenditure prices such as in the International Comparison Program (ICP). Expenditure-based PPP comparisons are based on the purchasers' prices of final goods and services with a detailed product specification. Hence, to apply them to output and productivity comparisons by industry, basic heading PPPs need to be mapped from expenditure categories to industry groups. However, so far no one has clearly outlined under which conditions expenditure PPPs provide a good proxy for the PPPs of gross output and what kind of adjustments are needed. In this section, we use the basic balance equation between supply and use of goods in the supply-use table framework to derive an exact relationship between expenditure and industry output prices. This relationship is used to indicate which adjustments need to be made to expenditure prices so they are a reasonable proxy for basic output prices. Alternatively, the adjustments can be used to assess the usefulness of expenditure PPPs in output comparisons.

Supply-use tables provide a convenient way of summarizing and presenting a coherent set of economic transactions within a country. Whereas a supply table indicates for each product where it comes from (domestically produced or imported), the use table provides information on product use as intermediate or final consumption. In the SUT framework, the valuation of domestic output is at basic prices, while the use of products is recorded at purchasers' prices.[6] This distinction is crucial in the link between expenditure and production PPPs (Commission of the European Communities et al. 1993, sec. VI.J):

> purchaser's price = basic price of the product received by the producer + taxes on the product[7] – subsidies on the product + trade and transport margins in delivering the product to the purchaser.

This section provides an exposition of the full structure of the SUT framework. The following notation is used, which includes commodities i ($i = 1, \ldots, m$) and industries j ($j = 1, \ldots, n$); quantities are indicated with capitals:

S_i = quantity of total supply of product i
U_i = quantity of total use of product i

M_i = imported quantity of product i
F_i = quantity of product i for final domestic demand
E_i = quantity of product i exported
Y_{ij} = quantity of commodity i produced by industry j
X_{ij} = quantity of commodity i used as intermediate input by industry j
L_j = value of labor services used in industry j
K_j = value of capital services used in industry j.

Lowercase p's are used for the corresponding prices:

p_{ij}^{Y} = basic price received by industry j for selling commodity i
p_{ij}^{X} = purchaser's price paid by industry j for intermediate consumption of commodity i
p_{i}^{M} = basic (c.i.f.) price of imported commodity i
p_{i}^{F} = purchaser's price for final domestic demand of commodity i
p_{i}^{E} = purchaser's (f.o.b.) price of exported commodity i.

Margins and taxes are defined as follows:

T = total taxes net of subsidies on products
R = total trade and transport margins
r_{i}^{S} = trade and transport margin rate on supplied product i
t_{i}^{S} = net tax rate on supplied product i.

Finally, a capital V in front of a quantity symbol is used to indicate its value through multiplication by the corresponding price.

Table 24.1 is a simplified outline of a supply-use table.[8] In both the supply and use tables, commodities are in the rows and industries in the columns. The use table indicates the usage for each product i: intermediate, final domestic demand, or export. The last column indicates total use. The entries are at the purchasers' prices. In addition, the use table contains a so-called value added block. For each industry j, total intermediate input at purchasers' prices plus value added at the basic price adds up to gross output at basic prices (last row). The supply table indicates the origin of each product, whether domestic production or import. The fourth column records total supply at basic prices. The other columns provide information on taxes and subsidies on products and trade and transport margins. These are needed to arrive at the total supply at purchasers' prices, which can be set against total use at purchasers' prices from the use table. The output of all products produced in industry j valued at basic prices sums to gross output at basic prices in this industry (last row in the supply table).

The supply and use tables are linked by two basic identities: row and column. The column identity requires identity for each industry between the sum of gross output over all products produced in an industry, on the one hand, and value added plus intermediate consumption, on the other:

$$VX_j + VK_j + VL_j = VY_j. \quad (24.9)$$

The row identity requires balance between use and supply for each product and links the expenditure and production approaches at the product level. The identity should hold in terms of both quantities and values. In quantity terms,

$$X_i + F_i + E_i = S_i. \quad (24.10)$$

TABLE 24.1 Outline of a Supply-Use Table

USE table at purchasers' prices								
		Industries 1.... *j* .... *n*	**Total intermediate use**	**Final domestic demand**	**Exports f.o.b.**	**Total use at purchasers' prices**		
Commodities	1 : i : *m*	.... $P_{Xij} X_{ij}$	VX_i	$P_{Fi} F_i$	$P_{Ei} E_i$	$VX_i + VF_i + VE_i$		
Total intermediate input at purchasers' prices		.... VX_j	VX	VF	VE	$VX + VF + VE$		
Gross value added at basic prices		.... $Kj + Lj$						
Gross output at basic prices		.... VY_j						
SUPPLY table at basic prices								
		Industries 1.... *j* .... *n*	**Total domestic supply**	**Import c.i.f.**	**Total supply at basic prices**	**Taxes minus subsidies**	**Trade and transport margins**	**Total supply at purchasers' prices**
Commodities	1 : i : *m*	.... $P_{Yij} Y_{ij}$	VY_i	$P_{Mi} M_i$	$VS_i = VY_i + VM_i$	$t_i VS_i$	$r_i VS_i$	$(1 + t_i + r_i) VS_i$
Total at basic prices	....	VY_j	VY	VM	$VS = VY + VM$	T	R	$VS + R + T$

This identity states that the quantity of supply of product i must be equal to its use, consisting of intermediate use, final domestic demand, and exports. In value terms, at purchasers' prices the identity is

$$VX_i + VF_i + VE_i = VS_i + T_i + R_i. \quad (24.11)$$

The value of total intermediate use of i (VX_i) is equal to the sum of values of intermediate use of i by all producers, and the total value of supply (VS_i) is equal to the value of supply by all producers and imports. By rewriting values as the product of prices and quantities, (24.11) can be stated as

$$\sum_j p_{ij}^X X_{ij} + p_i^F F_i + p_i^E E_i = (1 + t_i^S + r_i^S)\left(\sum_j p_{ij}^Y Y_{ij} + p_i^M M_i\right). \quad (24.12)$$

By rewriting equation (24.12), the relationship between purchasers' prices (p_{ij}^X, p_i^F, p_i^E), on the one hand, and basic output prices (p_{ij}^Y), on the other, can be derived. This identity provides the basic relationship between the final domestic demand price and the output price at the product level, which we are seeking. To bring out this relationship more clearly, we assume, without loss of generality, that there is only one basic price in the system for an individual product i—that is, the basic output price of a product is independent from its industry of origin:

$$p_{ij}^Y = p_i^Y. \quad (24.13)$$

By rearranging equation (24.12), substituting (24.13), and using identity (24.10), the following basic result can be derived (omitting index i for clarity). Under the assumption given in (24.13), the general relationship between basic output prices and final domestic demand prices can be written as

$$p^Y = \frac{1}{(1 + t^S + r^S)} p^F + A^{E,M} + A^X. \quad (24.14)$$

This is a key result for our purpose. It indicates that three types of adjustments are needed to derive an output price from a final domestic demand price: an adjustment for margins and taxes, an adjustment for international trade ($A^{E,M}$), and an adjustment for intermediate consumption (A^X). The latter two are given by

$$\mathrm{A}^{E,M} = \frac{1}{(1 + t^S + r^S)}\left[(P^E - P^F)\frac{E}{Y} - \left((1 + t^S + r^S)P^M - P^F\right)\frac{M}{Y}\right] \quad (24.15a)$$

and

$$A^X = \frac{1}{(1 + t^S + r^S)} \sum_j (P_j^X - P^F)\frac{X_j}{Y}. \quad (24.15b)$$

The first term on the right-hand side of (24.14) is the final expenditure price,[9] adjusted for average net taxes and margins on total supply of the product. The second adjustment is for international trade, given in (24.15a). This is especially important for comparisons involving small, open economies. The size of the adjustment depends on the differences between the final expenditure prices and the export and import prices, and on the ratios of export and import quantities to total domestic output. The third adjustment in (24.15b) depends on the size of the differences between the final expenditure price and the intermediate consumption price for a particular item, and on the ratio of intermediate consumption to total domestic output for that item. This basic result suggests that if export, import, and domestic prices differ, for products that are characterized by larger shares of imports and exports or intermediate consumption in total output, expenditure prices will be poorer proxies for output prices. But for industries that are mainly producing for final consumption and whose products are hardly internationally traded, an adjusted final expenditure price might be a reasonable proxy for the industry output price. This type of information can be derived from input-output tables.

Using this result, we can also state the adjustments needed for expenditure PPPs to properly reflect output PPPs:

$$(24.16) \qquad PPP_c^Y = \frac{\dfrac{1}{(1 + t_c^S + r_c^S)}\, p_c^F + A_c^{E,M} + A_c^X}{\dfrac{1}{(1 + t_{US}^S + r_{US}^S)}\, p_{US}^F + A_{US}^{E,M} + A_{US}^X}.$$

If the adjustments for international trade and intermediate consumption are assumed to be zero in both countries, (12.16) is simplified to

$$(24.17) \qquad PPP_c^Y = \frac{(1 + t_{US}^S + r_{US}^S)}{(1 + t_c^S + r_c^S)}\, PPP_c^F.$$

In this case, the expenditure PPP, adjusted for average net taxes and margins on total supply of the product, equals the output PPP. In fact, this adjusted expenditure PPP has been used as a proxy for output prices by, for example, Jorgenson, Kuroda, and Nishimizu (1987), Lee and Tang (2000), and most recently Sørensen and Schjerning (2008) and van Biesebroeck (2009). However, (24.17) shows that two further adjustments may be needed. In a pioneering attempt, Hooper (1996) tried to adjust expenditure PPPs for international trade prices, but his methodology was ad hoc, and the adjustments were based on very aggregate data. As a result, this approach was not pursued. Also, adjustments for intermediate consumption have not yet been tried, and there is little hope in view of the paucity of data on prices for intermediate consumption. The conclusion is that only the first adjustment for margins and taxes is feasible in practice. The expected size of the other adjustments that need to be made but cannot provides information about the possible bias associated with the use of expenditure PPPs as a proxy for output PPPs.

Based on information from input-output tables (see van Ark and Timmer 2009), it is possible to make some general statements about the possible biases, in particular in comparisons involving small, open economies with large export and import shares. This bias will differ for each sector. For industries that mainly produce goods for intermediate demand such as agriculture, mining, transport, basic goods manufacturing, and business services, expenditure PPPs (E-PPPs) are not useful as proxies for output PPPs (O-PPPs).[10] On the other hand, E-PPPs appear acceptable for relative price differences in food manufacturing, utilities, and communications after adjusting for taxes and margins. E-PPPs are also useful for construction, hotels, and real estate activities because final expenditure shares are very high for these sectors and imports are negligible.

PPPs in the GGDC Productivity Level Database

This section discusses the sources and methodology of the PPPs for output, intermediate input, labor, and capital used in the GGDC Productivity Level database. This set of PPPs is based on a combination of expenditure and production PPPs.

Output and Value Added PPPs

The output PPPs used in the GGDC Productivity Level database rely heavily on a study by Timmer, Ypma, and van Ark (2007). They presented a new and comprehensive data set of bilateral output PPPs for a set of 30 OECD countries, with the United States as the base country at the industry level for the year 1997. This data set is based on a combination of several data sources, both from the expenditure and industry of origin approaches. Expenditure PPPs by expenditure category were taken from the OECD comparison allocated to industries. For example, the expenditure prices of bread and sugar were allocated to food manufacturing. In a second step, the expenditure PPPs were adjusted to a basic price concept by "peeling off" trade and transport margins and taxes net of subsidies as outlined in the previous section. Production PPPs were based mainly on unit value ratios. The choice for PPPs derived from either the expenditure or industry of origin approach was in part dictated by the availability of price data for a particular (three-digit) industry and a careful assessment of the usefulness of each in case both alternatives were available. This approach is outlined in Timmer, Ypma, and van Ark (2007) and van Ark and Timmer (2009).

Table 24.2 gives the type of PPP used for output for major sectors. In addition, its quality is assessed. PPPs are ranked from 1 (very poor) to 5 (very good) on the basis of the following criteria. The quality of E-PPPs at the industry level depends on the share of final expenditure in total use and the share of import in total supply, as described in the previous section. This quality can be evaluated on the bases of input-output tables, also as described earlier. The criteria for assessing the quality of O-PPPs are different from those for E-PPPs. Conceptually, O-PPPs refer to the prices of domestically produced products. But as discussed earlier, the main weaknesses of O-PPPs are the product mix and quality problems. Especially for high-tech goods, or heterogeneous services, O-PPPs can be affected. In addition, for many services no data are available on unit values because of a lack of appropriate value data and the difficulty in defining quantities. O-PPPs are therefore particularly useful for industries for which products are relatively homogeneous and for which differences in product quality problems are small.

Agricultural output consists almost exclusively of the products used for intermediate input by other firms, not for final consumption. Therefore, expenditure PPPs cannot be used as a proxy for agricultural output PPPs. Instead, the agricultural PPPs for this study are developed along the same lines as earlier ICOP work on agriculture (Rao 1993). We rely exclusively on production PPPs based on producer prices from the FAOSTAT database of the Food and Agriculture Organization (FAO). This database contains a very extensive set of quantities and farm price values of up to 146 agricultural products. Similarly, for mining and most manufacturing industries unit value ratios are used. Unit values for European countries are derived from PRODCOM, which has a harmonized set of product data for European Union member states. The PRODCOM database includes quantities and sales values by product, linked to the NACE classification, for up to 7,000 product items.[11] This database is essentially based on the original national production censuses and industry surveys, but uses a harmonized product coding system. PRODCOM greatly enhances the number of product matches on the basis of which unit value ratios were constructed. For non-European countries, it uses comparable data from national production surveys. In addition, it applies hedonic

TABLE 24.2 Source and Grading for Industry PPPs in GGDC Productivity Level Database

Industry	ISIC rev. 3 code	Grade	PPP type used	Remark
A. Output PPPs				
Agriculture	01–05	5	O-PPP	Homogeneous goods
Mining and quarrying	10–14	4	O-PPP	Homogeneous goods
Manufacturing	15–37	4	E-PPP/O-PPP	
Food, drink, and tobacco	15, 16	4	Mainly O-PPP	Homogeneous goods
Basic goods	17, 20, 21, 23–28	4	Mainly O-PPP	Homogeneous goods
Nondurable	18, 19, 22, 36, 37	4	Mainly O-PPP	Homogeneous goods
Durable	29–35	2	Mainly E-PPP	Quality, import, and coverage problem
Electricity, gas, and water supply	40, 41	4	E-PPP/O-PPP	Homogeneous goods
Construction	45	4	E-PPP	High expenditure share
Trade	50–52	2	O-PPP/E-PPP	Quality problem
Hotels and catering	55	4	E-PPP	High expenditure share
Transport	60–63	3	O-PPP	Quality problem
Communications	64	3	O-PPP	Quality problem
Finance	65–67	0	E-PPP	Reference PPP
Real estate activities	70	4	E-PPP	High expenditure share
Business services	71–74	1	E-PPP	Small expenditure share
Public administration and defense	75	1	Mainly wages	Based on input PPPs
Education and health	80, 85	1	Mainly wages	Based on input PPPs
Other services	90–95	2	E-PPP	Different product mix
B. Intermediate input PPPs				
All industries		1–4	E-PPP/O-PPP	Based on output PPPs, so grade depends on mix of input products
C. Capital input PPPs, all industries				
Construction		3	E-PPP	PPP for investments
Machinery and equipment		4	E-PPP	PPP for investments
D. Labor input, all industries		4	Wages	Relative wages for various labor types

Note: Ranking: 0 = not available; 1 = very poor; 2 = poor; 3 = acceptable; 4 = useful; 5 = very useful. E-PPP refers to expenditure PPPs for the OECD from the 1999 round, and O-PPP refers to production PPPs for 1997 from Timmer, Ypma, and van Ark (2007); ISIC = International Standard Industrial Classification.

UVRs for cars. Much of the output in manufacturing industries such as textiles, pulp and paper, basic metals, nonmetallic minerals, and chemicals consists of relatively homogeneous basic goods, and hence the quality of the O-PPPs is relatively high. This is not true for industries producing more sophisticated specialized goods such as in electrical and nonelectrical equipment, transport equipment, and instrument manufacturing. For these industries, the data set mainly makes use of adjusted component expenditure PPPs from the ICP. Although their quality is higher than that of unit value ratios, quality problems also plague purchaser's price comparisons of high-tech goods.

E-PPPs cannot be directly used for the distribution sector, because the output in this sector is measured as the margin of sales over purchases and separate deflation of intermediate purchases is necessary. But with an adjustment for the margin to sales ratio for each item, E-PPPs can be used for the retail sector. For retail trade, expenditure PPPs for individual expenditure categories were directly applied to sales output. The PPP at the margin level is derived as a weighted average of the sales PPPs of all goods, corrected for differences in the margin to sales ratios between two countries. In the case of wholesale trade, only the unit values of goods purchased by the wholesale sector are observable. Margin PPPs are derived by adjusting for differences in margin to cost ratios between two countries. Information on retail and wholesale sales, purchases, and margins were obtained from national trade census and survey data. Although this approach is superior to using unadjusted E-PPPs, it only partially corrects for differences in the quality of the trade service provided—see Timmer and Ypma (2006) for additional discussion on this approach.

For transport and communication services, UVRs were used, based on value and quantity data from a wide variety of international sources. Because of the high level of intermediate use, E-PPPs are only poor proxies. But given the relatively broad descriptions of the products used (up to nine product groups are distinguished), the quality of the UVRs is lower than that for manufacturing industries.

For other sectors (e.g., construction), production PPPs are very poor or nonexistent, and adjusted expenditure PPPs are used extensively. Conceptually, expenditure PPPs are a very good proxy for the PPPs for the gross output of construction, hotel and restaurant, and real estate activities[12] because almost all the output of these industries is for final expenditure, with very little export and import activity, so that adjustments need only be minimal. However, the quality of the ICP expenditure PPPs themselves is not always particularly high (e.g., for construction).

For other industries, expenditure PPPs are poor proxies because a sizable share of these services is used for intermediate, not final, consumption. And the mix of services used by producers will differ considerably from the services used by final consumers, such as for business and other services. Because we lack alternatives, we use adjusted expenditure PPPs, but note in table 24.2 that they are a poor proxy for an output PPP.

The expenditure PPP for finance is a reference PPP that is based on the overall expenditure PPP rather than on the relative prices of financial services. Because of the way in which financial output is currently deflated in most national accounts, this practice is perhaps defendable, but it is clearly unsatisfactory, and more research is needed to measure both financial output and prices.

For public administration, education and health expenditure PPPs have not been used. In almost all countries, the output in these sectors is measured by means of inputs. 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, 1997. 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 expenditure PPPs given by the OECD for these industries, large differences were found. In particular, the labor PPPs used by the OECD are rather different from our labor PPPs. Further scrutiny of the ICP PPPs for this sector is warranted (see chapter 11 of this book). Therefore, we decided to define the output PPPs for nonmarket services (industries L, M, N, and P) as a weighted sum of our input PPPs. Consequently, the comparative multifactor productivity levels in these industries are all equal to one by definition.

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 associated with obtaining input PPPs for individual industries are larger than those associated with output. There is often no input price parallel to the output PPPs. Business statistics surveys and production censuses provide little or no information on quantities and values of inputs in manufacturing, and for nonmanufacturing industries the information is largely absent. Moreover, by definition, PPPs from the expenditure side do not reflect the prices of intermediate inputs because they cover only the 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 deliveries from this industry to other industries. The aggregate intermediate input PPP for a particular industry can be derived by weighting intermediate inputs at the output PPP from the delivering industries. Imported goods are identified separately, 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 because there is little evidence that the law of one price holds for all goods even when internationally traded. However, so far these data are not readily available.

PPPs for output and intermediate input can be combined to calculate PPPs for value added as described earlier. Table 24.3 presents value added PPPs for the market economy and three main sectors

TABLE 24.3 Various Alternative Value Added PPP Measures: Selected Countries, 1997

national currency per U.S. dollar

		Value added PPPs				
	GDP (OECD)	Market economy	Manufacturing	Other goods	Market services	Exchange rate
Australia	1.32	1.44	1.88	0.99	1.48	1.35
Austria	0.92	1.26	1.36	1.19	1.22	0.89
Belgium	0.91	1.06	0.94	1.26	1.06	0.89
Czech Republic	12.70	16.00	15.20	15.40	18.10	31.70
Denmark	8.43	9.07	11.16	11.22	7.81	6.60
Finland	1.00	1.02	1.01	0.85	1.08	0.87
France	0.97	1.18	1.07	1.48	1.13	0.89
Germany	0.99	1.08	1.05	1.52	1.01	0.89
Hungary	85.00	96.50	89.90	132.10	90.90	186.80
Ireland	0.85	0.99	1.13	1.17	0.94	0.84
Italy	0.82	0.96	0.70	1.02	1.07	0.88
Japan	168.00	229.00	166.00	366.00	230.00	121.00
Luxembourg	0.96	0.94	1.13	1.77	0.75	0.89
Netherlands	0.91	0.99	1.09	1.44	0.88	0.89
Portugal	0.67	0.75	0.91	0.82	0.68	0.87
Slovenia	0.46	0.59	0.53	0.69	0.62	0.67
Spain	0.72	0.86	0.87	0.93	0.84	0.88
Sweden	9.30	10.30	10.40	10.00	10.20	7.63
United Kingdom	0.63	0.75	0.74	0.85	0.71	0.61
United States	1.00	1.00	1.00	1.00	1.00	1.00

Sources: Value added PPPs are based on the GGDC Productivity Level database (Inklaar and Timmer 2009); GDP PPPs and exchange rates are from OECD (2002). The GDP PPP is extrapolated from 1999; see OECD (2002).
Note: All entries are in national currency per U.S. dollar. For countries that adopted the euro in 1999, the 1999 conversion rate was used on the pre-euro currencies.

of the economy—manufacturing, other goods, and market services—for 1997. In addition, it provides PPPs for aggregate GDP and exchange rates as available from the OECD; both have been used as alternatives in previous studies. As noted in the literature, this approach ignores the differences in prices across various industries, as well as the differences in the prices of intermediate inputs and outputs—generally seen as a major weakness (Sørensen 2001). Instead, the value added PPPs have been derived by separate deflation of output and intermediate inputs as in equation (24.9). As shown in table 24.3, the ratio of sectoral value added to GDP PPPs can vary between 75 percent and more than 200 percent. The PPPs for the market economy are generally higher than the GDP PPPs, mainly because the latter includes nonmarket services, which, according to the OECD PPP results, are expensive in the United States compared with other countries. Importantly, the table shows large differences in relative prices across sectors, confirming the findings by Sørenson and Schjerning (2008) and van Biesebroeck (2009). For example, the PPP for other goods in Japan is much higher than the PPP for manufacturing goods. This difference is mainly due to the high output prices in the agriculture sector, which is famous for its weak competitiveness and strong import protection (van Ark and Pilat 1993). The use of an overall GDP PPP would greatly overestimate productivity levels in this sector. On balance, the value added PPPs for manufacturing differ by about 16 percent from the GDP PPP across our set of countries (absolute log differences). This directly translates into a 16 percent difference in measures of productivity levels. For market services, the difference is comparable (15 percent), while for other goods it is even bigger (32 percent).

Labor and Capital PPPs

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

The PPP for labor represents the relative price of one unit of labor between two countries. For each type of labor, relative wages can be calculated. The EU KLEMS Growth Accounts distinguish between 18 different labor types: two gender categories, three age categories, and three educational attainment categories. The educational attainment categories are low skilled (preprimary, primary, and lower secondary education—International Standard Classification of Education [ISCED] 0–2), medium skilled (upper secondary education, ISCED 3), and high skilled (total tertiary education, ISCED 5–7). However, in particular for level comparisons this classification is rough and might be misleading because educational systems in Europe and the United States are very different. In particular, the different roles of vocational schooling systems cause problems of comparability across countries. For example, in Germany vocational training is important to entering many occupations, but this is less prevalent in the United States. Based on the work by the Britain' s National Institute of Economic and Social Research (see Mason, O'Leary, and Vecchi 2009), we made a more detailed comparison and further decomposed the medium-skill level into three categories for a total of five. Further research on the comparability of schooling qualifications across countries is needed, however.

To convert capital input measured in national prices into common prices, capital input PPPs must be developed. Capital PPPs give the relative price of the use of a unit of capital in two countries from the purchaser's perspective. The calculation of the capital input PPP is less straightforward than for output, intermediate input, or labor input PPPs because of the conceptualization of capital input as capital services rather than capital stocks. To obtain the 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, PPP_k^K, the relative rental price of asset k between country C and the base country, the United States, is calculated as

$$(24.18) \qquad PPP_k^K = PPP_k^I \frac{\dfrac{p_{k,C}^K}{p_{k,C}^I}}{\dfrac{p_{k,US}^K}{p_{k,US}^I}}.$$

This definition indicates that the relative rental price of a unit of capital between two countries depends on the relative purchaser's price of a new capital good of asset k between country C and the United States ($PPP_{k,t}^I$) and the relative cost of capital input, with p_k^K the user cost and p_k^I the investment price. One can think of the user cost ratio p_k^K/p_k^I as the relative price of hiring a similar capital good for one year in both countries. In the absence of taxation, the familiar cost of capital equation for asset type k can be written as (Jorgenson and Griliches 1967)[13]

$$(24.19) \qquad \frac{p_k^K}{p_k^I} \approx r + \delta_k + \hat{p}_k^I.$$

This formula shows that the user cost is determined by the nominal rate of return (r), the rate of economic depreciation (δ), and the asset-specific capital gains measured as the change in investment price ($\hat{p}_k^I$).

Investment PPPs are collected in the OECD ICP program and are available for 35 capital assets from the OECD (2002) for 1999. Because they are already at purchasers' prices, no adjustment is needed to arrive at the input price concept. 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 PPPs to the benchmark year, 1997. The rates of depreciation are geometric rates that vary across assets, but are assumed to be identical across countries as in the EU KLEMS growth accounts (originally based on Fraumeni 1997). Because we use the ex ante approach to capital measurement, the nominal rate of return is the 10-year government bond yield for 1997 taken from the International Monetary Fund's database International Financial Statistics. It indicates the opportunity cost of using the investment fund in a risk-free alternative. The asset revaluation term can be derived from investment price indexes. To minimize the impact of sometimes volatile changes, annual averages over the period 1992–97 are used. 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 normalize the compensation by asset to the national accounts figure by proportionality.[14]

Table 24.4 is an overview of the labor and capital PPPs for the market economy in 1997. For reference, we also include the value added PPP for each country. It appears that capital services are relatively expensive in most countries compared with the United States—the capital input PPP is often much higher than the value added or the labor PPP. Especially in Eastern Europe and Ireland, the use of capital in production is expensive. Labor-input PPPs, on the other hand, vary widely across the set of countries. In countries such as Belgium, Denmark, Germany, and the Netherlands, wages are relatively high, whereas in the lower-income countries such as Portugal, Spain, and those in Eastern Europe, the labor input is

TABLE 24.4 Labor and Capital PPPs: Selected Countries, 1997

national currency per U.S. dollar

	Value added PPP	Labor input PPP	Capital input PPP
Australia	1.44	1.23	1.68
Austria	1.26	0.95	0.98
Belgium	1.06	1.22	1.07
Czech Republic	16.05	5.37	37.81
Denmark	9.07	9.86	9.50
Finland	1.02	0.95	1.09
France	1.18	1.04	1.31
Germany	1.08	1.13	1.17
Hungary	96.52	31.40	218.60
Ireland	0.99	0.72	1.24
Italy	0.96	0.85	0.88
Japan	229.30	120.36	128.14
Luxembourg	0.94	1.15	1.13
Netherlands	0.99	1.00	1.07
Portugal	0.75	0.48	0.93
Slovenia	0.59	0.32	0.99
Spain	0.86	0.66	0.82
Sweden	10.31	9.20	11.64
United Kingdom	0.75	0.60	0.82
United States	1.00	1.00	1.00

Sources: GGDC Productivity Level database (Inklaar and Timmer 2009).
Note: All entries are in national currency per U.S. dollar. For countries that adopted the euro in 1999, the 1999 conversion rate was used on the pre-euro currencies.

cheap. But that is not because the share of low-skilled workers is higher in the latter set of countries; we compare the wages of groups of workers with equivalent levels of educational attainment in all countries.[15]

Productivity Level Comparisons for the OECD

The GGDC Productivity Level database provides a wide range of results on comparative prices, input and output quantities, and productivity at the industry level. In this section, we provide only a selection of the data available in the GGDC Productivity Level database; detailed results can be found at http://www.ggdc.net/databases/levels.htm. We also discuss the sensitivity of the results.

Productivity Levels

Basically, our productivity level comparisons are based on deflating nominal inputs and output as given in national input-output tables by a set of relative prices. The nominal values of inputs and outputs are based on national 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 so we used supply-use tables to construct comparable IOTs. The starting point of our analysis is the national supply-use table for each country, valued in national currency for 1997. For Canada, the United States, and Australia, these tables were obtained from the national statistical offices. Eurostat makes these tables available for the European countries based on a common industry classification and at a sufficient level of industry detail for the purposes of this study. For Canada, the United States, and Australia, the classification for these tables had to be adjusted to the European industry classification. The value added block of the use table distinguishes only two primary factors—capital and labor—and so further disaggregation of these factor inputs is required. We use the labor and capital compensation given in the EU KLEMS database in which a correction is made for the labor income of the self-employed. Total hours worked and wages for each of the 18 labor types is taken from the EU KLEMS database (O'Mahony and Timmer 2009) and extended to 30 types by incorporating more detailed educational attainment data. Capital compensation is split into three ICT assets (computers, communication equipment, and software) and five non-ICT assets (residential structures, nonresidential 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. We multiply the asset- and industry-specific rental prices with the capital stock taken from the capital input files from the EU KLEMS database to derive the ex ante capital compensation. This will typically differ from the (ex post) capital compensation given in the national accounts. We normalize the compensation by asset to the national accounts figure by proportionality.

It is useful at this stage to present an example of the level accounting method for a flavor of the type of results that can be derived. We use the comparison of output, inputs, and productivity in transport equipment manufacturing in Germany with those in the United States in 1997. Table 24.5 is an overview of the nominal output and inputs in each country and the corresponding

TABLE 24.5 Example of Input-Output Comparison, Transport Equipment Manufacturing: Germany and United States, 1997

	Nominal values			Relative volume (Germany/ United States)
	Germany (billion euros)	United States (billion US$)	PPP (euro/US$)	
Sectoral output	141.8	454.8	1.25	0.25
Sectoral intermediate inputs	87.2	291.5	0.96	0.31
Energy	2.7	3.7	1.32	0.55
Materials	63.0	180.1	0.94	0.37
Services	21.5	107.8	1.02	0.20
Gross value added	54.7	163.2	2.04	0.16
Labor	43.1	122.6	1.36	0.26
High-skilled	10.4	34.9	1.32	0.23
Non-high-skilled	32.8	87.7	1.37	0.27
Capital	11.6	40.6	1.13	0.42
ICT capital	1.3	10.5	0.94	0.22
Non-ICT capital	10.2	30.1	1.16	0.48

Note: ICT = information and communication technology. Relative volumes are derived as the nominal value of Germany divided by the corresponding PPP over the nominal value of the United States, except for capital. Relative volumes for capital are determined based on the ex ante approach to capital measurement (see text).

PPPs. The values in the first two columns are at national prices: euros for Germany and U.S. dollars for the United States. The PPPs in the third column are given in euros per U.S. dollar. These PPPs are based on industry-specific prices of outputs and detailed inputs. They show that energy inputs and particularly labor are more expensive in Germany than in the United States, whereas materials and ICT capital are relatively cheap. In the final column, we give relative volumes derived as nominal value for Germany divided by the corresponding PPP over the nominal value for the United States, except for capital. The relative volumes for capital are determined based on the ex ante approach to capital measurement. The final column shows that the U.S. transport equipment output is four times as big as that of Germany. Production in the United States uses relatively less energy and non-ICT capital, but more services inputs and ICT capital than in Germany.

The GGDC Productivity Level database contains data only for the benchmark year, 1997. An attractive feature of the database is that 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 2009). As such, the level and growth accounts for the benchmark year, 1997, can be used together in comparative analyses of long-run productivity trends. Tables 24.6 and 24.7 provide labor and multifactor productivity levels for the year 2005. These results are based on our preferred set of estimates for 1997 (using a mix of PPPs), extrapolated to 2005, which is the latest year for which data are available in the EU KLEMS database (March 2008 release). To update a volume comparison to 2005, we simply apply the relative volume growth rates between the two countries for the period 1997–2005.[16] Our comparisons of the market economy exclude public administration, health, education, and real estate because we consider these sectors to be more meaningful than comparisons for the total economy. Output in these sectors is measured mostly through inputs, and relative productivity levels should be one by definition.

Table 24.6 shows large differences in value added per hour worked within the OECD area. Belgian labor productivity levels are equal to those of the United States, but all other countries are lagging behind. Relative levels in France, Germany, and the United Kingdom are 70–80 percent, and less than 60 percent in Italy and Spain. Levels in Greece and Portugal are even below 40 percent of the U.S. level. In almost all European countries, comparative levels are highest in (nonelectrical) manufacturing, while gaps are typically much bigger for market services.

Table 24.7 provides measures of multifactor productivity. Assuming a common technology across countries, MFPs are an indication of the relative levels of the efficiency of input use between countries. They are measured as the difference in output between countries when differences in all inputs have been accounted for. Under the set of neoclassical assumptions, differences in MFP levels can be interpreted as differences in the level of disembodied technology. In table 24.7, we provide levels for the year 2005 for a set of 20 countries for which capital data are available. Estimates are given for six major sectors and higher aggregates with United States equal to one. It appears that European MFP gaps are smaller than labor productivity gaps because of the higher inputs in the United States compared with those in most European countries. In terms of both capital and skills, inputs in the United States are generally higher than in other countries. In most countries, the MFP gap is smallest in manufacturing and biggest in market services. Within market services, MFP levels are generally high in trade and financial services, but low in transport and business services.

Sensitivity of PPPs and Productivity Levels

A particular issue in level accounts is the double deflation of 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 are exactly the same as for

TABLE 24.6 Value Added per Hour Worked: OECD Countries, 2005 (US = 1)

	MARKT	ELECOM	MexElec	OtherG	MSERV	DISTR	FINBU	PERS
AUS	0.69	0.38	0.53	1.41	0.67	0.64	0.69	0.75
AUT	0.61	0.37	0.71	0.80	0.58	0.60	0.47	0.93
BEL	1.00	0.53	1.37	1.16	0.91	0.97	0.84	0.82
CYP	0.48	0.59	0.28	0.60	0.59	0.58	1.13	0.57
CZE	0.36	0.10	0.39	0.42	0.36	0.48	0.26	0.55
DNK	0.80	0.36	0.65	0.87	0.93	1.10	0.78	0.97
ESP	0.57	0.35	0.60	0.57	0.61	0.62	0.70	0.75
EST	0.24	0.04	0.10	0.38	0.30	0.24	0.86	0.52
FIN	0.83	0.92	1.09	0.70	0.69	1.10	0.41	0.59
FRA	0.74	0.69	0.95	0.59	0.76	0.89	0.57	1.01
GER	0.80	0.58	0.93	0.63	0.82	0.88	0.71	1.01
GRE	0.39	0.35	0.37	0.37	0.44	0.37	0.49	0.79
HUN	0.40	0.27	0.37	0.35	0.42	0.28	0.57	1.04
IRL	0.84	0.42	1.74	0.43	0.75	0.65	1.06	0.67
ITA	0.58	0.49	0.81	0.66	0.51	0.46	0.69	0.45
JAP	0.50	0.66	0.69	0.30	0.49	0.47	0.63	0.48
KOR	0.41	0.59	0.73	0.37	0.25	0.21	0.45	0.23
LTU	0.24	0.05	0.17	0.29	0.30	0.34	0.29	0.56
LUX	1.23	2.33	0.99	0.58	1.56	1.42	1.59	0.76
LVA	0.31	0.14	0.12	0.51	0.40	0.39	0.63	0.50
MLT	0.38	0.15	0.25	0.47	0.41	0.43	0.37	0.86
NLD	0.88	0.52	1.04	0.76	0.96	1.54	0.65	0.91
POL	0.38	0.09	0.35	0.26	0.56	0.66	0.61	0.63
PRT	0.34	0.31	0.27	0.24	0.49	0.50	0.90	0.40
SVK	0.31	0.11	0.20	0.43	0.42	0.32	0.50	0.96
SVN	0.07	0.04	0.02	0.05	0.20	0.13	0.27	0.40
SWE	0.90	2.49	0.92	0.87	0.82	0.80	0.74	0.52
UK	0.67	0.75	0.80	0.67	0.66	0.58	0.64	0.57
USA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Source: GGDC Productivity Level database (Inklaar and Timmer 2009).
Note: See note to annex table for country codes. MARKT = market economy; ELECOM = electrical machinery, post, and communication services; MexElec = total manufacturing, excluding electrical; OtherG = other production; MSERV = market services, excluding post and telecommunications; DISTR = distribution; FINBU = finance and business, except real estate; PERS = personal services.

a gross output–based MFP measure. However, in practice, for the reasons discussed shortly, the prices of intermediate inputs are often ignored, and the PPP for gross output is used instead. This approach is called single deflation, as opposed to double deflation in which the prices of intermediate inputs are taken into account as in equation (24.8). Single deflation has some significant problems: 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. However, in practice

TABLE 24.7 Multifactor Productivity: Selected Countries, 2005 (US = 1)

	MARKT	ELECOM	MexElec	OtherG	MSERV	DISTR	FINBU	PERS
AUS	0.76	0.50	0.59	1.38	0.76	0.68	0.88	0.63
AUT	0.69	0.48	0.77	0.98	0.64	0.62	0.57	0.82
BEL	0.89	0.51	1.18	1.06	0.82	0.74	0.91	0.84
CZE	0.46	0.19	0.56	0.59	0.43	0.47	0.37	0.55
DNK	0.85	0.52	0.72	0.86	1.02	1.12	0.99	0.78
ESP	0.73	0.42	0.67	0.91	0.78	0.61	0.95	0.88
FIN	0.92	1.27	1.11	0.87	0.79	1.07	0.64	0.49
FRA	0.82	0.94	1.00	0.76	0.81	0.91	0.61	0.95
GER	0.86	0.81	0.99	0.75	0.85	0.98	0.68	0.86
HUN	0.49	0.48	0.55	0.55	0.46	0.32	0.81	0.43
IRL	0.97	0.56	1.61	0.58	0.90	0.70	1.55	0.53
ITA	0.66	0.62	0.84	0.79	0.60	0.45	0.76	0.61
JAP	0.47	0.66	0.60	0.33	0.46	0.43	0.52	0.34
LUX	1.13	1.37	0.95	0.71	1.35	1.18	1.81	0.70
NLD	0.94	0.55	1.02	0.83	1.04	1.55	0.79	0.79
PRT	0.63	0.44	0.57	0.57	0.78	0.70	1.07	0.64
SVN	0.08	0.06	0.03	0.05	0.23	0.13	0.35	0.34
SWE	0.86	2.65	0.87	0.95	0.77	0.70	0.73	0.45
UK	0.79	0.92	0.93	0.79	0.77	0.67	0.82	0.55
USA	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Source: GGDC Productivity Level database (Inklaar and Timmer 2009).
Note: See note to annex table for country codes. MARKT = market economy; ELECOM = electrical machinery, post, and communication services; MexElec = total manufacturing, excluding electrical; OtherG = other production; MSERV = market services, excluding post and telecommunications; DISTR = distribution; FINBU = finance and business, except real estate; PERS = personal services. MFP is value added–based (double-deflated).

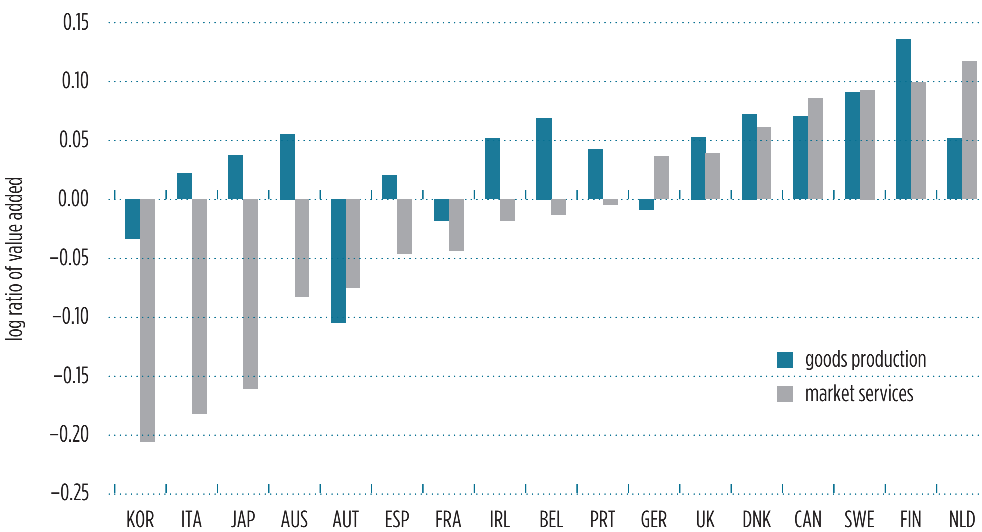
double deflation also has a number of well-known problems. For one thing, double deflation puts larger requirements on the data because intermediate input PPPs are needed in addition to the PPPs for gross output. However, the intermediate input PPPs are not directly available and must be constructed on the basis of output prices (see the third section of this chapter). Hill (1971) suggests that the use of single deflation may be less misleading than the use of 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 (see Hill 1971, 19). This may be one of the reasons the International Comparison Program opted in the 1950s and 1960s for the expenditure approach to GDP rather than the industry of origin approach.

Inklaar and Timmer (2008) have shown that the sensitivity of productivity level comparisons to the choice of single or double deflation techniques increases with the level of industry detail. At the market economy level, differences are large only for countries with exchange rates that are much higher than the GDP PPP in 1997 (e.g., Eastern European countries, but also Denmark). Also at the major sector levels, differences are generally small and can go either way. Differences are smallest for market services, which is to be expected because of the low share of intermediates in output. As such, measurement errors in intermediate input prices have only a minor impact. Differences can be larger for the goods-producing sectors because the intermediate input share is much larger; typically these shares are 60 percent, but only 30 percent for services.

As discussed earlier, our preferred choice of PPPs is based on a mix of the industry of origin UVRs and expenditure PPPs provided by Timmer, Ypma, and van Ark (2007). As an alternative, the GGDC Productivity Level database provides a set of results based on expenditure prices only. This illustrates the empirical differences between our mixed approach and the pure expenditure approach as followed, for example, by Sørenson and Schjerning (2008) and van Biesebroeck (2009). The alternative set is based only on expenditure PPPs, except for agriculture and mining for which no expenditure PPPs exist, as discussed earlier. For these industries, UVR estimates are used. Similarly, for distributive trade no expenditure PPP is available. The overall GDP expenditure PPP is used instead. Figure 24.1 shows the sensitivity of the comparisons to the choice of PPP set. It gives the log ratio of value added using a mix of PPPs (our preferred choice) and using PPPs from the expenditure side only.

Figure 24.1 reveals that differences can go either way because mixed PPPs are sometimes higher or lower than expenditure PPPs. For goods production, differences are relatively minor and often within 5 percent bounds. The differences for market services can be much larger, however. For example, real value added in Italy, the Republic of Korea, and Japan is more than 15 percent higher than that in the United States when using expenditure PPPs only. A more detailed analysis at the industry level reveals that this difference stems from differences for the trade and transportation sectors. The annex to this chapter provides detailed results by sector. For the other market

FIGURE 24.1 Difference in Value Added Based on Alternative PPP Sets: Selected Countries, 1997



Source: Annex table.
Note: See note to annex table for country codes. Graph shows the log ratio of value added using mix of PPPs (our preferred choice) and using PPPs from the expenditure side only. Value added is single-deflated.

service industries, only expenditure PPPs are available, and hence PPPs in the two sets are the same. Expenditure PPPs for these services are extremely low in various Asian and Eastern European countries. Arguably, these expenditure PPPs refer to highly subsidized prices for public transportation that have little relevance to the transport prices facing firms. It seems nearly impossible to correct for the huge amounts of direct and indirect subsidies from published national account statistics. By contrast, estimates of distribution PPPs based on expenditure prices appear to be too high for Nordic countries. The annex further shows that the lower the level of aggregation, the bigger differences can become. For some individual industry by country cells, the two estimates diverge markedly.

Conclusion

In this chapter, we have outlined a method for productivity level comparisons at the industry level and presented some results for a set of 30 OECD countries from the GGDC Productivity Level database. Productivity level comparisons by sector require not only PPPs for output, but also for intermediate input, capital, and labor inputs. This type of data is not only of interest to academics and international organizations, but also to the business community in, for example, deriving unit labor costs (O'Connor 2008). We discussed the importance of PPPs collected by the ICP for these types of studies. Comparisons of output prices from the production side are scarce and need to be complemented by expenditure PPPs, in particular for durable manufacturing goods, construction, and various services sectors (hotels, real estate, business, and personal services). In addition, expenditure PPPs for investment goods are crucial for the construction of capital input PPPs.

We also have outlined the types of adjustments needed to transform expenditure PPPs based on the purchaser's price concept to industry output PPPs based on the basic price concept. Using the supply-use table framework, we were able to indicate under what conditions expenditure PPPs adjusted for net taxes and margins provide a reasonable proxy for output PPPs. In general, the higher the degree of intermediate use and international trade of a product, the lower is the usefulness of an expenditure PPP. The confrontation of expenditure and output PPPs in the SUT framework is also useful for providing cross-checks on the plausibility of various sets of PPPs. For example, we found that expenditure PPPs for public administration, education, and health deviated strongly from the relative wage data on the production side. This finding raises new questions about the validity of the PPPs, and further scrutiny is warranted. It also illustrates the important synergies between international comparisons from the expenditure and the production sides.

Because of the limited availability of output PPPs, expenditure PPPs are crucial for productivity level comparisons within the OECD as analyzed in this chapter. Given the greater scarcity of production PPPs outside the OECD, the need for expenditure PPPs is even more so for comparisons of non-OECD member countries. New work is now being undertaken to provide new productivity level comparisons for a larger set of countries, including Brazil, China, India, Indonesia, Mexico, and the Russian Federation. Global comparisons of productivity will rely heavily on the results of the latest ICP benchmark (World Bank 2008).

ANNEX

Sensitivity to Choice of PPPs, 1997

	TOT	MARKT	ELECOM	GOODS	MexElec	OtherG	MSERV	DISTR	*G*	*60t63*	FINBU	*J*	*71t74*	PERS	NONMAR
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**

Source: Calculations based on the GGDC Productivity Level database.
Note: Column headings indicate industry groupings. Headings at higher levels (boldface) indicate aggregations of industries at lower level. MARKT = market economy; ELECOM = electrical machinery, post, and communication services; MexElec = total manufacturing, excluding electrical; OtherG = other production; MSERV = market services, excluding post and telecommunications; DISTR = distribution; G = trade; 60t63 = transport services; FINBU = finance and business, except real estate; J = finance; 71t74 = business services; PERS = personal services. Table shows log ratio of value added using mix of PPPs (our preferred choice) and using PPPs from expenditure side only. Value added is single-deflated. 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 = Korea, Rep.; LTU = Lithuania; LUX = Luxembourg; LVA = Latvia; MLT = Malta; NLD = Netherlands; POL = Poland; PRT = Portugal; SVK = Slovak Republic; SVN = Slovenia; SWE = Sweden; UK = United Kingdom; USA = United States.

NOTES

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2. Using the United States as our base country does not imply the use of a star system of comparisons. As discussed later, we will use base-invariant productivity measures.
3. Note that because of our approach to capital measurement, capital compensation in this formula is based on ex ante measures of rates of return and will differ from the ex post measure of capital compensation used as the weight in equation (24.2).
4. We aggregate over prices rather than over quantities because variation in prices across countries is much less than variation in quantities (also see Allen and Diewert 1981).
5. See van Ark and Timmer (2009) for a recent survey.
6. Exports are valued at free on board (f.o.b.) prices and the imports at cost, insurance, and freight (c.i.f.) prices. The export f.o.b. price is essentially a purchaser's price, including net taxes and trade and transport margins up to the border of the exporting country. The import c.i.f. price is essentially a basic price, excluding net taxes levied after crossing the border and trade and transport margins within the country.
7. Taxes include any taxes on products at the sales point such as a sales or a value added tax.
8. See the Eurostat manual on supply-use tables for more information (Eurostat 2008).
9. We use the terms *final expenditure price* and *final domestic demand* interchangeably.
10. In addition, subsidies on certain transport service categories are very difficult to peel off from the final expenditure price (e.g., bus, subway, and rail transport prices).
11. NACE is the acronym used for the General Industrial Classification of Economic Activities within the European Communities.
12. This PPP can be based on the expenditure PPP for rents.
13. This formula is an approximation because we exclude second-order effects. Country subscripts are dropped to avoid cluttering.
14. See Oulton (2007) for this hybrid approach to capital measurement.
15. See the caveats in the previous section.
16. At the lowest level of aggregation, this procedure delivers the same numbers as the alternative of extrapolating the PPPs based on national deflators. At higher levels of aggregation, differences become large, with the size of the difference related to the changing output shares.

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