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Disaggregate Productivity Comparisons: Sectoral Convergence in OECD Countries

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Abstract

International comparisons of productivity have used exchange rates or purchasing power parity (PPP) to make output comparable across countries. While aggregate PPP holds well in the long run, sectoral deviations are very persistent. It raises the need for a currency conversion factor at the same level of aggregation as the output that is compared. Mapping prices from household expenditure surveys into the industrial classification of sectors and adjusting for taxes and international trade, I obtain an expenditure-based sector-specific PPP. Using detailed price data for 1985, 1990, 1993, and 1996, I test whether the sectoral PPPs adequately capture differential changes in relative prices between countries. For agriculture and the majority of industrial sectors, but not for most service sectors, sectoral PPP is preferred over aggregate PPP. Using the most appropriate conversion factor for each industry, productivity convergence is found to be taking place in all but a few industries for a group of 14 OECD countries. The results are robust to the base year used for the currency conversion.

Keywords: PPP, productivity, convergence, sectoral comparison, base year
JEL codes: D24, F14, F31, O47

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1 Introduction

To compare economy-wide productivity or GDP per capita, researchers have the option to use purchasing power parity (PPP) or exchange rates to convert domestic output into a common currency. Similar comparisons at the sectoral level will only capture the productivity difference if the two countries share the same relative prices. Moreover, performing such sectoral comparisons at multiple points in time—for example to study cross-country convergence—will lump price changes with productivity changes if relative prices evolve differently by country.

PPP is constructed by aggregating relative prices on a basket of identical goods using expenditure weights. This generates an appropriate conversion factor only for output that is well represented by the basket. This is well known. For example, to compare TFP levels across countries, the value of capital also has to be converted into a common currency. Because price changes for investment goods often differ from the general rate of inflation, a specific PPP for capital is used, aggregating only prices of the relevant subset of goods.

To compare productivity between countries at the sectoral level, one should exert similar caution. For example, if the price of textiles relative to machinery increases faster in Japan than in the United States, it will not be correct to use the same aggregate PPP to convert both Japanese textile and machinery output into U.S. dollar. Japanese relative productivity growth in textiles will be overestimated and vice versa for machinery. Without a sectoral equivalent to PPP, one risks getting the productivity comparison wrong.

In the past, Dollar and Wolff (1988) and Bernard and Jones (1996) have used aggregate PPP to convert sectoral output. Sørensen (2001) shows this to be appropriate for the total business or service sectors, but not for manufacturing. In response to the Comment by Sørensen (2001), Bernard and Jones (2001) write:

> "The clear implication of the Comment is that future research is needed to construct conversion factors appropriate to each sector and that research relying on international comparisons of sectoral productivity should proceed with caution until these conversion factors are available." (p. 1169).

Still, some recent papers, e.g. Arcelus and Arocena (2000) or Malley et al. (2003), still use aggregate PPP for sectoral comparisons. They do not justify their choice, apparently in a belief that it is of secondary importance.

The evidence in Engel and Rogers (1996) highlights that price differences for identical goods are not merely a possibility, but an important phenomenon. They show that price differences between U.S. and Canadian cities are much larger than between equidistant cities within the same country. Trade barriers are likely to be important and Bradford (2003) uses detailed information on international price differences to construct new measures of final good trade protection. Engel and Rogers (2004) shows that price differences between European cities are also nonnegligible. At the same time, they find evidence of a significant reduction in price dispersion over the decade of the 1990s—although no acceleration after the introduction of the euro. Such a trend inevitably implies different evolutions of relative prices across countries. Ignoring these significant changes in relative prices will bias sectoral output or productivity comparisons over the same time period.

Some studies have recognized the problem and constructed disaggregate conversion factors. Hooper and Larin (1989), Hooper (1996) and Harrigan (1999) use published PPPs for different component factors of GDP. Only a few components are available and the correspondence to industrial sectors is only approximate. Jorgenson et al. (1987) and Pilat (1996) use the more disaggregate underlying data from the same consumer price and expenditure surveys. They map individual product categories—called basic headings—into the sectors for which they observe output. In contrast, van Ark and Pilat (1993) rely on producer price surveys to construct unit value ratios, an alternative to sectoral PPP. In theory, these are superior, but because they cover less products they might perform worse in practice. As these studies only calculate the sectoral PPPs for a single year, they cannot test their validity.

The contribution of this paper is to calculate expenditure-based sectoral PPPs in four different years.[1] Hence, we can verify whether these conversion factors accurately capture changes in relative prices, which is necessary to compare sectoral output at different times. A related paper is Sørensen and Schjerning (2003), which constructs sectoral PPPs for some manufacturing sectors using the component factors of GDP for different base years. They conclude that they do not pass the base-year invariance test from Sørensen (2001). In addition to constructing the conversion factors at an even more disaggregate level—aggregation tends to exacerbate the problems—and for all sectors in the economy, I propose a different

[1]When there is no risk for confusion, the label "expenditure-based" will be omitted. In Section 4.3, I present results using additional base years: 1970, 1975, 1980, and 1999. As the price data for the earlier years is slightly different and not all adjustments can be performed for these years, we initially focus on the results for the 1985, 1990, 1993, and 1996 base years.

benchmark. Base-year invariance of the convergence estimates is a necessary condition for the conversion factors to be valid, but it is only an indirect check. I verify directly whether changes in sectoral PPP over time correspond well to price changes relative to the U.S. (the reference country for our PPPs), which is one objective of the disaggregate conversion factors.[2]

An important application for sectoral productivity comparisons is in the convergence debate. Within the group of OECD countries, GDP per capita or aggregate labor productivity was found to be converging over the last 40 years.[3] A natural question is to ask what drives convergence in this group of countries. Are all sectors converging to the same extent or is the decline of sectors with large productivity differentials, such as agriculture, important? Alternatively, are service sectors that account for an ever larger portion of GDP more comparable across countries? It is also possible that increased trade intensity, especially in manufacturing, drives the convergence results. In order to answer any of the above questions, one needs to calculate sectoral productivity differences at several points in time.

The remainder of the paper is organized as follows: Section 2 illustrates the issues in comparing cross-country productivity differentials over time. In Section 3, I first discusses the literature on sector-specific (currency) conversion factors. Then, I describes the data and the construction of expenditure-based sectoral PPP. The validity of these measures is evaluated directly, in Section 4, by comparing relative price changes with changes in sectoral PPP. In Section 5, sectoral convergence rates are calculated using the most appropriate currency conversion factor for each industry. Section 6 concludes.

2 International productivity comparisons

To compare output between countries one needs to convert local currency values into a common unit. Exchange rates are often deemed inappropriate because they are very volatile and are only affected by tradables and financial assets. The proper conversion factor, for example into U.S. dollar, converts the value of domestic output into the dollar value of a comparable physical quantity in the U.S. For an industry comprising many goods, relative

[2] We still cannot verify whether the absolute size of the relative price differences are measured accurately.

[3] An overview of the debate with recent evidence can be found in a symposium in the July 1996 issue of the *Economic Journal* or in Durlauf and Quah (1999).

prices on a basket of goods, representative of the output being compared, are aggregated. Aggregate PPP is designed to accomplish this for GDP. For example, the labor productivity level of the Japanese economy relative to the U.S. (in U.S. dollar in 1970) is calculated as:

$$\text{level comparison:} \qquad \Big(\frac{LP^{J}}{LP^{US}}\Big)^{\$}_{70} \;=\; \frac{LP^{J,¥}_{70}/PPP^{¥/\$}_{70}}{LP^{US,\$}_{70}}, \tag{1}$$

with $PPP^{¥/\$} = \frac{P^{¥}}{P^{\$}}$, the number of yen needed to purchase the same basket of goods in Japan that costs \$1 in the U.S. LP is value added divided by total employment or any other input measure that is deemed appropriate. To compare output for a single sector, one should construct a sectoral PPP based only on the prices of the goods in that industry.

Comparing the evolution of relative productivity levels over time, two calculations are possible. The most straightforward one would be to compare the productivity levels in current prices in both years and measure the change in this ratio. The yen denominated Japanese production is converted into dollars at both times using time-specific conversion factors ($PPP^{¥/\$}_{t}$). A measure for the change in relative productivity level between Japan and the U.S. from 1970 to 2000 is

$$\text{growth comparison 1:} \qquad \frac{\text{relative LP}^{J/US}_{00}}{\text{relative LP}^{J/US}_{70}} \;\equiv\; \frac{\Big(\frac{LP^{J}}{LP^{US}}\Big)^{\$}_{00}}{\Big(\frac{LP^{J}}{LP^{US}}\Big)^{\$}_{70}} \;=\; \frac{\frac{LP^{J,¥}_{00}/PPP^{¥/\$}_{00}}{LP^{US,\$}_{00}}}{\frac{LP^{J,¥}_{70}/PPP^{¥/\$}_{70}}{LP^{US,\$}_{70}}}. \tag{2}$$

Alternatively, if we do not observe PPP in both periods or if we have more faith in price deflators, we can calculate real output or productivity growth separately for each country and compare the growth rates. Using country-specific deflation rates (P_{00}/P_{70}), the nominal values for 2000 are converted into real, 1970 values, which is indicated by $LP_{00,70}$. The productivity growth for Japan and the U.S., in real 1970 prices, is compared directly to measure their relative performance:

$$\text{growth comparison 2:} \qquad \frac{1+LPG^{J}_{70/00}}{1+LPG^{US}_{70/00}} \;\equiv\; \frac{\Big(\frac{LP_{00,70}}{LP_{70}}\Big)^{J,¥}}{\Big(\frac{LP_{00,70}}{LP_{70}}\Big)^{US,\$}} \;=\; \frac{\frac{LP^{J,¥}_{00}/(\frac{P_{00}}{P_{70}})^{¥}}{LP^{J,¥}_{70}}}{\frac{LP^{US,\$}_{00}/(\frac{P_{00}}{P_{70}})^{\$}}{LP^{US,\$}_{70}}} \tag{3}$$

Obviously, for (2) and (3) to give the same result, the price deflators and currency converters have to be related. Rearranging both equations reveals that they have to satisfy:[4]

$$\frac{PPP_{00}^{¥/\$}}{PPP_{70}^{¥/\$}} = \frac{\left(\frac{P_{00}}{P_{70}}\right)^{¥}}{\left(\frac{P_{00}}{P_{70}}\right)^{\$}}. \tag{4}$$

The ratio of the currency conversions factors at both points in time has to equal the ratio of price deflation in both countries. If one country experiences more rapid inflation than the other, its currency should depreciate in PPP terms. In theory, $PPP^{¥/\$}$ is defined as $\frac{P^{¥}}{P^{\$}}$ and (4) should hold. In practice, both sides of the equation are calculated from different data and equality is not guaranteed.

As an example of the potential pitfalls using aggregate PPP, consider photographic cameras in Japan. In 1985, cameras were relatively expensive in Japan, costing 268 yen per dollar's worth, while aggregate PPP was 218. By 1996, relative prices dropped to ¥8600 for a camera costing $100 in the U.S., while the aggregate price level only declined to 162. Even if convergence in productivity was perfect, it would not be picked up using aggregate PPP. Assume, for example, that Japan was initially less productive, but that the entire difference was eliminated through faster productivity growth. Converting output in dollars with aggregate PPP overestimates the Japanese initial productivity level, but underestimates its relative productivity level in 1996. The puzzling conclusion would be that a country with a relatively high initial productivity level in camera production enjoyed higher productivity growth than the U.S., but has fallen behind in relative productivity by 1996. It simply indicates that aggregate PPP does not satisfy equation (4).

Because relative prices are likely to evolve differently by country, sectoral productivity comparisons have to use currency conversion factors that adequately reflect relative prices. To assess convergence, one only has to compare initial productivity levels and subsequent real productivity growth is calculated using domestic deflation rates. The currency conversion has to be performed only once, but to assess the validity of the currency conversion factors, i.e. whether they satisfy the equality in equation (4), several years of data are needed.

[4] In the context of productivity comparisons, Sørensen (2001) illustrates how a failure of this equation to hold will affect the convergence results.

3 Sectoral PPP

3.1 Literature

To construct sectoral PPP measures, one can use producer or consumer prices. The industry-of-origin approach aggregates unit value ratios, obtained directly from producer price surveys, to the level of aggregation of output statistics. This method was pioneered by van Ark and Pilat (1993) and is explained in detail, with recent advances, in van Ark and Timmer (2001).[5] Its appeal stems from the natural concordance between price and output measures and the possibility to control accurately for changes in product mix.

The expenditure approach provides an alternative by aggregating consumer prices using expenditure shares, obtained from consumer and retail price surveys.[6] The same method is used to construct aggregate PPP. It has been the more popular approach in productivity comparisons, even though output is measured from the production side of the national accounts, while prices correspond to the expenditure side. In a comment on van Ark and Pilat (1993), Jorgenson argues:

> The unit value ratios are preferable, in principle, because they represent ratios of producers' prices for the two countries being compared. [...] The practical disadvantages of unit value ratios largely outweigh their conceptual advantages, so the purchasing power parities of Kravis and his associates [...] are far more satisfactory. ("Comment" on van Ark and Pilat (1993), p. 53)

The expenditure approach is described in detail in Jorgenson and Kuroda (1990) and was first used to compare sectoral productivity between Japan and the U.S. Using the same methodology, Conrad and Jorgenson (1985) extend the results and include Germany in the comparison. Lee and Tang (2001) perform similar comparisons between Canada and the U.S. for Industry Canada.[7]

[5]Researchers at the Groningen Growth and Development Centre have been instrumental in developing this approach. Relative productivity comparisons are available online in their data set "International Comparisons of Output and Productivity by Industry" at http://www.eco.rug.nl/GGDC/icop.html.

[6]The International Comparison Program (ICP) is regularly updating the data and methodology. The program was first established in 1968 as a joint venture of the UN and the International Comparisons Unit of the University of Pennsylvania. Currently, it entails a data collection and processing collaboration between many statistical agencies, foremost the World Bank, OECD, and Eurostat. Information on the program is available online at http://www.worldbank.org/data/.

[7]Using sectoral PPPs in a productivity comparison using gross output, as in Jorgenson and Kuroda

Pilat (1996) compares sectoral productivity levels for nine OECD countries. He uses industry-of-origin data (producer prices) where available, but supplements them with expenditure PPP data for 1985. The latter are consumer price ratios for a number of detailed commodity groups, called basic headings.[8] The original data, compiled by Kravis, Heston, and Summers (1978) for 1970, contained 153 categories, but this was expanded to 210 internationally comparable basic headings by 1985. These aggregate prices and expenditures on approximately 2500 goods and services, chosen to be representative of the entire economy, i.e. of total consumption by consumers, businesses, and government. The data collection is coordinated by the International Comparison Program.[9]

I construct expenditure PPPs, as in Pilat (1996), but for three additional years—1990, 1993 and 1996—and for all countries in Bernard and Jones (1996) (listed in Table 2). Details on the construction and necessary adjustments are in the next Section. Even though a conversion factor is only needed in a single year to study sectoral convergence, I calculate sectoral PPP for multiple years to test whether they adequately capture relative price changes. The implicit assumption that relative real growth rates are equally well measured by equations (2) or (3) is questioned in another comment on van Ark and Pilat (1993) by Frank Lichtenberg:

> Another, *less serious* limitation of the paper's approach is that the authors constructed "benchmark" estimates of relative productivity levels for only a single year—1987; ("Comment" on van Ark and Pilat (1993), p. 58).

All studies using sector-specific conversion rates to compare productivity levels between countries over time have similarly assumed that (4) holds. In contrast, we will test explicitly whether the relationship holds or not.[10]

In addition to the expenditure versus industry-of-origin choice, one has to determine the level of aggregation to work at. While Hooper and Larin (1989) construct a conversion

(1990), or adjusting unit value ratios for "double deflation", as in van Ark and Timmer (2001), requires detailed and internationally harmonized input-output tables. This is beyond the scope of this paper and I limit myself to comparing value added per worker, using sectoral PPP to convert value added directly. I similarly ignore the issue of aggregation as the merits of different methods, most notably the Geary-Khamis and EKS methods—are still debated, see for example Dowrick and Quiggin (1997) or OECD (2002).

[8] Basic headings are the most detailed product categories for which expenditure weights can be estimated for all countries. Bradford (2003) describes the data and uses them to measure protection in OECD countries.

[9] For the countries I study, all data is collected by the OECD and Eurostat.

[10] The analysis in Sørensen and Schjerning (2003) provides indirect evidence that equation (4) does not hold over with equality over the entire 1970–1993 period in the sectors and countries they study.

factor for manufacturing, Harrigan (1999) limits the comparison to eight narrowly defined industries in machinery and equipment. To study convergence, there is an obvious trade-off between the level of detail—which improves the match between output and price statistics—and a broad country coverage—few countries report statistics at a detailed level over an extended period. Hooper (1996) maps 101 final expenditure basic headings into five broadly defined manufacturing sectors; Pilat (1996) maps 220 basic headings into 25 sectors in the OECD's STAN database. Sørensen and Schjerning (2003) limit the industries they study to total manufacturing and two sub-sectors: machinery and equipment and food, beverages, and tobacco.

The level of detail has wider importance as there is a fundamental trade-off between comparability over time in each country and across countries in one year. As soon as an industry produces more than a single product, a price index has to be constructed which involves aggregating and weighting. Price deflators use domestic weights to make bilateral comparisons, i.e. between two years. Transitivity is not necessary and a Fisher index number, the geometric mean of indices using expenditure weights in either year, is often used. Moreover, compositional changes are likely to be limited, making the results fairly insensitive to the weighting scheme.

A similar approach is possible for PPP, but it will lead to intransitive cross-country price comparisons (see below). Moreover, PPP is likely to be much more sensitive to the weighting scheme as expenditure patterns differ between countries. It is well known, see Rao (2001), that extrapolating a country's PPP using its price evolution relative to the benchmark country—which relies only on its own weights—will miss its next period PPP—which also depends on expenditure shares in other countries. One could use only the own country's weights to construct PPP, but this is unappealing as it makes the resulting PPP estimates even less suitable for multilateral comparisons. Working at a more disaggregate industry level has the dual advantage of leaving less scope for substitution—hence limiting the cross-country differences in expenditure patterns—and one would also expect relative prices to be more similar within more narrowly defined industries.

3.2 Data and construction

The construction of sectoral PPPs has three components to it. First, the basic headings are mapped into the industrial classification of sectors. Second, prices are aggregated to the level at which output statistics are available. Third, adjustments are made for trade and indirect taxes.

The price and expenditure data on 220 basic headings for most OECD countries was obtained directly from the OECD's Statistics Department. Nominal and real value added and employment is from the STAN database (Volume 2004, release 7). I use internationally comparable input and output statistics at the 2 digit ISIC Revision 3 industry classification. A number of judgement calls have to be made to perform the mapping from basic headings to the ISIC classification. I experimented with different criteria yielding largely similar results.[11]

To calculate a single price index for each industry, basic heading categories are aggregated using expenditure shares as weights. Table 1 compares results for country-specific weights, producing the spatial equivalent of a Paasche index, for U.S. weights, producing a Laspeyres index, and a geometric average of these two indices, a bilateral Fisher index. The latter will be used in the productivity calculations.[12] Note that the Fisher indices are not transitive and most suitable for bilateral comparisons. As a result, all comparisons are explicitly relative to the U.S. Hill (1999) and Rao and Timmer (2003) construct conversion factors more suitable for multilateral comparisons. In our application, the U.S. is the productivity leader in the majority of industries. Convergence results are implicitly relative to the U.S. anyway.

The expenditure PPPs have to be adjusted for differences in indirect taxes or subsidies, as these are excluded from the output statistics. The adjustment for country i follows Pilat

[11]A complete list of the mapping is available upon request. Three basic headings were omitted as they could not be matched to any specific industry: 1182022 "Other personal goods and effect", 1431011 "other products" (the very last, catch-all category), 1500000 "change in stocks". Two other basic headings had to be omitted as they capture purchases abroad: 1191011 and 1600000. Consumption of fixed capital by hospitals, nonprofit institutions, and educational institutions are included in the sector where they sell their services. Implicitly this assumes that the cost of these expenditures will be passed on to consumers in the price of their services.

[12]One can also use a geometric average of the U.S. and country-specific weights, as in Hooper and Larin (1989). Results are virtually indistinguishable. This is consistent with recent results in Rao and Timmer (2003). They investigate the sensitivity to different weighting schemes in aggregating unit value ratios and find that the main impact is at the product level, not the "branch level" (comparable to basic headings).

(1996):

$$PPP^{i}_{\text{net}} \;=\; PPP^{i}_{\text{expenditure}} \Big/ \Big(\frac{1+\left(\frac{\text{Tax–Subsidy}}{\text{Production}}\right)_i}{1+\left(\frac{\text{Tax–Subsidy}}{\text{Production}}\right)_{USA}} \Big). \tag{5}$$

Gross expenditure prices are divided by the relative net tax difference with the U.S. The observed indirect tax ratios are taken from the ISDB data set, produced by the OECD, and vary by country, industry, and year.[13]

Because some production is exported and some expenditure is imported, expenditure prices are adjusted for trade to mirror more closely prices fetched by domestic producers. We follow the adjustment in Hooper (1996). The observed domestic price levels (PPP^j) are adjusted for difference with world prices (P^{World}), to the extent that the country is a net exporter or net importer:

$$PPP^{j}_{\text{adjusted}} \;=\; \frac{PPP^j + \frac{X_j - M_j}{Y_j}(P^{World} - PPP^j)}{PPP^{US} + \frac{X_{US} - M_{US}}{Y_{US}}(P^{World} - PPP^{US})}, \tag{6}$$

where the world price is obtained as a weighted average of each country's domestic price using its output share as weight. The denominator (Y_j) is the domestic production, approximated by value added multiplied by the average output-value added ratio if missing. If a country is a net exporter and its domestic price is below the world price, the adjustment will raise PPP as the domestic firms receive on balance more than the domestic consumers pay.

Ideally, adjustments should also be made for differences in retail and wholesale margins to better approximate producer prices. Unfortunately, the data is only available for the total manufacturing sector and for a limited set of countries. Hooper (1996) lists wholesale and retail margins for five countries, in addition to the U.S., based on data from the mid-1980s.[14] The same study also cites evidence from U.S. input-output tables that indicates that margins vary substantially across industries. Because information is not available at a more disaggregate sectoral classification and for the majority of countries, this adjustment is

[13]The ISDB data set was discontinued after 1998. When sectoral tax data was missing, the average tax rate over all non-missing years is used. If data was missing in all years, the tax ratio of the industry one level up in the aggregation is used.

[14]The differences are surprisingly large; margins range from 30% above to 1.5% below U.S. margins. The ranking of countries is also surprising; Japan has the lowest and France the highest distribution margin, with the United States at the upper range of the spectrum.

omitted. If country-differences are stable over time, it will not pose a problem. If differences vary over time, having only information for a single year, as in previous studies, will not help.

Statistics in Table 1 illustrate the impact of different weights and adjustments on the resulting PPP measures for the total manufacturing sector. Relative to the differences with other possible conversion factors, the impact of the different calculations is minor. The final column, with both adjustments to the geometric average of measures with country-specific weights, is the conversion factor we will use.

The compare with alternatives, the first three columns in Table 2 list the exchange rate, published (aggregate) PPP, and sectoral PPP for the total manufacturing sector in 1996. For most countries, aggregate PPP exceeded the exchange rate, suggesting that the U.S. dollar was undervalued. The sectoral PPP statistics for manufacturing were even higher, indicating that manufactured goods tend to be relatively cheap in the U.S. The last columns show the same conversion factors expressed as an index, to indicate their change over time. The depreciation of the U.S. dollar relative to most currencies overshot the change in aggregate price levels, while the prices of manufactured goods were relatively stable on average.[15]

[Table 1 approximately here]

[Table 2 approximately here]

4 Direct comparison of relative price evolutions

If you wonder whether it is really necessary to construct sectoral PPP, i.e. whether relative prices evolve differentially across countries, Figures 1 and 2 should convince you. The first figure plots the price deflator in 1996 (1985=100) for ten 2 digit ISIC manufacturing industries for three countries. The deflators are normalized in two ways: (i) by the domestic price deflator for the entire manufacturing industry and (ii) by the equivalent ratio for the U.S. The relative price increase for machinery and equipment (relative to the price increase in manufacturing) in the Netherlands was 57% higher than the comparable price increase in the U.S. The same comparisons for Canada and Japan reveal 17% and 14% larger price

[15] Van Biesebroeck (2004) contains additional statistics on unit value ratios for selected countries.

increases. At the other end of the spectrum, relative price increases for paper products were 4% higher in the U.S. than in Canada or Japan and 25% higher than in the Netherlands. For several industries, e.g. wood products, some countries see a relative price increase relative to the U.S., while others experience a relative price decrease.

The second figure shows that the differential sectoral price evolutions are not confined to these three countries. While the ratio of the relative price deflator for machinery and equipment to total manufacturing was higher in each of thirteen OECD countries than in the U.S.—all statistics are positive—the difference varies from 4% in South Korea to almost 100% in Belgium. The reverse is true for the paper, pulp, printing, and publishing industry, where the U.S. saw the largest price increase of all fourteen countries. The basic metals and fabricated metal products industry is intermediate, with changes in relative prices for most countries mirroring the price evolution in the U.S.

[Figure 1 approximately here]

[Figure 2 approximately here]

4.1 How well do expenditure-based sectoral PPP do?

In light of these important differences in the relative price evolution across countries, it seems important to assess how well the sectoral PPPs capture relative prices. The ICP regularly evaluates its estimates, most recently in United Nations (1999), but looks mainly at the accuracy of the collected data. One possibility is to compare the results with those from alternative approaches. Table 1 in Van Biesebroeck (2004) compares the sectoral expenditure PPPs with the unit value ratios for several manufacturing industries in E.U. countries, taken from O'Mahoney and van Ark (2003). The UVR estimates are invariably lower. The latter study explains this by the likely inclusion of ancillary services in the expenditure PPPs, which tend to be more expensive in the E.U. than in the U.S.

Such differences might affect convergence results even if they remain constant over time. Relative to the UVR results, productivity comparisons with sectoral PPP will overstate the U.S. productivity level and will tend to show stronger support for convergence the later the level comparison in equation (1) is carried out. Sørensen (2001) and Sørensen and Schjerning (2003) verify whether different conversion factors produce convergence results which are independent of the base year for the level comparison. Their test is a necessary condition for an appropriate conversion factor. Aggregate PPP and the sectoral PPP measures they construct for manufacturing and two sub-sectors clearly fail this test. In Section 5, I illustrate how well the sectoral PPPs I calculate perform.

The results in Sørensen and Schjerning (2003) suggest that the sectoral PPPs are simply "not good enough" and that sectoral comparisons are impossible. Most researchers comparing productivity across countries, even at the sectoral level, have done so using aggregate rather than sectoral PPP. A switch to sectoral PPP would only be warranted if they approximate relative price changes across countries better than the aggregate measures. The sensitivity of convergence results to the base year suggests that they don't.

We test explicitly which measure—aggregate or sectoral PPP—picks up most of the price changes relative to the U.S. If the majority of a country's relative price changes mirror the U.S. experience, data limitations in the construction of sectoral PPPs will introduce more noise than information. To test this, I calculate price changes relative to the U.S. for each industry in two ways: (i) from the country-specific sectoral deflators and (ii) from the change in PPP. The closer the two measures are, the better we control for changes in relative prices and the closer we will achieve base-year invariant convergence results. Verifying directly whether price changes are captured is closer to a sufficient test for conversion factors. it measures whether the equality in equation (4) holds. If it does, the usual practice of calculating real output growth using domestic deflators and only comparing productivity levels across countries once is valid.

One might assume that sectoral PPP is always superior. In theory this is the case, but data limitations introduce errors. Some errors are related to the fact that we work with prices faced by consumers, while output is deflated using measures constructed from producer prices. We make adjustments, but these are imperfect. Another source of errors relates to different weights used to aggregate prices in PPPs and deflators. This problem will be more serious for more aggregate industries and will be faced by unit value ratios calculated from producer prices as well. We do not have a formal test, because it is by construction impossible for PPP indices to maintain comparability over space, while retaining time consistency.[16] Rather, we simply check whether sectoral PPP dominates aggregate PPP.

[16] Results in Hill (1999) suggest that consistency can be improved by chain linking annual changes (three-yearly changes in the current application).

Ideally, this test should be carried out using gross output price deflators, as the expenditure-based sectoral PPPs are calculated from final good prices. We use value added price deflators for two reasons. First, a much smaller set of countries report gross output. Only 46% of all country-industry pairs for which we observe real value added also report real output. Coverage over time is also much more complete for value added than for output. Second, the measure of labor productivity in the convergence analysis is value added per worker. This measure has to be converted to a common currency and it is important to know how well sectoral PPP changes approximate the relative price changes for value added.[17]

Continuing the earlier example of Japanese PPP for sector i, changes in PPP (sectoral or aggregate) measure[18]

$$\log \frac{PPP_{it}^{¥/\$}}{PPP_{it-1}^{¥/\$}} = \log \frac{P_{it}^{¥}\big/P_{it}^{\$}}{P_{it-1}^{¥}\big/P_{it-1}^{\$}} = \log\Big(\frac{P_{it}}{P_{it-1}}\Big)^{¥} - \log\Big(\frac{P_{it}}{P_{it-1}}\Big)^{\$}. \tag{7}$$

The same measure of relative price change can be obtained from the implicit sector-specific deflation rates from the STAN database:

$$\log \frac{(\text{real VA}\big/\text{nom. VA})_{it}^{J,¥}}{(\text{real VA}\big/\text{nom. VA})_{it-1}^{J,¥}} - \log \frac{(\text{real VA}\big/\text{nom. VA})_{it}^{US,\$}}{(\text{real VA}\big/\text{nom. VA})_{it-1}^{US,\$}} = \log\Big(\frac{P_{it}}{P_{it-1}}\Big)^{¥} - \log\Big(\frac{P_{it}}{P_{it-1}}\Big)^{\$}. \tag{8}$$

The price changes in (7) and (8) are calculated from entirely different data sources, but they should measure the same relative price evolution.[19] Even if the underlying prices were identical the measures would only be exact for individual products. For industry price indices aggregation weights will differ.

[17]Where we observe both deflators, the correlation for relative price changes using the two different deflators is high: 0.865. Results with gross output deflators for a limited set of countries are in Table 3.

[18]We take the log difference of PPP. Alternatively, one can calculate percentage changes, which gives

$$\frac{PPP_{it}^{¥/\$} - PPP_{it-1}^{¥/\$}}{PPP_{it-1}^{¥/\$}} = \frac{(\frac{\Delta p_{it}}{p_{it-1}})^{¥} - (\frac{\Delta p_{it}}{p_{it-1}})^{\$}}{1 + (\frac{\Delta p_{it}}{p_{it-1}})^{\$}},$$

and the percentage price changes on the RHS can be calculated from nominal and real value added as

$$\frac{\Delta p_{it}}{p_{it-1}} = \frac{\frac{\Delta va_{it}}{va_{it-1}} - \frac{\Delta var_{it}}{var_{it-1}}}{1 + \frac{\Delta var_{it}}{var_{it-1}}}.$$

While the estimated changes differ somewhat—the log-ratio does not approximate large percentage changes well—the correlations are extremely similar to the correlations obtained using log-ratios.

[19]Average changes for both price measures are listed in the Appendix of Van Biesebroeck (2004).

The first column in Table 3 lists the correlation across countries between relative deflation rates and the change in sectoral PPP over the 1985-1996 period separately for all industries. Except for manufacturing not elsewhere classified and recycling—an industry that differs a lot by country—all correlation statistics are positive and often very high. A second statistic, in the second column, lists the number of countries (out of a maximum of 13) for which the sign of the relative price evolution is predicted similarly by both equations. Comparable statistics for aggregate PPP are in columns (3) and (4) and for gross output deflators in columns (5) and (6).

The evidence is mixed. For the first nine industries in Table 3, Agriculture to Non-metallic minerals, and for Transportation equipment and Community, social, and personal services the correlation is higher for sectoral than aggregate PPP and the sign equality holds for more countries using sectoral PPP. For this group of industries—11 of the 20 industries included—it clearly makes sense to use the disaggregate conversion factors. In the remaining nine industries, including the Total economy entry, the correlation statistics are higher for aggregate PPP, even though only six industries have more correct sign predictions using aggregate PPP. For some industries, the use of sectoral PPP will be relatively inconsequential, but for others, most notably Manufacturing, not elsewhere classified & recycling, Transportation & communication, and Financial & business services, using sectoral PPP would introduce noise.[20]

[Table 3 approximately here]

Working at a less aggregate sectoral level improves the performance of sectoral PPP. Because information is not available for all fourteen countries, results are not reported in Table 3. For example, distinguishing between the sub-sectors of Transportation and communication (the fourth last industry in Table 3) gives a clear advantage to sectoral PPP in predicting communication prices. The correlation advantage for sectoral PPP (aggregate PPP) is 0.78 (0.69) and ten (seven) of the eleven signs are predicted correctly. For the transportation sub-sector, the two conversion factors produce similar results. Similarly, for Textiles and

[20] Similar results for shorter time changes, in Van Biesebroeck (2004), are slightly less supportive for sectoral PPP. For short run changes, the information to noise ratio in sectoral PPP seems lower. The same paper also contains a limited set of results for unit value ratios. Here as well, the correlations tend to be higher for industries higher up in Table 3.

wearing apparel (excluding leather products from the fifth industry) the correlation advantage of sectoral versus aggregate PPP amounts to 0.62 versus 0.51, a lot larger than for the aggregate. Only ten countries report information for this sub-sector, but the signs on all price changes are predicted correctly with sectoral PPP, but only for four countries with aggregate PPP.

As mentioned earlier, one would expect predictions to be even more similar if gross output deflators were used instead of value added deflators. Only seven countries (including the U.S.) report this information and the comparable statistics are reported in the last two columns of Table 3. With only two exceptions (Mining and Manufacturing not elsewhere classified) the correlation statistics are higher, often a lot higher. The average correlation excluding the anomalous "not elsewhere classified" industry, is 0.81. Clearly, the sectoral PPP capture an important part of relative price changes.

The choice of weights to aggregate basic heading prices is relatively immaterial, which could be expected from the relatively similar PPP statistics in columns (1) and (2) of Table 1. The average correlation statistic is unchanged if own-weights are used instead of the average of own- and U.S.-weights which are used for the results in the first column of Table 3. The correlation with the relative change in gross output deflators is even slightly lower. It suggests that the mismatch between expenditure and producer prices is more important than compositional changes.

Another check on the accuracy of the sectoral PPPs is whether within each country the two measures for relative price changes are correlated. Aggregate PPP, by construction, ignores changes in relative prices within a country. Using aggregate PPP to compare sectoral productivity implicitly assumes that each industry experiences the same price change as the total economy or that the relative price changes for each industry follow the same pattern as in the U.S. No differential changes in relative prices are allowed.

The correlations and sign predictions in Table 4 are for relative price changes across industries, separately by country. For twelve of the thirteen countries the change in sectoral PPP is positively correlated with the relative deflation rate. The average correlation statistic is 0.14, positive but low. Only Canada has a negative correlation. Including only the Agriculture, Mining, and Manufacturing industries in the comparison, as aggregate PPP was preferred in the other industries, several correlations increase substantially, even though two more countries have negative correlation statistics, results are in the third column. The average correlation statistic rises to 0.18 on this limited set of industries, again indicating that at least part of the relative price changes are captured. In the vast majority of cases, around 75%, the direction of the relative price change predicted from sectoral PPP corresponds with the direction calculated from country-specific deflators.[21]

[Table 4 approximately here]

4.2 Discussion

Before turning to convergence results, it is useful to discuss the relative importance of different concerns regarding expenditure-based sectoral PPP. Van Biesebroeck (2004) contains an explicit statistical investigation which factors are correlated with the ratio of the correlations for sectoral and aggregate PPP in the first and third columns in Table 3. Three findings stand out.

The discrepancy between consumer and producer prices is important. The adjustment for trade, for example, is clearly imperfect. The relative success of sectoral PPP in predicting relative price changes is declining in the trade intensity of an industry. Adjustments for distribution margins, while potentially important, would not be possible for the majority of countries and the indirect tax data suggests that taxes are slightly higher than average in the U.S., contrary to expectation.

A second problem specific to the expenditure approach is the need for a mapping from expenditure categories to industrial sectors. While the sectoral PPPs are fairly robust to the criteria used to make the mapping, the price data might not contain enough information to be representative for each industry. Many service industries had especially few products allocated to them. The ability of sectoral PPP to capture relative price changes was found to be increasing in the number of products used to construct them and was significantly reduced if only a single product could be used.[22]

[21] The results for price changes over shorter time periods and using unit value ratios, in Van Biesebroeck (2004), confirm that the sectoral conversion factors manage to capture some of the cross-industry variation in relative prices.

[22] At the same time, a large standard deviation of relative prices within an industry is associated with better PPP measures. One interpretation is that observing prices over a wide range allows for a more precise estimate of the average price.

A third situation where the use of sectoral PPP might introduce more noise than information is for industries with low relative price changes. In such case, aggregate PPP will do nicely because aggregate price changes resemble the changes in the U.S. The average absolute size and standard deviation of the difference between sectoral and economy-wide deflators are both positively correlated with the relative performance of sectoral PPP in predicting relative price changes. If sectoral prices change in line with the aggregate price level, i.e. relative prices do not change, sectoral PPP does not bring much benefit. Similarly, if changes in relative prices are relatively homogeneous across countries, there is again no need for sector-specific conversion factors.

Finally, differences across countries in the extent to which improvements in product quality are controlled for is a fourth reason why changes in sectoral PPP might be imperfectly correlated with sectoral deflation rates. Statistical agencies in each country decompose nominal output changes into price and quantity changes, counting improved quality as higher quantity. Some countries account more widely for quality improvement, which are subtracted from price increases. As a result, the interpretation of sectoral deflation rates might differ by countries. Sectoral PPPs do not face the same problem, because prices of exactly the same goods are compared simultaneously in each country. The relative price at any point in time is well defined and easy to measure, as long as the same products are sold in both countries. As a result, changes in sectoral PPP can differ from observed relative sectoral price changes because they measure something else, i.e. the test is inappropriate.

Industries with most scope for quality change are sophisticated manufacturing and service industries. Exactly those where sectoral PPP performed worst in Table 3. The computer industry, in Machinery & equipment, provides the best example.[23] The average price per computer changed little over time, while quality improved substantially. The per unit price for all characteristics that consumers value—processor speed, hard drive capacity, quality of the video output—declines constantly. To account for this quality improvement, the U.S. Bureau of Labor Statistics estimates a decrease in the real price and uses this to deflate—in this case inflate—industry output. If the adjustment procedure varies by country, the sectoral deflation rates loose comparability. For example, the U.S. recently switched from a matched model approach to an adjustment based on hedonic regressions, see Pakes (2003).

[23]At a much more detailed level, the impact of price changes on international productivity comparisons has been studied for this industry in Wykoff (1995).

This impacts the relative price change obtained from sectoral deflation rates, but leaves sectoral PPP unchanged.

As an example of this phenomenon, we can look directly at price changes in Machinery & equipment. The U.S. deflator indicates that prices have declined by 28% from 1985 to 1996, while other countries record an average price increase of 19%. For example, Figure 1 shows a relative price increase of machinery relative to all goods for the Netherlands relative to the U.S. of 57%. The relative price of machinery declined by 2% in the Netherlands, while the U.S. records an astonishing 59% relative price decline, quality adjusted. Evidence for this relative increase in Dutch machinery prices is hard to detect in the price surveys that underlie the construction of PPP. Only a few products experienced an increase in price relative to the U.S.: *heaters and air conditioners, vacuum cleaners,* and *record players.* Some more products, e.g. *products of boilermaking, machinery for working wood, refrigerators,* and *television sets*, became relatively cheaper, but the price decline was smaller than for the Dutch aggregate PPP, contributing to the increase in relative price for machinery. Examples of products that saw prices relative to the U.S. decline faster than aggregate PPP abound, which works in the opposite direction of the price change suggested by industry deflators. A distinct possibility is that the U.S. goes further in making adjustment for quality improvements than other countries. The price surveys look for standardized products and do not have such a problem.

4.3 Other periods

As a robustness check, we perform the calculations reported in Table 3 for different time periods. An additional base year, 1999, is obtained using the most recent OECD data. The discontinuation of the ISDB database by the OECD makes it impossible to perform the adjustment for indirect taxes in this year, which is why we limited the comparison to the 1985–1996 period in the previous sections.

Using the price data available through ICP, it is possible to construct sectoral PPP indices for earlier years as well.[24] A number of caveats apply. The set of countries in the ICP data set varies by year. Value added or gross output information in real and nominal terms is only available continuously for 8 countries—the same set of countries is retained by Sørensen

[24]The data can be found online at http://pwt.econ.upenn.edu/Downloads/benchmark/benchmark.html.

and Schjerning (2003) in their 'group 4'.[25] Prices are available for fewer products. On average, prices are reported for 150 product groups, as opposed to 220 basic headings in the OECD data. Moreover, goods that are classified into services or more differentiated manufacturing products are notably underrepresented. Almost two thirds of ICP products are manufacturers and 42% of manufacturers are in the first category: 'Food, beverages, and tobacco'. The adjustments for trade and indirect taxes can also not be performed throughout, as data availability on trade flows is more spotty and only three countries have information on indirect tax rates in the earliest years. Nevertheless, with the ICP data we can construct additional sectoral PPPs for 1970, 1975, 1980.

Using the additional base years we perform an analysis similar as the one presented in Table 3. We calculate the correlation between sectoral price inflation relative to the U.S.—calculated as before—and changes in the sectoral PPPs. In Table 5, we report the ratio of the correlations for sectoral and aggregate PPP for four different time periods. In the first column, we look at changes over the entire 30-year period, from 1970 to 1999. In the second column, we calculate the changes separately for the three 10 year intervals and pool all observations, i.e. the correlations for each industry are now calculated on three times as many observations. This analysis is limited to only eight countries (see footnote 25). In the last two columns, we report similar results limited to the most recent decade, where the price data should be most comparable. Results in column 3 cover the entire 1990–1999 period and results in the final column of Table 5 are for changes over the three 3-year intervals within that decade.

[Table 5 approximately here]

The main message from Table 5 can be picked up from the bottom three rows, where a number of averages are reported. Over the 1970-1999 period, the correlations between relative price changes and sectoral PPP changes tend to be slightly lower than the comparable correlations for aggregate PPP, consistent with the evidence in Sørensen and Schjerning (2003). On average, the ratio is 0.96. The gap becomes larger, the average ratio falls to 0.81, if we split the period in three and look at the changes by decade (second column).

[25]These countries are: Belgium, Germany, France, Italy, Japan, the Netherlands, United States, and United Kingdom.

However, limiting attention to the first nine sectors, those for which sectoral PPP was found to be superior over the 1985–1996 period in Table 3, the conclusion is not as negative. The average correlations for sectoral PPP are slightly higher, respectively 0.97 and 0.87, and for several of these sectors the detailed measures capture relative price changes somewhat better. Over the entire 1970-1999 period, the correlations for all manufacturing sectors are almost identical for both sets of PPPs: all ratios are in the narrow 0.95–1.04 range. It seems that over such a long time horizon, the advantage of incorporating sectoral price information in the conversion factors becomes less important, while the noise that is introduced through these imperfect measures, as less adjustments can be performed for earlier years, increases.

In contrast, for the more recent and shorter 1990-1999 period, the average of the ratios across all industries are higher than unity, 1.07 over the entire decade and 1.06 for the 3-year changes, making sectoral PPPs more attractive.[26] This is, again, especially the case for the first nine sectors in Table 5, the correlation is 32% higher on average over the entire decade. Calculating the 3-year changes separately, the advantage of sectoral PPPs becomes even more pronounced: the average correlation is twice as high as for aggregate PPP.

The bottom row of Table 5 lists the average correlations between relative price and PPP changes for the sectoral conversion factors. Moving from left to right in the table, as the relative advantage of sectoral PPP increases, the similarity between relative price changes and PPP changes declines notably. In the first column, the correlation is very high (0.89) and it is relatively unimportant whether we use sectoral or aggregate PPP. Over such a long period, price changes vary much more by country than across sectors within a country and both conversion factors will do. Over a shorter time period, 1990–1999, PPP changes correspond less well to price changes, the average correlation declines to 0.42, but the advantage of using the sectoral PPP measures increase (especially for the first nine sectors). In the last column, the relation between relative price and PPP changes becomes even less tight, the average correlation is only 0.14 and the correlation is even negative for several industries, but sectoral PPPs capture at least some of the price changes and it clearly outperforms aggregate PPP.[27]

In summary, sectoral PPPs capture a nontrivial part of relative price changes. Especially

[26] To calculate these averages, we omitted the top and bottom outliers; otherwise, the average ratios would be even higher.

[27] It is worthwhile to point out that when Sørensen and Schjerning (2003) calculate productivity convergence for 14 OECD countries, limited to the 1985–1993 period, they find that the conversion factors pass their base-year invariance test. However, over the 1970–1993 period and limited to 8 countries, they do not.

for agriculture and less sophisticated industrial sectors, it dominates aggregate PPP to compare output internationally. This advantage is more pronounced over shorter time horizons and for higher frequency price changes, situations where sectoral price changes are likely to be more common. A myriad of data limitations and imperfections limits the extent to which relative price changes can be approximated. Variations in quality adjustment of price indices across countries are likely to introduce additional noise.

5 Sectoral convergence

Two types of convergence are often studied. β-convergence takes place if countries with the lowest initial (productivity) level experience the highest rate of (productivity) growth. We obtain the relevant coefficient by regressing average real productivity growth over the 1970-2000 period on the logarithm of the initial productivity level pooling all countries. σ-convergence takes place if the standard deviation of productivity levels across countries declines over time. In the figures with results, all statistics are normalized by the standard deviation in the first year. It should be clear that β-convergence is a necessary, but not a sufficient condition for σ-convergence.

Several studies use aggregate PPP to study sectoral convergence. Sørensen (2001) tests whether the results in Bernard and Jones (1996) for 14 OECD countries in six broadly defined sectors are invariant to the choice of base year for the currency conversion. He finds that in the manufacturing sector the initial productivity levels for each country relative to the U.S., and hence the convergence conclusions, are not invariant to the base year. Manufacturing sectors in different countries do seem to be converging if base years earlier than 1985 are used, while some convergence appears using more recent PPP measures. For the service sector, which accounts for more than 50% of GDP in the included OECD economies, the use of aggregate PPP did not pose the same problem.[28]

The top row of Figure 3 contains the same two graphs as in Sørensen (2001), reproduced

[28]Sørensen and Schjerning (2003) carry out a similar exercise for six base years and they add results with sectoral PPP for total manufacturing and two manufacturing sub-sectors, food, beverages and tobacco and machinery and equipment. They find the same dependence on the base year for aggregate and sectoral PPP in each manufacturing sector. Note that our results in Table 3 indicated that in the two sub-sectors included in Sørensen and Schjerning (2003) sectoral PPP did relatively poorly in capturing relative price changes.

with my data set using aggregate PPP.[29] The bottom row shows the corresponding graphs when sectoral PPP is used for currency conversions. Relative to the previous studies, the time period is extended from 1993 to 2000 and the expenditure-based sectoral PPPs are calculated differently—they are constructed from more detailed price data and several adjustments are implemented, as explained in Section 3.2.

The graphs on the left plot the β-coefficient estimate with 95% confidence bounds using four base years (1985, 1990, 1993, and 1996) to carry out the currency conversion in the comparison of initial productivity levels. If the results are base year invariant, we would find a horizontal line. A line above zero is evidence of divergence over the 1970–2000 period, below zero of convergence. The results using aggregate PPP are insignificant for early base years, which led Bernard and Jones (1996)—who used 1985—to conclude no convergence was taking place in manufacturing. The point-estimates for the last two base years are significantly below zero and suggest convergence. The downward slope indicates that aggregate PPP is inappropriate to carry out the productivity comparison, i.e. that equation (4) is violated by aggregate PPP. Using sectoral PPP instead, in the left-bottom graph, convergence is significant at the 5% significance level for each of the four base years. Moreover, the line is almost perfectly horizontal, indicating robustness to different base years.

[Figure 3 approximately here]

The graphs on the right plot the standard deviation of productivity levels across countries over time and illustrate the degree to which σ-convergence is taking place. Each base year for the currency conversion now generates a different curve. If the conversion factors were time invariant all four lines would lie on top of one another. This is largely the case in the bottom graph, using sectoral PPP, but much less so in the top graph, using aggregate PPP.

Focusing on the bottom graph, the standard deviation in the sample is trending down gradually until 1994, indicative of σ-convergence early on. From 1995 onwards, the lines bend up sharply, suggesting divergence in recent years. The dispersion in manufacturing

[29] For comparability with the corresponding graphs for sectoral PPP, I limit the calculations in the top graphs to the same four base years, even though aggregate PPP is available in each year. Sørensen (2001) contains another graph, comparing initial productivity levels calculated using different base years directly. Our results are hardly better on this graph if we move from aggregate to sectoral PPP, but it is hard to figure out what is going on because there is a line for each country. We omit this graphs here, but the interested reader will find them in Van Biesebroeck (2004).

productivity between OECD countries is approximately as large in 2000 as in 1970, but in between there was a period of greater similarity. Again, we find robust convergence results using sectoral PPP, but much less so for aggregate PPP. The results also indicate that the convergence dynamics have changed over time.

Figures 4 and 5 illustrate both types of convergence for all industries. The first ten graphs, in the top two rows, are for the ten industries that make up aggregate GDP. The next ten graphs, in the bottom two rows, are for manufacturing sub-sectors.[30] For each industry, the conversion factor that was found to be most appropriate to capture relative price changes in Section 4.1 was used.[31]

Figure 4 shows the β-convergence results in the same format as the left graphs in Figure 3. With the sole exception of Mining, each of the ten components of GDP has negative coefficient estimates that are significantly below zero, indicating that β-convergence is taking place. Not surprisingly, convergence is estimated very precisely for the total economy, but also in electricity, gas and water, which displays the strongest rate of convergence, and construction the confidence bounds are relatively tight. The robust finding in the literature of convergence in aggregate GDP per worker is thus not solely caused by countries focusing on industries they excel in. Most industries experience convergence and the increased importance of services, where convergence is particularly strong, plays a role.[32]

In most service sectors the tendency for countries with the lowest productivity levels to grow more rapidly seems stronger than in manufacturing or agriculture. It might suggest that comparative advantage plays less of a role in services or that technology in services is more comparable across countries. The substantially lower estimate for the β-convergence statistics in industries producing mostly nontradables, in the second row, relative to the industries producing mostly tradables, in the first row, seems a promising area for future research.

Moreover, most lines are virtually horizontal, indicating that the base year for the cur-

[30]I only look at labor productivity as Bernard and Jones (1996) indicate that the results for TFP are similar in the industries they study and capital stock information is available for only a fraction of the industry-country pairs.

[31]The conversion factor that yielded the highest correlation between relative price changes and PPP changes in Table 3 was used.

[32]The average employment share of transport and communication, retail and wholesale trade and hotels and restaurants, and business and financial services jumped from 0.22 in 1970 to 0.33 in 2000.

rency conversion does not matter. Most of the industries for which sectoral PPP is used—agriculture, mining, manufacturing, and community, personal, and social services—show very robust results. Only in mining, where the imperfect adjustments for international trade and indirect taxes and subsidies are likely to be important, is the point estimate noticeably higher using 1985 PPP. However, results are even less robust if aggregate PPP is used instead (results available upon request).

In most manufacturing sub-sectors, the bottom two rows in Figure 4, convergence is still taking place, but at a slower pace. In all but a few industries, convergence is still found to be taking place at the 5% significance level. The results are surprisingly invariant to base year, especially given the important changes in relative prices illustrated in Figures 1 and 2. In two sub-sectors, food, beverages and tobacco and machinery and equipment (the same two covered by Sørensen and Schjerning (2003)), convergence only appears using the last three base years, but not for 1985 PPP. It should be stressed that these are the only two out of twenty industries where the choice of base year matters! In two more industries, textiles and transport equipment, the β-convergence statistic is estimated not significantly different from zero, although it is estimated similarly using each of the four base years.

Overall, Figure 4 presents strong evidence that in the majority of industries, countries with initial low productivity levels experience more rapid productivity growth. This is somewhat unexpected, given the results in Harrigan (1999) that indicate persistent technology differences across countries (in machinery and equipment sub-sectors).

[Figure 4 approximately here]

Figure 5 shows the results for σ-convergence in the same format as the graphs on the right in Figure 3. Each line plots the annual standard deviation of labor productivity across countries, for a different base year, normalized by the standard deviation in 1970. If the results are base year invariant, the four lines should lie on top of one another. One problem is that data anomalies in a single country can throw the statistics off. Harrigan (1999), who also used the STAN database, illustrated a number of puzzling findings that are likely to indicate data errors.[33] In our case, the different evolution of σ-convergence using PPPs from

[33] For example, careful inspection of the individual data series revealed that the STAN database contains employment statistics for the Netherlands in manufacturing sub-sectors pre-1986 in hundreds of employees, while all other statistics are for single workers. It cannot be ruled out that there are more coding errors.

1985 in electricity, gas, and water, trade, and financial services entirely disappears if Belgium is deleted from the sample.

If σ-convergence is taking place, the lines should trend downward. While this is the case for some industries, most notably the total economy, the first 24 years for manufacturing, metals and fabricated metal products, trade and financial services, the pattern is by no means universal. For construction and community, personal, and social services we find initial productivity divergence, which changes to convergence in the last part of the sample period. Divergence is unambiguous for mining. While the lines for most industries follow a similar pattern over time, they sometimes diverge for at least one base year. The patterns are clearly not as invariance to the base year as the β-convergence results. Still, agriculture and transport and telecommunication are the only two industries were the σ-convergence conclusions are clearly dependent on the base year. Using 1993 or 1996 PPP there is clear convergence, while no change in dispersion is apparent using 1985 or 1990 PPP.

The graphs for the manufacturing sub-sectors are more ambiguous. Clearly, the lines for different base years trace out different patterns for many industries. One finding that is independent of the base year, is the initial convergence followed by divergence towards the end of the sample period in several manufacturing sub-sectors, which replicates the pattern for total manufacturing in Figure 3. There is a tendency for industries that displayed the highest rate of β-convergence to show σ-convergence as well. As expected, industries with β-convergence results that were entirely invariant to the base year, have their lines in Figure 5 closest together.

An additional problem for the standard deviation calculations that underly the measure of σ-convergence is the different weights used to construct sectoral PPP in different countries. We used the average of the expenditure weights in the U.S. and in the respective country, which produces nontransitive PPP indices. While adequate for β-convergence, as the U.S. is the implicit productivity benchmark in each industry, it is less appropriate to study σ-convergence. The OECD uses the EKS (Eltetö-Köves-Szulc) method to ensure overall transitivity in its published aggregate PPP statistics.[34] This partly explains the greater volatility in standard deviations for the manufacturing sub-sectors, which are more likely to use sectoral than aggregate PPP.

[34] The EKS method uses each of the countries in the sample as a bridge to construct a PPP index between each country and the benchmark, the U.S. The geometric mean of all these indices is the final PPP estimate.

Finally, some industries experienced β- but not σ-convergence, most notably transport and telecommunication. The simple explanation is that for these industries some productivity laggards leapfrog the U.S. and the overall dispersion remains similar, even though low productivity countries grow more rapidly. For the total economy, the previous literature has not shown such conflicting conclusions for both convergence measures because the U.S. remained the productivity leader throughout.

[Figure 5 approximately here]

6 Conclusions

Relative prices evolve differently by country and one should account for this when studying sectoral convergence. We show that a nontrivial part of the relative price changes are accounted for by the adjusted expenditure-based sectoral PPP indices. In 11 of the 20 industries—agriculture and mostly 'industrial' sectors—sectoral PPP approximated cross-country differences in relative price evolutions better than aggregate PPP over the benchmark 1985–1996 period. For most service industries, however, changes in aggregate PPP provide a better approximation to relative price changes. Results also indicate that the advantage of sectoral PPP over aggregate PPP increases for shorter time horizons, even though sectoral price changes can be less well approximated.

We can draw two conclusions from Figures 3, 4 and 5. First, converting total manufacturing output using sectoral PPP leads to convergence conclusions which are independent of the base year used for PPP. For most industries that are investigated, using the most appropriate conversion factor will achieve the same feat. Results still vary somewhat by base year—β-convergence results are notably more robust than σ-convergence results—but with few exceptions not enough to affect the conclusions.

Second, labor productivity in total manufacturing for fourteen OECD countries has converged in the first two decades of the 1970-2000 period, but this trend has been reversed in the final decade. β-convergence conclusions are the same in every sector: initial productivity laggards enjoy higher average productivity growth. σ-convergence results are less uniform. The strong downward trend in standard deviation for the total economy or for manufacturing between 1970 and 1994 is not replicated in most industries.

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Figure 1: Relative deflation rates for three countries across industries (1985-1996)

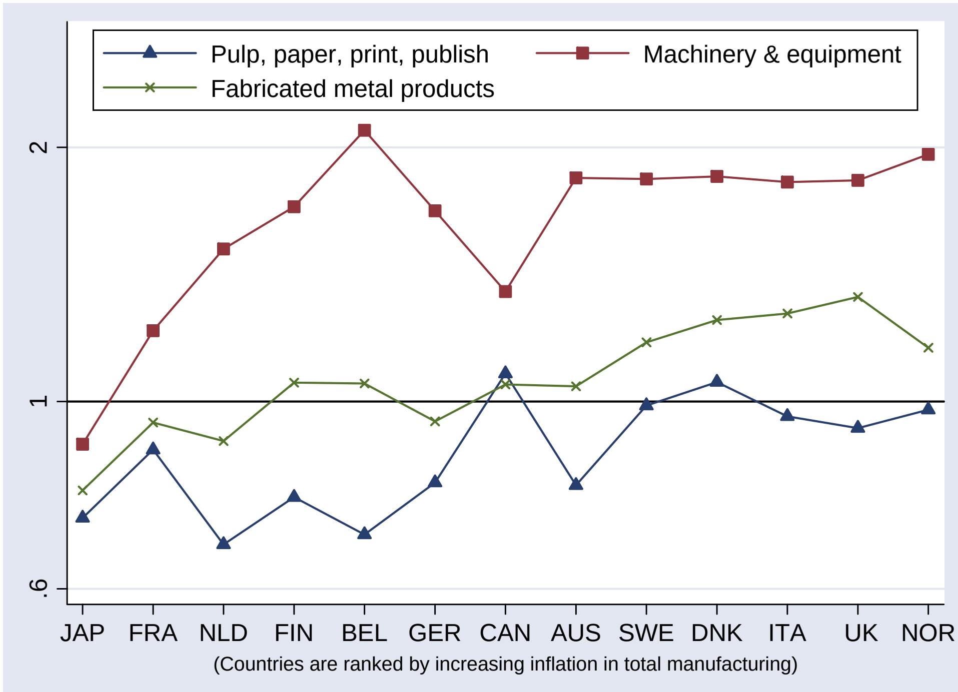


Figure 2: Relative deflation rates for three industries across countries (1985-1996)

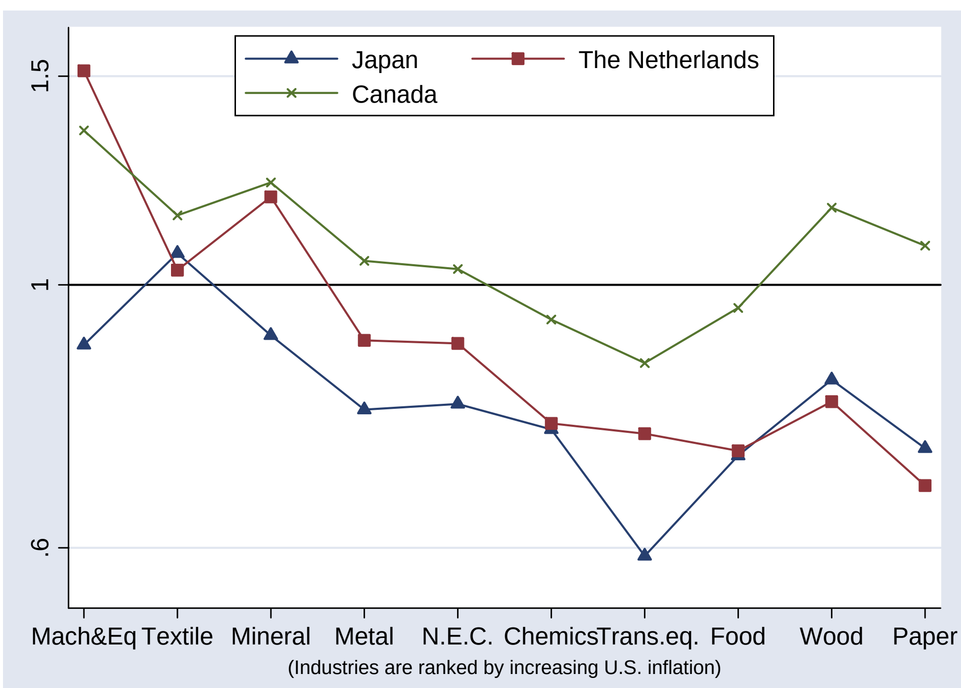
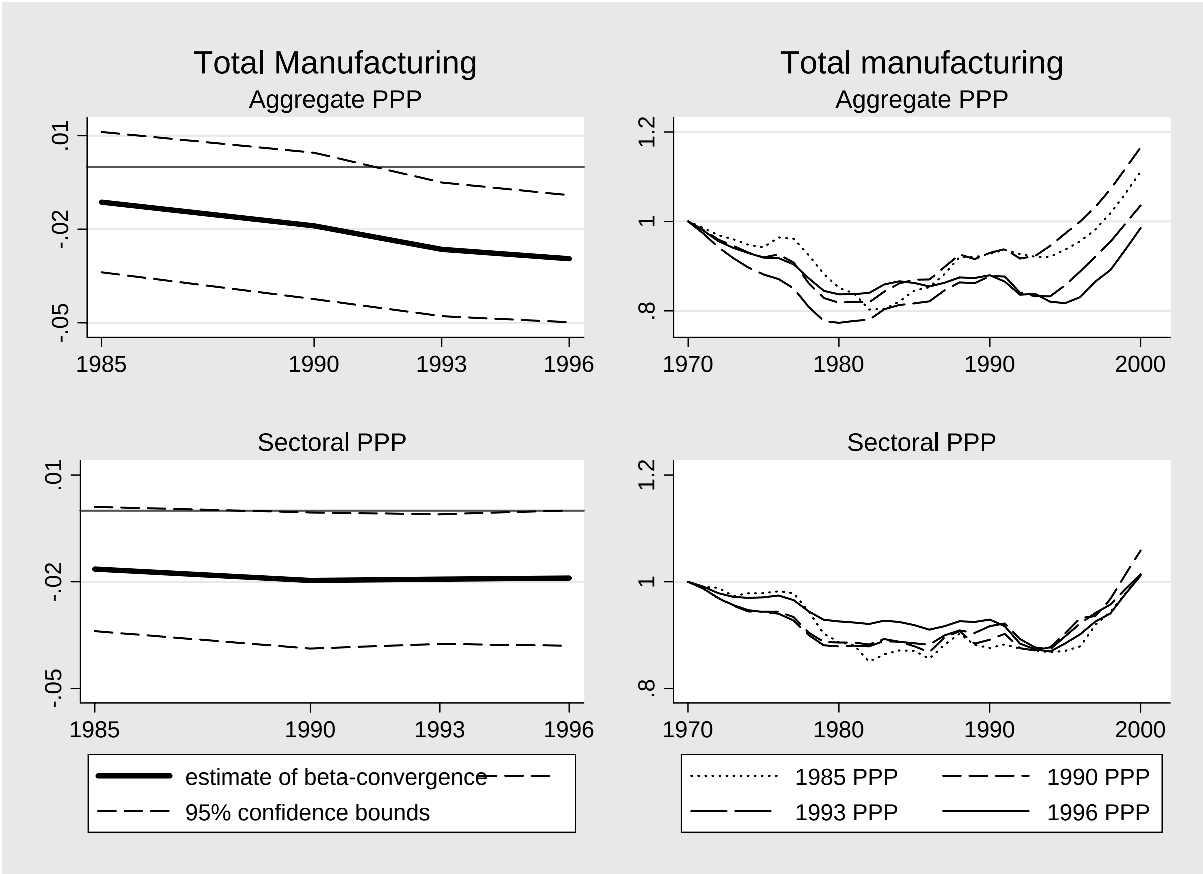


Figure 3: Two convergence tests for the manufacturing sector



Note: The graphs on the left plot four coefficient estimates with 95% confidence bounds—one using each of the four base years—on the initial productivity level in a regression with average productivity growth over 1970–2000 as dependent variable. (β-convergence)

The graphs on the right plot the standard deviation of the productivity level across all countries in the sample over time, normalized by the standard deviation in 1970. For each base year for the currency conversion there is a different line. (σ-convergence)

Graphs at the top use aggregate PPP to convert currencies, those at the bottom sectoral PPP.

Figure 4: β-convergence at the sectoral level

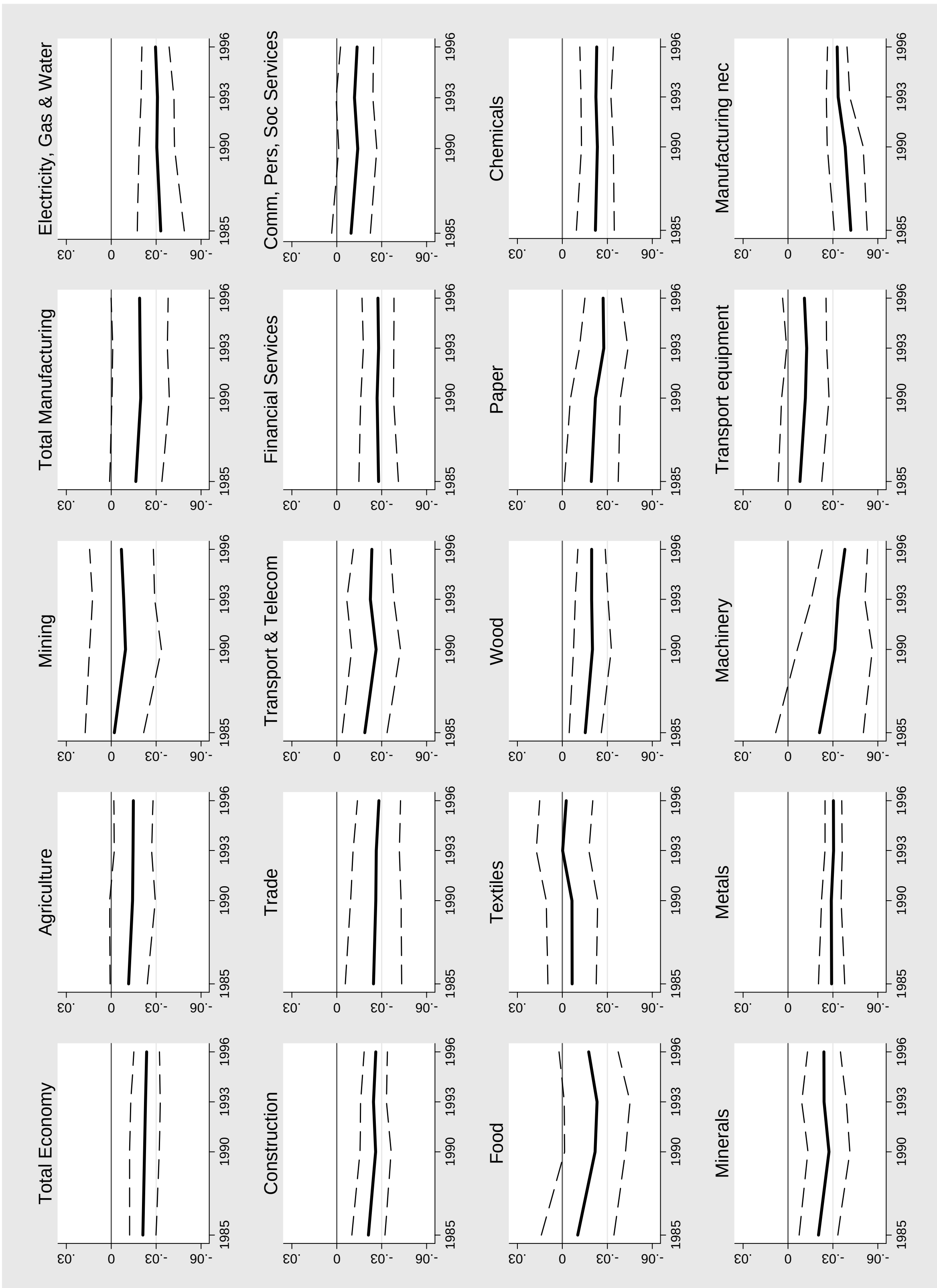


Figure 5: σ-convergence at the sectoral level

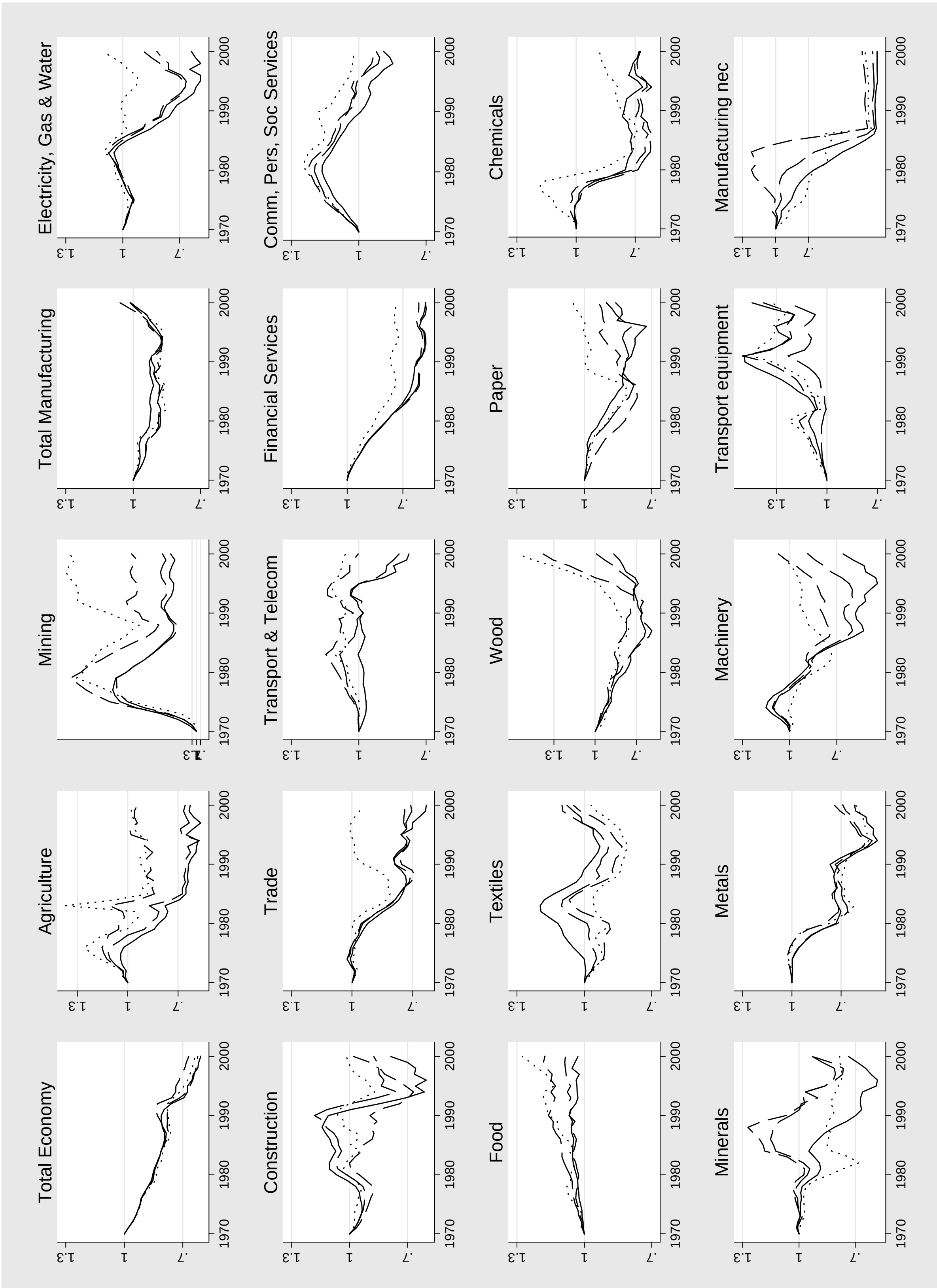


Table 1: Construction of sectoral PPP for manufacturing (1996)

	country weights	US weights	average	tax adjusted	trade adjusted	both adjusted
Australia	1.59	1.62	1.60	1.52	1.67	1.58
Belgium	1.07	1.08	1.07	1.09	1.09	1.11
Canada	1.40	1.37	1.38	1.41	1.39	1.41
Denmark	9.92	10.08	10.00	9.09	9.70	8.82
Finland	1.30	1.32	1.31	1.37	1.30	1.35
France	1.12	1.14	1.13	1.09	1.14	1.10
Germany	1.07	1.11	1.09	1.04	1.11	1.06
Italy	1.03	1.06	1.05	1.07	1.07	1.09
Japan	183.0	183.8	183.4	173.5	175.9	166.4
Netherlands	1.02	1.07	1.04	1.03	1.06	1.06
Norway	10.98	11.33	11.15	11.88	12.77	13.61
Sweden	11.04	11.19	11.12	11.50	10.01	10.35
U. K.	0.81	0.81	0.81	0.75	0.80	0.74

Own calculations; for all countries currently in the euro zone, PPPs and exchange rate have been expressed in euros.

Table 2: Levels and changes in currency conversion factors for manufacturing (1996)

	Levels: 1996			Index: 1996 (1985=100)		
	ER[1]	PPP[1]	Sectoral PPP[2]	ER[1]	PPP[1]	Sectoral PPP[2]
Australia	1.28	1.30	1.58	89	110	129
Belgium[3]	0.77	0.91	1.11	52	91	86
Canada	1.36	1.19	1.41	100	93	103
Denmark	5.80	8.33	8.82	55	91	83
Finland[3]	0.77	0.99	1.35	74	101	102
France[3]	0.78	1.00	1.10	57	99	94
Germany[3]	0.77	1.04	1.06	51	91	86
Italy[3]	0.80	0.82	1.09	81	130	126
Japan	108.8	166.0	166.4	46	76	73
Netherlands[3]	0.77	0.93	1.06	51	82	83
Norway	6.45	9.11	13.61	75	95	101
Sweden	6.71	9.68	10.35	78	121	109
U. K.	0.64	0.64	0.74	82	117	126

[1] Exchange rates and aggregate PPP are taken from the OECD web site;

[2] own calculations;

[3] For all countries currently in the euro zone, PPPs and exchange rate have been expressed in euros.

Table 3: Correlations across countries between changes in PPP and relative prices (1985-96)

Industry	Sectoral PPP (VA deflator)		Aggregate PPP (VA deflator)		Sectoral PPP[1] (gross output)	
	corr.	= sign	corr.	= sign	corr.	= sign
Agriculture	0.70	12	0.66	9	0.83	6
Mining	0.53	10	0.32	9	0.45	4*
Total manufacturing	0.75	10	0.66	8	0.93	6
Food, beverages, tobacco	0.63	10	0.60	9	0.91	4
Textiles, wearing apparel, leather	0.65	13	0.63	6	0.74	5
Wood & cork	0.42	12	0.14	7	0.85	4*
Pulp, paper, printing, publishing	0.54	9	0.47	6	0.81	5*
Chemical & plastic products	0.64	12	0.53	10	0.87	6
Non-metallic minerals	0.75	7	0.64	6	0.83	3
Basic & fabricated metals	0.45	10	0.75	9	0.60	3*
Machinery & equipment	0.43	5	0.53	6	0.87	3*
Transport equipment	0.71	10	0.57	8	0.95	6
Manufacturing NEC & recycling	-0.06	8	0.38	7	-0.24	3*
Electricity, gas & water supply	0.56	11	0.65	8	0.69	6
Construction	0.37	6	0.54	10	0.83	6
Wholesale & retail; Rest. & Hotels	0.67	7	0.79	9	0.95	5
Transport & communication	0.42	8	0.67	9		
Financial & business services	0.25	5	0.96	10		
Comm., soc. & pers. services	0.92	12	0.89	11		
Total economy	0.88	11	0.96	12		

The "corr." statistics indicate the correlation across countries between relative price changes calculated in two ways. The first way is to difference the change in sectoral deflator for each country with the change in the U.S. deflator, equation (8). The first four columns use value added deflators and the last two columns gross output deflators. The second way is to calculate the change in PPP, equation (7), using sectoral PPP in the first two and last two columns and aggregate PPP in the middle columns. The statistics in the "= sign" column indicate how many of the 13 countries have the same sign on the two different estimates for the relative price evolution.

[1] Gross output deflators are only available for six countries (five if the statistic is starred *)

Table 4: Correlations across industries between changes in PPP and relative prices (1985-96)

	All 20 sectors from Table 3		First 13 Sectors from Table 3 (Agriculture, mining, manufacturing)	
	corr.	= sign	corr.	= sign
Australia	0.22	13	0.63	10
Belgium	0.14	14	0.27	9
Canada	-0.06	13	-0.35	7
Denmark	0.08	8	-0.13	6
Finland	0.28	13	0.50	13
France	0.06	12	0.17	9
Germany	0.14	14	0.10	9
Italy	0.14	18	0.32	12
Japan	0.06	19	-0.01	12
Netherlands	0.17	18	0.09	11
Norway	0.14	14	0.22	10
Sweden	0.21	17	0.18	11
U. K.	0.21	15	0.28	10
average	0.14	14.5	0.18	9.8

Relative price changes are calculated using the same two approaches as in Table 3, but now the correlations and sign equalities are calculated across industries, separately by country. All statistics use value added deflators and sectoral PPP, but the sample of industries is limited in the last two columns.

Table 5: Ratio of correlations between sectoral and aggregate PPP for different periods

Industry	1970-1999	1970-1980, 1980-1990, 1990-1999	1990-1999	1990-1993, 1993-1996, 1996-1999
Agriculture	1.01	1.28	1.18	(a)
Mining	0.87	1.44	1.50	2.53
Total manufacturing	0.99	0.93	1.35	1.21
Food, beverages, tobacco	1.00	0.83	1.76	(b)
Textiles, wearing apparel, leather	0.95	0.60	1.27	5.82
Wood & cork	1.01	0.92	(b)	(a,b)
Pulp, paper, printing, publishing	1.00	0.48	1.29	0.83
Chemical & plastic products	0.96	1.01	1.92	0.81
Non-metallic minerals	0.96	0.36	1.11	0.91
Basic & fabricated metals	1.00	1.19	0.33	(a)
Machinery & equipment	1.03	0.78	1.12	1.30
Transport equipment	1.04	0.38	0.19	(a)
Manufacturing NEC & recycling	0.96	0.91	1.35	(a)
Electricity, gas & water supply	0.72	0.73	1.05	0.64
Construction	0.92	0.91	22.14	1.61
Wholesale & retail; Rest. & Hotels	0.89	0.59	0.59	0.25
Transport & communication	1.03	0.53	1.31	0.66
Financial & business services	0.86	0.51	0.10	(a)
Comm., soc. & pers. services	1.00	0.96	0.79	0.46
Total economy	1.00	0.96	0.99	0.73
Average ratio	0.96	0.81	1.07 (c)	1.06 (d)
Average ratio for first nine sectors	0.97	0.87	1.42	2.02
Average correlation for sectoral PPP	0.89	0.59	0.42	0.14

Notes: Each statistic represents the ratio of two correlation statistics. In the numerator is the correlation between the change in sectoral PPP and the sectoral price inflation relative to the U.S. (as calculated from industry deflators) and in the denominator is the comparable correlation for aggregate PPP changes.

(a) sectoral PPP is negatively correlated with relative price changes; (b) correlation is negative for aggregate PPP; (c) excluding the two outliers: transportation equipment and construction; (d) excluding two outliers: textiles and wholesale & retail trade.