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World Productivity: 1996 - 2014*

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Abstract

We account for the sources of world productivity growth, using data for more than 36 industries and 40 major economies from 1996 to 2014, explicitly taking into account changes in the misallocation of resources in labor, capital, and product markets. Productivity growth in advanced economies slowed but emerging markets grew more quickly which kept global productivity growth relatively constant until around 2010. After that, productivity growth in all major regions slowed. Much of the volatility in world productivity growth reflects shifts in the misallocation of labor across countries and industries. Using new data on PPP-based value-added measures by country and industry, we show that about a third of these shifts is due to employment growing in countries, most notably China and India, that benefit from an international cost advantage. Markups are large and rising and impact the imputed misalloction of capital. However, they have little effect on the country-industry technology contribution to global productivity.

Keywords: Growth accounting, misallocation, productivity, purchasing power parity, world economy.

JEL codes: F43, O47, O50.

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1 Introduction

We account for world productivity growth from 1996-2014 by combining data on more than 36 industries and 40 countries. World productivity is a concept that is often discussed in models of economic growth and innovation (Caselli & Coleman, 2006) in the context of a world technology frontier. But few studies formally account for world productivity growth. In this paper, we use new global growth-accounting techniques and datasets to decompose world GDP growth into parts driven by technology, labor, and capital—and, importantly, into changes in distortions in product, labor, and capital markets.

Our results provide a clear narrative regarding global productivity in recent decades. First, world productivity growth—measured as either Average Labor Productivity (ALP) or Total Factor Productivity (TFP)—is highly volatile from year to year and even over multi-year periods. Second, despite this volatility, the contribution of underlying productivity growth at a country-industry level (that is, the weighted average of productivity growth across the 36 industries in each of the 40 or so countries, for a total of some 1,440 country-industries) is relatively constant until the Great Recession. Since the Great Recession, growth in country-industry productivity (as well as in overall world productivity) has been markedly slower. Third, the major source of volatility in world productivity reflects shifts in the misallocation of labor across countries. This shifting misallocation is not only a source of year-to-year volatility, but is, on average, a drag of about half a percentage point per year on world productivity growth. The reason, as we discuss, is that hours typically grow faster in low-wage/low-productivity countries.

To reach these conclusions, we make three methodological contributions. First, we apply a new growth-accounting decomposition that isolates distortions in product, labor, and capital markets. Second, to implement this decomposition, we use the World Input-Output Database (WIOD) as a global growth accounting database. For the 2016 vintage of the WIOD database, we augment the existing dataset with new data on capital services for industries across countries. Third, to allow for output distortions in the decomposition, we extend recent work by Barkai (2019) and Karabarbounis & Neiman (2018) to the world. Specifically, we estimate (rising) economic profits and (sizeable) markups of price over marginal cost across countries and industries. Interestingly, though profits and markups are quantitatively important—with both labor and capital shares of output falling—the broad narrative about global productivity is robust to whether we control for this source of distortion, or not. That is, these estimates, though sizeable, do not drive our key takeaways.

The global growth accounting method that we apply builds on three strands of literature. The first focuses on cross-country productivity levels using economy-wide data (Conference Board, 2015; Feenstra *et al.* , 2015). Because these studies do not include industry-level data, they do not provide an estimate of the industry origins of world productivity growth. Moreover, they also do not formally account for reallocation of resources across countries, which turns out to be quantitatively important in the data.

The second strand of literature, based on the methodology pioneered by Domar (1962), Hulten (1978), and Jorgenson *et al.* (1987), consists of studies of productivity growth using industry-level data.[1] These studies do analyze the industry-origins of productivity growth and the importance of the reallocation of production factors, but only at the country level or for a few countries.

The growth-accounting methods in this second strand of literature account for distortions in labor and capital markets, but not in output markets. As a result, they show how to aggregate country-industry TFP growth, regardless of whether country-industry TFP growth represents changes in technology. Under neoclassical assumptions of perfect competition, these TFP changes do, in fact, represent technology changes. However, in the presence of markups of price over marginal cost, TFP changes are not technology changes.

The third strand of literature we follow corrects TFP changes for markups in order to measure technology change at a country-industry level. This literature goes back at least to Hall (1986). Most closely, we follow Basu & Fernald (2002) and related literature in considering productivity aggregation in an economy with distortions in product, capital, and labor markets. Baqaee & Farhi (2019b) is a recent contribution to this literature. We develop a novel version of this accounting that isolates the terms of interest.

Specifically, we start from a decomposition of world GDP growth, measured on the production side, that is similar to that in Jorgenson *et al.* (1987). We then extend it to the case with markups, along the lines of Basu & Fernald (1997) and Basu & Fernald (2002). Our methodological

[1] Among the many studies in this literature are Byrne *et al.* (2016) and Oliner & Sichel (2000) for the United States, Xu (2011) for China, Das *et al.* (2016) for India, and Rao & van Ark (2013) for Europe.

contribution is that we provide a normative interpretation of terms associated with inefficiency of the allocation of resources. In particular, our decomposition isolates terms that represent changes in the misallocation of global productive resources due to distortions in product, capital, and labor markets.[2]

The data we use are two vintages (2013 and 2016) of the WIOD, described in Timmer (2012) and Timmer *et al.* (2015). These data cover input-output and productivity data for more than 40 countries and 36 industries from 1996-2014. These countries cover about 80 percent of World GDP measured in dollars over the years in the sample. Unfortunately, industry capital services are missing from the 2016 vintage of the data. We address this shortcoming by constructing the missing capital services data. We also estimate rates of pure economic profits and (under the assumption of constant returns to scale) markups for all countries and industries.

Our main takeaways—volatile world productivity, relatively smooth country-industry productivity, and a sizeable role for changes in labor misallocation—are robust to the measurement assumptions we make. They hold for ALP, for TFP calculated under the Solow assumption of perfect competition (price equals marginal cost), and for TFP calculated using our estimated markup estimates.

The relative constancy of productivity at a country-industry level until the Great Recession masks a marked change in the regional composition of this part of world productivity growth. Consistent with other evidence, our results reveal a slowdown in growth in ALP and TFP for advanced countries starting in the second half of the 2000s, prior to the Great Recession.[3] At a global level, this slowdown is offset, however, by an acceleration of productivity growth in emerging economies, most notably India and China. After 2007 (for TFP) or 2010 (for labor productivity), the productivity slowdown is more widespread.

In all cases, the bulk of the year-to-year volatility reflects shifts in the misallocation of capital and, especially, labor in the world economy.[4] The contribution of the actual underlying country-

[2]The decomposition is also closely related to Hsieh & Klenow (2009). Because we use observed equilibrium outcomes, we can look at changes in misallocation from year to year, starting from the distorted equilibrium. In the absence of a structural model, we cannot do counterfactuals the way Hsieh & Klenow (2009) can.

[3]See, for example, Fernald (2015), ECB (2017), and OECD (2017a).

[4]Country-level and regional studies that find a large role for the reallocation of capital and/or labor include (e.g Oliner & Sichel, 2000) for the United States, Wu (2016) for China and Hofman *et al.* (2016) for Latin America.

industry level productivity growth rates to world productivity growth is relatively constant over time prior to the Great Recession.

When we do not allow for markups of price over marginal cost, our growth accounting method yields substantial changes over time in the misallocation of capital. The bulk of this is across industries *within* countries rather than *across* countries; that is, within countries, capital input grows faster in industries with a higher apparent internal rate of return. However, after accounting for markups, the implied changes in the misallocation of capital over time are very small, since the high internal rate of return to capital is reapportioned to pure economic profits. Over time, the misallocation of resources due to markups declines, which adds about half a percentage point per year to world GDP growth. This reflects that output grows disproportionately in sectors with high markups—that is, where output is more distorted. This markup distortion leads to an undersupply, so reducing this distortion raises world GDP. Interestingly, the inclusion of markups has little effect on the country-industry contribution of technology to global productivity.

The outsized role we find for world productivity growth from fluctuations in the misallocation of labor hinges on the assumption that relative dollar-denominated wages are equal to relative marginal productivity levels of labor. In order to drop this assumption we extend data from Inklaar & Timmer (2014) and construct Purchasing Power Parity (PPP) data at the country-industry level for all countries, industries, and years in our sample. These PPP data allow us to measure relative productivity levels directly, rather than having to infer them from factor prices.

With this in mind, we generalize the growth accounting methods we use to take into account deviations from PPP. This enables us to split our measured misallocation of labor into a part due to economic activity shifting to countries that have a cost advantage in terms of PPP and to a part that reflects relative productivity differences.

This correction for PPP differentials accounts for only a third of the misallocation effect of labor that we quantify using dollar-based measures of world GDP. Even after this correction, misallocation of labor on net is a substantial drag on world productivity growth and contributes a lot to its volatility. This suggests that it is important to understand barriers to factor movements and distortions in labor markets when analyzing global economic performance.[5]

[5] Studies of gains from removing the barriers to factor movements across political borders usually find large effects on output and capital accumulation. For example, Klein & Ventura (2009) show that a hypothetical creation of a

2 Global growth accounting with distortions

In this section, we introduce a growth-accounting decomposition of world GDP that separates the parts of GDP growth accounted for by changes in technology, aggregate labor, and aggregate capital from the parts of GDP growth driven by changes in aggregate distortions in product, capital, and labor markets. A special case of our decomposition is where the world allocation of resources is efficient. In practice, however, we find that the world economy does not appear efficient. That is, the distortions we allow for are quantitatively important.

Our decomposition draws on a long literature, starting with Hulten (1978), that traces aggregate productivity to its industry sources. Hulten considered the case where the market allocation of resources is efficient. Jorgenson *et al.* (1987) and Basu & Fernald (2002) extend Hulten's results to cases with market imperfections, including (in the latter case) imperfect competition. Because of these imperfections, the same factor of production may have a different value of its marginal product, depending on where it is used. Our decomposition builds on this literature.

The growth-accounting decomposition we develop here combines terms that isolate particular distortions. It is important to recognize that, with distortions, there is no unique decomposition and that the one applied depends on the research question. Our aim is to isolate the importance of growth in technology, capital, and labor for world GDP growth as well as the quantitative effects on world GDP growth of distortions in product, capital, and labor markets. The specific decomposition we use here is designed to do so. We discuss how it relates to others in the literature (including a recent contribution by Baqaee & Farhi (2019a,b)).

2.1 Producer level

This sub-section discusses the implications of distortions for productivity analysis at the producer level. The next sub-section discusses aggregation in this economy.

The main focus of our analysis is on the cost-minimizing decisions of producers to purchase inputs and produce output, and on how those decisions are affected by technology, factor prices, and the distortions they face. The (world) economy is made up of n sectors, indexed by $i = 1 \dots n$.

common labor market within NAFTA results in an increase in output in North America by 10.5%.

Each sector reflects a particular country-industry combination. Producers of product i pay taxes on their choices of capital, K_i, labor, L_i, and intermediate input, M_i. The respective constant tax rates are τ_i^K, τ_i^L, and τ_i^j, where the latter is the tax rate in intermediate inputs bought from sector j. They choose factor inputs, $\left\{K_i, L_i, \{M_{i,j}\}_{j=1}^n\right\}$, to minimize their cost of production

$$\left(1+\tau_i^K\right) R_i K_i + \left(1+\tau_i^L\right) W_i L_i + \sum_j \left(1+\tau_i^j\right) P_j M_{i,j}, \tag{1}$$

subject to the constraint that they produce a given level of output

$$Y_i = Z_i F_i \left(K_i, L_i, \{M_{i,j}\}_{j=1}^n\right). \tag{2}$$

We assume that producers in sector i charge a price, P_i, that includes a potential net markup, μ_i, over marginal cost implied by the above cost-minimization problem. In other words, if MC_i is marginal cost, then $(1+\mu_i) = P_i/MC_i$.

Firms' cost-minimizing first-order conditions for capital, labor, and intermediate inputs imply

$$\begin{aligned}
(1+\mu_i)\left(1+\tau_i^K\right) R_i = P_i Z_i F_i^K \quad &, \text{where } F_i^K = \frac{\partial}{\partial K_i} F_i\left(K_i, L_i, \{M_{i,j}\}_{j=1}^n\right), \\
(1+\mu_i)\left(1+\tau_i^L\right) W_i = P_i Z_i F_i^L \quad &, \text{where } F_i^L = \frac{\partial}{\partial L_i} F_i\left(K_i, L_i, \{M_{i,j}\}_{j=1}^n\right), \\
(1+\mu_i)\left(1+\tau_i^j\right) P_j = P_i Z_i F_i^j \quad &, \text{where } F_i^j = \frac{\partial}{\partial M_{i,j}} F_i\left(K_i, L_i, \{M_{i,j}\}_{j=1}^n\right), \forall j.
\end{aligned} \tag{3}$$

These first-order conditions state that the value of the marginal products are a markup $(1+\mu_i)$ above the nominal cost of the factor to the producer. We can, equivalently, express these first-order conditions in terms of factor shares and output elasticities. For each input J in industry i, define $\tilde{s}_i^K$ as the share of cost of input J_i in total revenue (i.e., in nominal gross output). For example, for $J_i = L_i$, $\tilde{s}_i^L$ is labor's share in revenue, $\frac{\left(1+\tau_i^L\right) W_i L_i}{P_i Y_i}$.

It follows that for any factor J_i, the output elasticity is a markup over the factor's revenue share:

$$\frac{F_i^J J_i}{Y_i} = (1+\mu_i)\, \tilde{s}_i^J. \tag{4}$$

As is standard since Solow (1957), we can take the differential of the production function to express output growth, $\dot{y}_i$, as the output-elasticity-weighted growth in factor inputs. Following Hall (1990), we can then impose the cost-minimizing first-order conditions in (3) to find

$$\dot{y}_i = (1+\mu_i)\left(\tilde{s}_i^K \dot{k}_i + \tilde{s}_i^L \dot{l}_i + \sum_j \tilde{s}_i^j \dot{m}_{i,j}\right) + \dot{z}_i. \tag{5}$$

Note that if there are zero profits, then payments to factors of production exhaust revenue and the factor shares sum to one. The factor shares sum to less than one if there are pure economic profits.

Given data on factor shares and growth in inputs and output, any assumed markup μ_i implies a value for the residual measure of technology growth $\dot{z}_i$. In this sense, equation (5) can be viewed as an identity that relates inputs, output, markups, and technology. Of course, $\dot{z}_i$ only measures actual technology if the assumptions are correct.

As an example, consider the Solow residual. If we assume constant returns and perfect competition ($\mu_i = 0$), then the factor shares sum to one and equation (5) defines $\dot{z}_i$ as the standard Solow residual. It can be calculated from the data even if markups and pure economic profits are *not* zero. In that case, of course, it is no longer (in general) a measure of technology, so its economic interpretation is less clear.

Since aggregate output is a value-added concept, which nets out intermediate-input use, it is useful to re-express the industry expression (5) in terms of value added. The Divisia definition of industry value added is

$$\dot{v}_i = \frac{P_i Y_i}{P_i^V V_i}\left[\dot{y}_i - \sum_j \tilde{s}_i^j \dot{m}_{i,j}\right] \tag{6}$$

Value added, as Basu & Fernald (1995) point out, is like a partial Solow residual: It subtracts revenue-share-weighted growth in intermediate inputs from gross-output growth, with no adjustment for markups. It then rescales by the ratio of nominal gross output to nominal value added from the point of view of the producer, where $P_i^V V_i = P_i Y_i - \sum_j \left(1+\tau_i^j\right) P_j M_{i,j}$ (i.e., nominal gross output less payments to purchase intermediate inputs).

It will also be useful to write output growth identically as

$$\dot{y}_i \equiv \left(\frac{\mu_i}{1+\mu_i}\right)\dot{y}_i + \left(\frac{1}{1+\mu_i}\right)\dot{y}_i$$

.

Substituting this expression into (5), we find

$$\dot{y}_i = \left(\frac{\mu_i}{1+\mu_i}\right)\dot{y}_i + \left(\tilde{s}_i^K\dot{k}_i + \tilde{s}_i^L\dot{l}_i + \sum_j \tilde{s}_i^j\dot{m}_{i,j}\right) + \left(\frac{1}{1+\mu_i}\right)\dot{z}_i \tag{7}$$

We can now substitute (7) into (6) to find

$$\dot{v}_i = \frac{P_iY_i}{P_i^VV_i}\left(\frac{\mu_i}{1+\mu_i}\right)\dot{y}_i + \left(s_i^K\dot{k}_i + s_i^L\dot{l}_i\right) + \left(\frac{1}{1+\mu_i}\right)\dot{z}_i. \tag{8}$$

In this equation, s_i^K and s_i^L are payments to capital and labor, respectively, as shares of nominal value added. For example, $s_i^L = \left(1+\tau_i^L\right)W_iL_i/(P_i^VV_i)$.

The second and third terms in equation (8) show that growth in value added depends on share-weighted growth in capital and labor and technology. With imperfect competition, however, value added-growth is not, in general, simply a function of these factors. Rather, as captured in the first term on the right-hand side, imperfect competition implies that there is an extra effect of inputs (including intermediates) and technology.[6]

Note that we have made no assumptions so far about returns to scale (the sum of the output elasticities, $\sum_J \frac{F_i^J J_i}{Y_i}$).

2.2 Aggregate growth accounting

Divisia growth in aggregate real GDP is value-added-weighted growth in industry real value added:

$$\dot{v} = \sum_i s_i^V\dot{v}_i, \text{ where } s_i^V = \frac{P_i^VV_i}{PV} \text{ and } PV = \sum_i P_i^VV_i. \tag{9}$$

Substituting for industry value-added growth from equation (8) yields

$$\dot{v} = \sum_i \frac{1}{(1+\mu_i)}s_i^D\dot{z}_i + \sum_i s_i^Vs_i^K\dot{k}_i + \sum_i s_i^Vs_i^L\dot{l}_i + \sum_i s_i^D\frac{\mu_i}{(1+\mu_i)}\dot{y}_i. \tag{10}$$

[6] In the special case in which intermediate inputs and gross output are used in fixed proportions, then one can show that value-added growth does then depend just on primary input growth (with coefficients that, with markups, will exceed one). Otherwise, intermediate inputs also matter. See Basu & Fernald (1997).

In this expression, the Domar (1962) weights of sector i are given by the ratio of industry gross output to aggregate value added, i.e.,

$$s_i^D = \frac{P_i Y_i}{PV}.$$

The first term in equation (10) relates aggregate output growth to the contribution of country-industry technology shocks. Dividing the Domar weight by the gross markup, $(1+\mu_i)$ removes the effect of the markup on prices from this term, so that it values technology shocks using marginal cost rather than prices. The second and third terms relate aggregate ouptut growth to the contribution of country-industry capital and labor growth. The final term captures the "extra" value added that comes from markups and isn't already accounted for by primary inputs or by technology.

Of course, aggregate productivity is typically defined in terms of aggregate inputs. So it will be useful to add and subtract aggregate capital and labor growth. The resulting decomposition, which we will use for our analysis of world productivity, is

$$\begin{aligned} \dot{v} &= \sum_i \frac{1}{(1+\mu_i)} s_i^D \dot{z}_i + s^K \dot{k} + s^L \dot{l} \\ &+ \sum_i s_i^D \frac{\mu_i}{(1+\mu_i)} \dot{y}_i + \sum_i s_i^V s_i^K \left(\dot{k}_i - \dot{k}\right) + \sum_i s_i^V s_i^L \left(\dot{l}_i - \dot{l}\right). \end{aligned} \tag{11}$$

Here, the aggregate and sector-specific factor shares in value added equal

$$s^K = \sum_i s_i^V s_i^K, \text{ where } s_i^K = \frac{\left(1+\tau_i^K\right) R_i K_i}{P_i V_i} \text{ and } s^L = \sum_i s_i^V s_i^L, \text{ where } s_i^L = \frac{\left(1+\tau_i^L\right) W_i L_i}{P_i V_i}. \tag{12}$$

These shares include the tax wedges in factor costs. For example, for labor they measure the employer cost of employee compensation.

Equation (11) allows us to account for the sources of growth in real value added in the world economy. The three terms in the first line are the direct effect of technology and the contributions of growth of aggregate capital and labor. The terms in the second line account for how the change in the global allocation of productive resources affects world GDP growth by either alleviating or increasing distortions.

2.3 Interpreting changes in global misallocation

Because the terms in equation (11) that measure the shift in the global misallocation of resources turn out to be important in our results, we discuss each of them here. The first thing to note is that these three terms account for the impact of markup distortions, μ_i, labor-demand distortions, τ_i^L, and capital-demand distortions, τ_i^K, respectively.

Markups and product market distortions The first term on the second line of (11) captures the change in the distortions due to markups. What is important to realize is that we quantify the impact of the reallocation of resources starting from an already distorted allocation. In that case, output in sectors with high markups is undersupplied. The markup term on the second line of (11) captures that, if output grows in sectors with markups, this alleviates this distortion and thus contributes positively to world GDP growth by reducing the global misallocation of productive resources.

Labor-market distortions The final term of (11) captures changes in the misallocation of resources due to labor-market distortions, τ_i^L. In our empirical results, this term turns out to explain much of the volatility of productivity, as well as being a net drag on growth over time.

Conceptually, this term is akin to changes in spatial misallocation discussed by Hsieh & Moretti (2019). They argue that, based on productivity differences, there are too few people working in high-productivity San Francisco and New York, and too many working in less productive (and less-densely populated) U.S. regions. If, for any reason, labor input grows faster in high-productivity locations, then this source of misallocation will fall.

Globally, the same force is at work. Productivity in German car manufacturing is much higher than that in Mexico. This means that, from a global perspective, there is a misallocation of production factors and that world GDP would increase if we moved resources, including workers, from Mexican to German car manufacturing (if we could).

To see how this intuition is captured in our decomposition, suppose there are no markups ($\mu_i = 0$). Suppose also that there are no changes in country-industry technology z_i, aggregate L or K, or in the distribution of K_i: $\dot{l} = 0$, $\dot{k} = 0$, and for all i, $\dot{z}_i = 0$ and $\dot{k}_i = 0$. The only thing that changes is the distribution of L_i. In this case, from (11), aggregate value added growth is just equal to the change-in-labor-misallocation term:

$$\dot{v} = \sum_i s_i^V s_i^L \left(\dot{l}_i - \dot{l}\right) = \sum_i \left(\frac{P_i^V V_i}{PV}\right)\left(\frac{W_i L_i}{P_i^V V_i}\right)\frac{dL_i}{L_i} - \left(\frac{\sum_i W_i L_i}{PV}\right)\dot{l} \quad (13)$$
$$= \left(\frac{1}{PV}\right)\sum_i W_i dL_i.$$

Suppose there are only two producers. Given fixed aggregate L, $dL_1 = -dL_2$, so:

$$dV = \left(\frac{W_1 - W_2}{P}\right) dL_1 \quad (14)$$

Hence, aggregate value added rises if we shift resources towards the industry with the higher wage. This is intuitive from the first-order condition (3), which says that the value of the marginal product (the right-hand side of (3)) is higher if the wage is higher (the left-hand side).[7]

Capital-market distortions The next-to-last term in (11) captures how the change in misallocation of capital across countries and industries affects world GDP growth. The intuition for this capital-reallocation term is very similar to the change-in-labor-misallocation term. In particular, in an efficient allocation the composition of the world capital stock is adjusted in every period to equate the marginal product of capital across all sectors. As Hulten (1978) showed, this means that this term is zero. When this term is positive then this reflects that capital is growing disproportionately in sectors with high marginal products of capital, which reduces the misallocation of productive resources and, thus, contributes positively to world GDP growth.

Impact of deviations from PPP In practice, when one considers industries with many different types of output, the units of measurement of the marginal products of capital and labor differ. That is, in agriculture, the marginal products are measured in terms of agricultural products while in metal manufacturing they are measured in terms of metal.

To compare these marginal products across industries one needs to translate them into a common unit. This is most naturally done by using relative output prices and that is what is captured by the value added shares, s_i^V. For our global analysis of productivity, we face another choice, namely

[7] The value of the marginal product also depends on the markup, but we have accounted for that in the markup-reallocation term.

what unit to express these prices in.

For our baseline results we use U.S.-dollar-denominated prices. In that case, the misallocation terms in (11) measure the degree to which production factors disproportionately grow in industries with high dollar-denominated marginal products. The use of U.S.-dollar-denominated prices makes sense if all goods and services are tradable. In the case of our car manufacturing example, Volkswagen will focus on the dollar-denominated marginal products when it decides on where to produce Beetles that it sells on the global car market.

However, the Balassa-Samuelson (BS)-effect (Balassa, 1964; Samuelson, 1964) implies that there might be persistent deviations in relative dollar-denominated marginal products from relative physical marginal products for non-tradable goods. These differences are reflected in deviations from PPP. To take this into account, we also present a set of results in which we use PPP-dollar denominated value-added shares for s_i^V. As we discuss in the next section, this requires the use of a newly-constructed dataset with country-industry level PPP price deflators.

2.4 Discussion of alternative aggregation equations

The industry-to-aggregate relationships in Hulten (1978) and Jorgenson *et al.* (1987) are special cases of equation (11). Hulten considers the no-markup case (for all i, $\mu_i = 0$) and where all purchasers face the same input costs for capital and labor. Jorgenson *et al.* retain the the no-markup assumption, but allow purchasers to face different input prices.

Basu & Fernald (2002) extend Jorgenson *et al.* to allow for imperfect competition. Basu & Fernald and Basu *et al.* (2006) wrestled with the observation that, with imperfect competition, the effects of disaggregated technology shocks on aggregate output depend on what is held fixed. The reason is that, as the first-order conditions in (3) show, markups create a wedge between the "cost" of a factor and the value of its marginal product.[8] Indeed, the social value of the marginal product depends on the markup of the *purchasing* industry. As a result, if markups differ across industries, then the effect on aggregate output depends on how the extra output is allocated across uses. In the frictionless world of Hulten (1978), in contrast, the allocation doesn't matter because resources

[8] It is the value of the marginal product that matters, not the marginal revenue product. The reason is that aggregate output is valued using prices (marginal rates of substitution).

have the same social values wherever used.

Given this lack of uniqueness, (Basu & Fernald, 2002, p.979) chose a benchmark allocation rule for production where intermediate inputs (the share weighted average $\dot{m}_i = \sum_j \tilde{s}_i^j \dot{m}_{i,j} / \sum_j \tilde{s}_i^j$) are used in fixed proportions to output. This allocation benchmark corresponds to the typical assumption in representative-agent models with imperfect competition , e.g., Rotemberg & Woodford (1995). Of course, materials might *not* be used in fixed proportions. In that case, there is an additional aggregation term in the Basu & Fernald (2002) equation for the reallocation of intermediate inputs. However, (Basu & Fernald, 2002, p.982) note that it nevertheless has a clear economic interpretation as the change in aggregate TFP (and welfare) in the model of Basu (1995).

Given this lack of uniqueness in the aggregation, other papers have made different choices about the allocation rule. These include Petrin & Levinsohn (2013), Osotimehin (2019) and, more recently, Baqaee & Farhi (2019a,b). Baqaee & Farhi take as their benchmark for measuring aggregate technology the case where, following an industry technology shock, all uses of industry output (final expenditures and uses as intermediate inputs) expand in equal multiplicative proportions. They argue that this allocation rule is more natural in some settings.

The different decompositions in the literature can all be interpreted as accounting identities. That is, all of them are equally "correct" in an accounting sense, in that all of them describe the data perfectly. But if the benchmark assumptions are not correct, the terms might not necessarily have a clear economic interpretation.[9]

In this regard, note that the identities include the industry growth-accounting relationship (5). As we noted in discussing that equation, it can be considered an identity linking output, inputs, assumed markups, and technology; given the first three, the fourth (technology) is pinned down as a residual.

Relative to the existing literature, the decomposition in (11) does not take an explicit stand on what is being held fixed. Rather, it isolates the effects of particular distortions (markups and

[9] The Baqaee & Farhi (2019b) aggregation equation has very strong data requirements, such that the authors are not actually able to estimate all the pieces of their equation directly. In addition, their maintained assumptions include constant returns to scale. Although they argue that some sources of non-constant returns can be accommodated by their framework, the interpretation of the terms in their equation in a world with increasing returns remains unclear. In contrast, our equation, and the one in Basu & Fernald (2002) requires no assumptions at all on returns to scale. That said, when we implement the aggregation equation (11), we will impose constant returns in order to measure markups.

factor-specific taxes). Our decomposition is thus well-suited to quantify the effect of shifts in the misallocation of resources on world GDP over time. It is not suited, however, to do a *sources-of-growth* accounting that is used to split up world GDP growth in parts due to capital, labor, and technology growth. Such an accounting exercise would involve splitting up gross output growth, $\dot{y}_i$ in (11) into parts due to capital, labor, technology, and intermediate inputs.[10]

One additional difference between our analysis and that in Baqaee & Farhi (2019a,b) is that we explicitly derive our decomposition in terms of wedges in product, capital, and labor markets, rather than transforming it all in terms of markups. This turns out to be important, because the effects of the distortions in these three markets yield three separate terms in our decomposition that each coincide with terms already used in other growth accounting decompositions. Hence, our derivation helps show how the decomposition in Baqaee & Farhi (2019b) is related to conventional growth accounting results.

3 WIOD-data

For the empirical implementation of our global growth accounting method with distortions, we use Socio-Economic Accounts (SEA) data from the WIOD. The reason we use these data is that it is the only productivity dataset that covers a broad set of industries across the major world economies.[11] Two vintages of the WIOD have been released, one in 2013 and one in 2016. We calculate results using both of them.[12]

[10] As a practical matter, our decomposition has the advantage that we are able to isolate the distortion terms even when we are limited to using data on average labor productivity rather than TFP. Neither the Basu-Fernald nor Baqaee-Farhi aggregation equations easily allow this use.

[11] Other datasets, like Conference Board (2015) and Feenstra *et al.* (2015) only provide aggregate data at the country level. The closest alternative dataset is the Organization for Economic Cooperation and Development (OECD)'s STAN database (OECD, 2017b). However, it covers fewer years and countries than the WIOD data we use.

[12] We merge data from two additional sources with the WIOD: Data from Timmer *et al.* (2007) for the construction of PPP deflators and data from OECD (2017b) for capital price deflators used for the 2016 vintage of WIOD. Appendix B.2 details how we do this merge.

3.1 Comparison across vintages and with other data sources

The two vintages differ somewhat in the industries, countries, and years covered. Important for our analysis is that the years in the samples in the two vintages contain an overlapping period from 2000-2007. We use this period in the rest of the paper to compare results across vintages to make sure that there are no major qualitative differences in results due to differences in countries and industries covered as well as methodological differences in the construction of variables.

Table 1 provides a comparison of the two vintages of the WIOD that we use for our study. The top part of the table shows the difference in coverage between the vintages in terms of years, countries, and industries.

The sample of countries in the data is largely comparable across vintages. The 2016 vintage contains three more countries than the 2013, namely Norway, Switzerland, and Croatia. The economies of these countries make up a relatively small fraction of world GDP. This can be seen from the average share of world GDP covered in the data, reported in Table 1. Throughout, we aggregate our results by country into regions. These regions include the individual major world economies as well as groups of countries organized by geographical location.[13]

We present our results for major sectors of the economy, which are listed in Table B.12 in Appendix B.2. Each of these sectors are made up of ISIC industries for which the WIOD data is reported. Even though the 2016 vintage of the data contains many more industries than the 2013 vintage (see Table 1), the major sectors that we focus on are consistent over time and across vintages.

Two differences between the vintages are important to note for the interpretation of our results. First, there is a discrepancy between the two data vintages in terms of hours growth. In particular, hours growth in the 2001-2004 periods is half as much in the 2016 vintage as in the 2013 vintage. This is largely due to the different ways hours growth in China and India are constructed in the two vintages.[14] Second, the 2016 vintage does not contain data on capital price deflators. We supplement the available WIOD data and constructed such deflators using data from OECD (2017b).

For the overlapping years the two vintages of the data line up very closely in terms of aggregates.

[13]The specific regions we use are listed in Table B.11 in Appendix B.2.
[14]We discuss these differences in more detail in Appendix B.2.

Moreover, both vintages closely track world-level aggregates from the World Bank (2018).[15] Figure 1 shows that the real GDP growth pattern in the WIOD data mimics that of world GDP.[16] Both show that there is an acceleration in world GDP growth after 2000 up until the Great Recession in 2008. Global economic activity shrank in 2008, causing a dip in world GDP before accelerating again during the recovery phase of 2009-2014. The main difference is that world real GDP growth is a bit higher from 2002 than in our data because our sample of countries does not include many fast-growing emerging economies. The fact that the WIOD data show the same qualitative patterns as those from the World Bank (2018) makes us confident they capture the main economic movements at a global level.

So, our sample covers over three quarters of the global economy and the growth rate of GDP that we decompose in the rest of this paper closely resembles that of the world economy.

3.2 Implementation of world productivity growth measurement

The WIOD-SEA dataset contains measures that correspond to many of the terms in (11): Nominal and real gross output, labor inputs, and compensation. What is not directly reported, for one or both of the vintages, are measures related to capital input and markups.

Gross output and value added: Nominal gross output, P_iY_i, and the growth rate of real gross output, $\dot{y}_i$, nominal value added, $P_i^V V_i$, and the growth rate of real value added $\dot{v}_i$, are all directly reported in the data.

Labor input and compensation Hours, i.e., labor input, L_i, are included in the data for all industries and countries and the growth rate of hours, $\dot{l}_i$, can thus be directly calculated. In addition, the compensation of labor, i.e. $\left(1+\tau_i^L\right) W_i L_i$ is also reported in both vintages of the SEA accounts of the WIOD data.

Markups and payments to capital The remaining part of nominal value added, which is not paid to labor, consists of required payments to capital plus profits.[17] Denoting profits by Π_i, we can write

[15] Value added in World Bank (2018) is measured at purchaser's prices while WIOD-SEA value added is reported at basic prices. The difference is taxes on products and imports, i.e. τ_i^j in our theoretical framework. Of course, our data also do not cover all countries in the world.

[16] See Appendix B.1.1 for a comparison of nominal GDP measures.

[17] An empirical challenge in interpreting the results is that not all capital that receives compensation is measured

$$P_i^V V_i - \left(1+\tau_i^L\right) W_i L_i = R_i \left(1+\tau_i^K\right) K_i + \Pi_i. \tag{15}$$

The WIOD-SEA data are reported under the assumption that there are no pure profits. With these assumptions, payments to capital equal all of value added not paid to labor. However, for the implementation of our growth accounting equation, (11), we drop this assumption and, after imposing constant returns to scale, we construct markups for all industries and countries in our data.

In particular, direct measures of markups for the 1400 industries (in the 2013 vintage of data, where we have 35 industries in 40 countries) in our data are not available. We infer the level of markups, μ_i, in a similar manner to Barkai (2019) and Karabarbounis & Neiman (2018). Specifically, we first estimate pure economic profits, Π_i, and second, after imposing constant returns to scale, we back out a markup that is consistent with that profit rate.[18]

We discuss each of these steps in turn. First, to estimate economic profits, Π_i, we estimate a required return on capital, R_i, in a user-cost framework as in Hall & Jorgenson (1969). That allows us to calculate required payments to capital, $R_i\left(1+\tau_i^K\right)K_i$. Profits are then a residual from

in the data. As Karabarbounis & Neiman (2018) point out, what we refer to below as "profits" potentially includes payments for unmeasured capital (their Case K)—including, notably, intangible capital that is not part of the standard capital stock—as well as pure economic profits (their Case Π). Payments for unmeasured capital comprise the gross compensation that must be paid to this capital net of any unmeasured (implicit) investment in this capital. The latter represents nominal output that is, conceptually, part of aggregate value added $P_i^V V_i$ but is omitted. (For example, when the U.S. national accounts in 2013 added R&D and other new intangibles to the gross fixed capital formation statistics, nominal GDP as well as nominal gross operating surplus increased by the amount of the investment in these new intangibles; growth accounting then attributed something more than that increase in output as compensation to the new intangibles. Hence, if the accounting identity in (15) is applied to data that does not include these and other intangibles, then the right-hand side includes the implicit compensation net of the implicit investment flow.) We note that even our measures of standard capital do not include land (a non-produced capital good) or inventories. As a result, we are bound to find higher profit estimates than datasets that do include these types of capital. This is because our profit estimates include the implicit compensation for land and inventories. For comparison, Fernald (2012) attributes 12 percent of capital compensation, amounting to 3 to 4 percent of business-sector output, to land and inventories.

[18] One alternative approach, pursued by Baqaee & Farhi (2019b), would be to use direct estimates of firm-level markups, e.g. those by Loecker & Eeckhout (2017, 2018). As Traina (2018) discusses, these estimates directly pertain to the wedge between price and marginal cost and their magnitude critically hinges on what is assumed to make up variable costs for firms. In our aggregate growth accounting framework such markups would not be the right measure because they would also be non-zero in the case of fixed operating costs or entry costs in which firms' individual technology exhibits decreasing returns to scale (increasing marginal cost in variable factors) but aggregate technology exhibits constant returns to scale and the market allocation is efficient, e.g. Hopenhayn & Rogerson (1993). A second alternative approach, following Hall (1990) and Basu & Fernald (1997), estimates industry returns to scale and markups jointly, but is more data intensive than is possible with 1400 or more industries in 40 countries.

equation (15). Specifically, we assume that the nominal capital service flows equal the nominal replacement value of the capital stock (which is reported in the data) times a real user cost of capital. This real user cost consists of a nominal return on capital corrected for depreciation and capital price inflation. The details are explained in Appendix B.2. The implicit nominal return we use is the 10-yr BBB U.S. nominal corporate bond rate.[19]

Second, to back out the country-industry-specific markups from the profit estimates, we follow much of the recent literature and assume constant returns to scale at the industry level. This assumption is roughly consistent with Basu & Fernald (1997), who find that constant returns are a reasonable approximation for the typical U.S. industry. With this assumption, profits $\Pi_i = (\mu_i/(1+\mu_i))\, P_i Y_i$.[20]

Given the calculated markups, we construct TFP measures, the $\dot{z}_i$, based on equation (5). Because of the constant-returns-to-scale assumptions, this is equivalent to calculating TFP with cost shares rather than revenue shares of the factor inputs.[21]

3.3 Calculating results in four steps

The advantage of using the WIOD-SEA data is that they cover a broad set of industries for not only advanced but also for emerging economies. The disadvantage is that some variables in the data are not that reliably measured, especially for the latter group of countries.

With these data limitations in mind, we construct the decomposition in (11) in four steps. We start with a decomposition that uses the most reliably measured components first. Namely, we consider ALP growth and ignore markups. This relies only on value-added and hours growth.

To begin, recall that $\dot{v} = \sum_i s_i^V \dot{v}_i$ and, trivially, note that world labor growth, $\dot{l}$, equals $\sum_i s_i^V \dot{l}$.

[19] We assume that there are no markups in public administration and education, where value added is largely calculated as the cost of inputs. When we allow for such markups, they turn out to be negative. For the other sectors, we use the average depreciation and capital price inflation rates over the years in our sample to smooth out measurement error in these time series. Our qualitative results are similar when we use the 10-year U.S. treasury yield, e.g. Schmelzing (2017).

[20] The sum of the output elasticities is thus equal to one. From the first-order conditions (4), the sum of the elasticities is $\sum_J (1+\mu_i)\, \tilde{s}_i^J = (1+\mu_i)\, s_i^\Pi$. Rearranging yields the equation in the text.

[21] In Case K of Karabarbounis & Neiman (2018), TFP would still be mismeasured (in aggregate and at a country-industry level) because of the missing capital services as well as mismeasured factor shares. Byrne *et al.* (2016) suggest that the magnitude of the mismeasurement is likely to be fairly small. They do an experiment on U.S. data where the include a wide range of additional, speculative intangibles. For the 1996-2014 period, the resulting correction reduces aggregate TFP growth by about 0.1 percentage point per year.

Using these expressions, and subtracting and adding $\sum_i s_i^V \dot{l}_i$, we can write world ALP growth as

$$\dot{alp} = \dot{v} - \dot{l} \quad = \quad \sum_i s_i^V \dot{alp}_i + \sum_i s_i^V \left(\dot{l}_i - \dot{l} \right) \tag{16}$$

Here, the first term is the contribution of country-industry specific ALP growth. The second "reallocation" term in this expression will, in general, be nonzero if nominal value added per hour worked differs across country-industries.[22] Nominal value added per hour worked might, in turn, differ across country-industries for efficient reasons (such as differences in factor shares) or because of wedges (such as factor-price wedges). For this reason, it is useful to decompose the reallocation term into two pieces: (i) the effect of the change in misallocation of labor—as in equation (11) and Section 2.3; and (ii) the remaining reallocation of labor.

The resulting decomposition that we use is, thus:

$$\dot{alp} = \dot{v} - \dot{l} \quad = \quad \sum_i s_i^V \dot{alp}_i + \sum_i s_i^V s_i^L \left(\dot{l}_i - \dot{l} \right) + \sum_i s_i^V \left(1 - s_i^L \right) \left(\dot{l}_i - \dot{l} \right). \tag{17}$$

The second term is the effect of the change in misallocation of labor on world GDP, as in equation (11). In case of an efficient allocation of resources, this term would be zero. The final term is the remaining reallocation of labor (which might or might not be efficient).

The set of results that we present in the second step adds capital to the above decomposition but maintains the assumption of no markups. That is, it considers a version of the full TFP decomposition in (11) under the assumption of zero markups ($\mu_i = 0$). These results are useful because they directly allow for the comparison with results from other studies that use standard TFP measures calculated under the assumption of constant returns and zero markups, such as those based on Jorgenson *et al.* (1987).

In the third step, we present the full decomposition (11), including non-zero markups. This enables us to quantify the impact of changes in product-market distortions on world GDP growth. By comparing the results from this step with those from step two, we can assess how markups affect global productivity growth estimates.

[22] To see this, note that we can write the second term as $\sum_i \left(s_i^V - L_i/L \right) \dot{l}_i = \sum_i \left(\frac{L_i}{L} \right) \left(\frac{P_i^V V_i / L_i}{P^V V / L} - 1 \right) \dot{l}_i$.

In the final step of our analysis, we consider the impact of deviations from PPP on the decomposition (11). For this we construct PPP value added measures by country-industry and use them to construct value-added shares, s_i^V, in terms of 2005 PPP dollars rather than current U.S. dollars.[23] So, our final set of results implements a PPP value-added share weighted version of (11).

4 Results

We use the two WIOD vintages to construct annual estimates of each of the components of equations (11) and (17). The key takeaways from this section are that (i) world productivity growth is volatile from year to year or over multi-year periods, even though (ii) underlying country-industry productivity growth is relatively smooth; and (iii) changes in misallocation, particularly of labor across countries, explains the bulk of the high-frequency volatility in world productivity.

Before we present the growth-accounting results in the steps described in the previous section, we first discuss the value-added and factor shares that help put the subsequent results in context.

Value-added and factor shares

In some form or another, all our results based on (11) are weighted averages of growth rates across industries by country. The weights are the country-industry share in world value-added, either in current U.S. dollars or in 2005 PPP dollars. It is thus important to understand the main properties of these shares.

In terms of current U.S. dollars, the U.S. and Japan are the two largest individual economies, together covering more than 40 percent of world GDP. The share of the U.S. and Japan in world GDP has declined over the 19 years in our sample. This is mainly because of the relatively strong growth performance of China, whose value-added share increased by 10 percentage points.

There are notable differences between value-added shares by country in terms of current U.S. dollars and in terms of PPP dollars. The main difference between the PPP-based and dollar-based valued-added shares is that, due to high PPP prices in the U.S., the U.S. value-added share in U.S. dollars is much higher than in PPP dollars. China and India are the two countries whose

[23] A discussion of how these PPP measures are constructed is in the Appendix B.2.4. Because we use country-industry level PPP data there can be different degrees of deviation from PPP across industries within a country.

value-added shares increase the most when the unit of measurement is changed from current U.S. dollars to 2005 PPP dollars. Both of their shares more than double. This is consistent with the BS-effect that more productive economies tend to have "overvalued" currencies.

No matter whether we use dollar-denominated or PPP-denominated value-added shares, manufacturing, trade, and Finance, Insurance, and Real Estate (FIRE) are the sectors with the highest value-added shares. These shares do not fluctuate much across the subperiods we consider. Agriculture and manufacturing have slightly higher PPP-shares than dollar shares, while those in FIRE and business services are slightly lower. This reflects that the latter two sectors are larger in advanced economies, especially the U.S.

The other shares that matter for the decomposition in (11) are factor shares. Figure 2 plots the global factors shares from 1996-2014 for both vintages of the data. It reveals that the global labor share has declined, as documented by Karabarbounis & Neiman (2014). Most notable from the figure is how this decline in the labor share pales in comparison to the movements in the factor shares of capital and profits. Just like Barkai (2019) for the U.S., we find that the capital share in world GDP has declined substantially, i.e. by more than 10 percentage points, since 1996. The joint declines of the labor and capital shares are absorbed by an increase in the profit share. By the end of the sample, pure profits amount to nearly 20% of world GDP.

These profits are concentrated in manufacturing, trade, and FIRE. Most notably, profit rates in FIRE showed the largest increase over the sample. Markups are particularly high in manufacturing in China and in FIRE in the United States.

Although the estimated profits and markups are high, it is important to note that our main takeaways below are robust to whether or not we account for markups.

Growth-accounting results

We now turn to the growth-accounting results. As discussed, we proceed in four steps: (1) (relatively well measured) labor productivity, (2) conventional TFP, (3) markup-adjusted TFP, and (4) PPP-adjusted (conventional) TFP. Each step requires additional, stronger assumptions to construct the data. Nevertheless, the main takeaways remain remarkably consistent throughout this progression, indicating that the data assumptions do not drive the results.

For each step, we group the results by WIOD vintage and, further, into five subperiods: (*i*) the 1990's expansion, 1996-2000, (*ii*) the 2001 recession and recovery, 2001-2004, (*iii*) the mid-2000's expansion, 2005-2007, (*iv*) the Great Recession and early recovery, 2008-2010, and (*v*) the recovery from the Great Recession, 2011-2014, which is the period of the Euro crisis in many countries in our sample. The 2001-2004 and 2005-2007 periods exist in both WIOD vintages, allowing a direct comparison of results. We focus primarily on the qualitative results that both vintages have in common, rather than on the precise numbers.[24]

Step 1: World ALP growth

In this step, we implement the world ALP decomposition in (17). Before turning to the detailed data table, we begin graphically with Figure 3. The figure illustrates three key takeaways that we discuss further below—and that turn out to apply throughout the four-step analysis that follows. (For visual clarity, we show the data only from the 2016 WIOD vintage.)

First, the darker line in the figure shows the substantial volatility year-to-year (and even over multi-year periods) in world ALP growth, $\dot{v} - \dot{l}$. Second, the lighter line shows the much smoother contribution of country-industry ALP growth, $\sum_i s_i^V \dot{alp}_i$. For example, the country-industry growth rate stays relatively constant in the 2003-2007 period; and it drops much less than world ALP growth in 2009 or 2011. Algebraically, equation (17) shows that the difference between the two lines is the contribution of labor reallocation. The third takeaway, then, is that labor reallocation—most importantly, as we discuss below, changes in labor misallocation across countries—is highly volatile from year to year. Indeed, it is the main source of volatility in world ALP.[25]

Table 2 shows the detailed subperiod numbers for the two vintages. Line 1 of the table shows world GDP growth in each period. During the Great Recession period (2008-10, shown in the 2016 vintage), output grows much more slowly than in any previous period; it is followed by a sizeable recovery in 2011-14. Line 2 shows growth in world hours. Comparing the 2001-2004 and 2005-2007 periods across vintages, one can see the discrepancy in hours growth across vintages that

[24] Section B.1 of the Appendix includes the underlying details relevant for the points we make in the main text.

[25] The cyclicality of labor productivity around the Great Recession is to be expected. In addition to the reallocation effects, several channels operate at a country-industry level. These include variations in factor utilization, which cause TFP to be procyclical, and variations in the capital-labor ratio, which is a countercyclical force on labor productivity.

we discussed in Subsection 3.1. Specifically, world growth in hours in the 2016 vintage was about 1-1/4 percent lower from 2001-04 than in the 2013 vintage, but then was about 1/2 percentage point higher from 2005-07. Perhaps surprisingly, these revisions in hours are not large enough to substantially affect the key takeaways from this section.

The first key takeaway is shown in Line 3: There are sizable fluctuations in world ALP growth across the five subperiods that we distinguish. During the expansion of the late 1990's, world ALP growth was above 2 percent. It declined substantially in the early 2000's and (in both vintages) rebounded sharply in the mid-2000's. During the Great Recession (2008-10), world ALP growth retreated to under 1 percent per year. In the 2011-14 period, world ALP growth got even worse, and turned sharply negative.

Lines 4 to 8 together sum to line 3, and decompose world ALP growth into the part that that can be traced back to country-industry-specific ALP growth rates and reallocation. Line 8 shows the contribution of country-industry ALP growth rates, $\sum_i s_i^V \left(1 - s_i^L\right) \left(\dot{l}_i - \dot{l}\right)$. Lines 4-7 summarize the reallocation terms (labor misallocation and other misallocation), split up by within-country and between-country components.[26]

The second key takeaway, from line 8, is the much smoother evolution of ALP growth at a country-industry level. Indeed, growth was relatively constant at about 2 percent per year—regardless of which vintage you look at—over the first four of the five subperiods we consider. A sharp deterioration in country-industry ALP growth is apparent only in the final 2011-14 subperiod. Even there, country-industry growth remains positive, despite the sharply negative growth rate in world ALP from line 3.

The third takeaway is that the bulk of the variation in world ALP growth arises from substantial volatility in labor reallocation. Algebraically, equation (17) shows that the difference between world ALP growth and country-industry ALP growth is the contribution of labor reallocation. The combination of the fluctuations in world ALP growth and the relatively constant contribution of country-industry specific ALP growth implies that the bulk of the fluctuations in world ALP growth come from variations in the reallocation of labor across industries within countries and across countries.

[26]See Appendix A for more details on how we split misallocation term into within- and across-country components.

This is borne out by lines 4-7 of Table 2. Lines 6 and 7 show changes in the misallocation of labor, as discussed in Section 2.3. This is the growth-accounting reallocation that is related to differences in wages across countries and industries. Lines 4 and 5 show "other reallocation," where the welfare interpretation is less clear (these terms disappear in the TFP decompositions below).

What turns out to be quantitatively most important is the shifts in the misallocation of hours across countries, reported in line 7 of the Table. These shifts are, on average, a drag on world GDP growth of between around 0.4 and 0.5 percentage points. This reflects the fact that hours growth in emerging economies has typically outpaced hours growth in developed economies. The first-order conditions interpret these shifts as a reallocation of labor from high to low marginal-product-of-labor countries, as valued using measured prices. The contribution of the cross-country misallocation of labor is more negative in periods when there is a bigger wedge in hours growth between emerging and developed economies, as in 2001-2004, 2008-2010, and 2011-2014. It was slightly positive during the expansion in developed economies from 2005-2007. Note also, from line 6, that shifts in the within-country misallocation of labor contribute little to world GDP growth.

In terms of the intuition we discussed in subsection 2.3, these results capture that recessionary periods in advanced economies are quantified as an increase in the misallocation of labor because they lead to a reduction in relative hours worked in economies with higher wages and labor productivity levels. One caveat of this interpretation is that it assumes that these productivity differences are not embodied in workers, i.e., that in terms of productive potential (i.e., efficiency units) an hour worked in the United States is the same as in China.

Table 3 decomposes the fairly constant contribution of country-industry ALP growth into its regional composition. It shows that the *composition* of this component across countries has changed notably over time. In terms of the cross-country details, these results are in line with studies that document a broad productivity slowdown in industrialized countries starting in the early 2000's (Byrne *et al.* , 2016; OECD, 2017a). We find that the contribution of country-industry specific ALP growth of these countries (United States, Japan, and the United Kingdom in particular) declines in the last three periods in our sample that cover 2005-2014. The global productivity impact of this slowdown was largely offset by an increase in the contributions of country-industry specific ALP growth to world GDP growth of Brazil, Russia, India, and China (BRIC countries).

The contribution of BRIC countries' country-industry specific ALP to world productivity growth declined during 2011-2014. This, together with country-industry specific ALP growth in the United States, is the main driver of the decline in world ALP growth during that period.

What this result points out is how important it is to do growth accounting on a global scale to understand shifts in the center of gravity of global productivity growth. This is especially important during the 1996-2014 period that we consider, because of the growth performance of emerging economies in Asia.

Step 2: World TFP growth without markups

In step two, we account explicitly for capital and do the accounting with standard TFP growth. Specifically, we implement equation (11) under the assumption that markups are zero everywhere. The three key takeaways remain the same as we already saw with labor productivity: (i) World TFP is volatile, even though (ii) the weighted average of country-industry TFP is comparatively smooth; (iii) changes in labor misallocation across countries are the primary reason world TFP is more volatile than country-industry TFP .

Table 4 shows the results. This table has lines 1, 7, and 8 in common with the ALP results in Table 2; line 3 is also the same, but rescaled by s^L. Given this, our discussion here focuses on the contribution of aggregate capital growth (Line 2), world TFP growth (Line 4), the misallocation of capital (Lines 5 and 6), and country-industry specific TFP growth (Line 9).

Line 2 shows the contribution of aggregate capital growth, $\dot{k}$, to world GDP growth for the subperiods in our data. The most notable feature of this line is that there is a substantial discrepancy between the two vintages for the overlapping periods 2001-2004 and 2005-2007. This mainly reflects the lower labor share (and, hence, higher residual capital share) in the 2016 vintage, as shown in Figure 2.

Line 4 reveals that, just like world ALP growth, there are substantial fluctuations in world TFP growth across the five subperiods that we consider.

Lines 5 and 6 show that, if we do not account for markups, we find sizable effects of changes in the misallocation of capital on world GDP growth. Most of this capital-misallocation effect occurs between industries *within* countries (Line 5) rather than *across* countries (Line 6). This capital misallocation is largely due to two sectors: Trade, transportation, and utilities as well as business services. The changes in the misallocation of capital across countries account for a much smaller part of world GDP growth. The misallocation contributions in Lines 5 and 6 of Table 4 are positive, which reflects that capital grows faster in industries and countries for which the implied internal rate of return to capital (i.e., the implied marginal product of capital under the assumption of no markups) is higher.

Finally, in Line 9, we find that, just like for ALP growth, the country-industry component of TFP growth is much less volatile than world TFP growth.

Of course, as we showed earlier in this section, our estimates imply that profits make up a substantial, and increasing, fraction of world GDP. The results without markups ignore this evidence. So, in the next step we redo our decomposition, accounting for the role of markups.

Step 3: World TFP growth with markups

Tables 5 incorporates our profit and markup estimates. Perhaps surprisingly, the three main takeaways that were apparent from the previous two steps continue to hold: (i) World TFP (adjusted for markups) is volatile, (ii) country-industry TFP is relatively smooth (especially until 2007), and (iii) changes in labor misallocation across countries explains much of the volatility.

Of course, there are some notable differences when we allow for markups. Starting with the contribution of world capital to growth in line 2 of Tables 5 and 4, a substantial part of the growth contribution of aggregate capital in Table 4 is attributable to markups.

That is, when we account for markups, a portion of $(1-s^L)$ is allocated to profits rather than to the revenue share of capital, s^K. This recharacterization reduces the contribution of capital growth in Line 2 of Table 5 for all subperiods. In fact, accounting for markups reduces the measured contribution of aggregate capital growth to world GDP growth by 0.26 and 0.57 percentage points in the 2013 and 2016 vintages of the data respectively.

Not only is the contribution of capital to world GDP growth lower when we explicitly account for markups, it is also remarkably constant, with a mean of 0.78, across subperiods and vintages in our data. Moreover, the large differences across vintages in the contribution of aggregate capital growth for the periods 2001-2004 and 2005-2007 that we found in Line 2 of Table 4 almost disappear when we account for markups.

The lower contribution of aggregate capital growth to world GDP growth in Line 2 results in somewhat higher world TFP growth in Line 4 of Table 5 compared to Table 4. That said, world TFP growth remains quite volatile across subperiods, and it slows substantially after 2007.

One of the biggest differences between the results with and without markups is the implied contribution of the change in the misallocation of capital to world GDP growth, reported in Lines 5 and 6 of the respective tables. Once we account for markups, i.e. Table 5, the measured effect of changes in the misallocation of capital within countries on world GDP growth is much smaller, by almost a factor of a half. If our markup estimates are accurate, it suggests that we found spurious effects of capital misallocation in Table 4 because we misassessed the marginal products of capital by not taking into account markups. With markups, the effect of changes in the cross-country misallocation of capital on world GDP growth, i.e. Line 6 in Table 5, remains negligible.

Line 9 of Table 5 reports the impact of the shifts in markups on world GDP growth. These shifts add around half a percentage point annually to world GDP growth over the period we consider. As Basu & Fernald (2002) emphasize, this implies that gross output is growing faster in industries with higher markups and below efficient levels of output. Thus, higher output growth in these industries *reduces* the impact of distortions in product markets on world GDP and lowers the degree of misallocation in the world economy. The contribution of these shifts to world GDP growth is relatively constant and these shifts cannot explain the slowdown in world TFP growth that we saw after 2008.

Our detailed results indicate that the effect of shifts in markups on world GDP growth is mainly due to manufacturing, trade, and FIRE in China and the United States.

Finally, Line 10 of Table 5 lists the part of world GDP growth accounted for by country-industry specific TFP growth. The picture here is very similar as for the contribution of country-industry specific ALP growth in Line 8 of Table 3. Before 2008 the contribution of country-industry specific TFP growth to world productivity was relatively constant at around 1.1 percent. After that, country-industry specific TFP growth declined to near zero during global financial crisis and accelerated slightly afterwards.

It is striking that allowing for markups makes a minimal difference to line 10. Rather, the effect of markups in line 9 came, in an algebraic sense, from a reduced contribution of capital (line 2) and from changes in within-country misallocation of capital (line 5).

Just like for ALP, the relative constancy of the number reported in Line 10 of Table 5 for before 2008 masks a shift in technology growth from advanced economies to emerging economies, especially from 2005-2007. This can be seen from Table B.7, which splits Line 10 up by country.

Step 4: PPP value-added share weighted results

One of the striking takeaways from the first three steps is that changes in labor misallocation appears to explain much of the volatility in world productivity. These first three steps valued world output using current dollars. A natural question that arises is whether this volatility in fact reflects true differences in productivity, or rather the effects of exchange rates? Table 6 addresses this question by quantifying the impact of deviations from PPP on our results. It contains the decomposition of equation (11) for the case where country-industry value-added shares are measured in terms of 2005 PPP dollars rather than current U.S. dollars. The table reveals that our qualitative results are not affected much by deviations from PPP.

Line 1 of the table shows that PPP-weighted world GDP growth is larger than current dollar-weighted GDP growth. The reason for this is that PPP value-added shares in World GDP tend to be higher than dollar shares for emerging economies, which tend to grow at an above average rate.

Deviations from PPP have little impact on the contributions of aggregate factor growth of capital and labor listed in lines 2 and 3 of the table. This can be seen by comparing these lines with the same lines in Table 5.[27] As a result, the implied level of World TFP growth, reported in Line 4, is higher for the PPP-weighted case than for the dollar-weighted case.

Our results suggest that deviations from PPP do have a marked impact on the contributions of the changes in the misallocation of capital and labor, especially across countries, to World GDP growth. The impact of the cross-country misallocation of capital in Line 6 of Table 6 is large compared to that in Table 5, in which it was negligible. This potentially reflects that capital flows across the world to equate dollar-denominated returns on investment across country-industry

[27]The numbers do not match exactly since our sample changed slightly due to PPP data availability. See Table B.10 in Appendix B.2 for more details.

combinations. Deviations from PPP imply that this is inefficient because equating these dollar-denominated returns is not the same as equating physical marginal products.

For the changes in the misallocation of labor we find the opposite. Their impact on World GDP growth is reduced when we consider the PPP-weighted results in Table 6. One explanation for this is that part of the impact of changes in the misallocation of labor on World GDP growth in the dollar-weighted results in Table 5 is economic activity shifting to sectors with an international cost advantage. These are industries with low relative wages compared to relative productivity levels—mainly manufacturing in China and India. Though present in the data, our results imply that such effects of deviations from PPP on the international allocation of labor only account for about a third of the total impact of changes in the misallocation of labor reported in Table 5.

Shifts in markups contribute slightly more to PPP-deflated World GDP growth than to dollar-weighted World GDP growth. This is largely due to markups in (Chinese) manufacturing.

Finally, comparing Lines 4 and 10 of Table 6 we find that fluctuations in PPP-deflated world TFP growth are much larger than those in country-industry PPP-deflated TFP growth. This is very similar to what we found for dollar-weighted ALP and TFP growth as well. Moreover, even though level of country-industry TFP growth is higher in the PPP-weighted data, the pattern over time is similar to the dollar-weighted results. Thus, qualitatively our results are very similar for dollar- and PPP-weighted world GDP growth.

5 Conclusion

We provide new global growth-accounting results from a novel growth decomposition applied to the period 1996-2014. We show how to implement this decomposition using the WIOD—along with other data, including new capital data—in order to split world GDP growth into parts due to technology, capital, labor, and changes in misallocation in product, capital, and labor markets. Allowing for such changes in misallocation turns out to be important for understanding global economic growth.

Our analysis reveals three main results: (i) World productivity is volatile from year to year and even over multi-year periods, even though (ii) the weighted average of country-industry productivity is comparatively smooth; (iii) changes in labor misallocation across countries are the primary reason for the volatility in world productivity.

In terms of country-industry productivity, an important point is that what looks like a productivity slowdown in the 2000's in advanced countries turns out to be a shift in the regional composition of productivity growth towards emerging markets at a global scale. World productivity growth (and country-industry productivity growth) only started slowing after the Great Recession.

Endogenous growth models typically have something to say about country-industry productivity (the second main result) which, as noted, differs markedly from overall world productivity. Indeed, it is striking that the bulk of fluctuations in world productivity growth is due to shifts in the global misallocation of resources rather than country-industry specific technological progress.

The main distortions that matter for these misallocation changes are in labor markets across countries. The primary driver of the changes in misallocation is that there are large differences in wages across countries (particularly when measured in dollar terms, but even in PPP terms). The first-order conditions interpret these as reflecting differences in the value of the marginal product of labor across countries and industries. These productivity differences interact with differences in hours growth across countries over time, so that the implied change in distortions swings between large negative contribution to a sizeable positive contribution.

These results suggest that it is important to understand barriers to factor movements and distortions in labor markets when analyzing global economic performance. An alternative interpretation, which we cannot quantify, is that the cross-country differences in wages reflects differences in productivity. In our view, the evidence seems most consistent with the view that moving a worker from Mexico to the United States raises that person's productivity, so we keep this productivity interpretation as our benchmark. These results thus show that the misallocation that a large literature has used to explain differential TFP across countries (e.g., Hsieh & Klenow (2009)) is also a key source of year-to-year volatility in productivity.

In addition to this volatility, the growth of emerging economies, with more distorted labor markets, decreases world efficiency and causes an average drag on global output growth about half a percentage point.

When we account for markups, the change in the global misallocation of capital is very small.

This doesn't mean that markups don't matter for world GDP growth. Output growth in sectors with markups reduces the global misallocation of resources and adds about 0.5 percentage points to world GDP growth. This contribution is relatively constant over time and, thus, has a limited impact on fluctuations. It is largely due to manufacturing in China and FIRE in the U.S.

Our analysis reveals that a global perspective on productivity and the evolution of the "world productivity frontier" provides a different picture from country-level analyses. It shows how the center of gravity of technological progress has shifted more towards emerging economies in the period we study and that changes in the misallocation of global productive resources account for a substantial part of increases and fluctuations in global productivity.

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Table 1: Comparison of WIOD-SEA vintages

Description	*Vintage* 2013	2016
	Coverage	
Years	1995-2007	2000-2014
Number of countries	40	43
Average share of world GDP		
...dollar denominated	80	82
...PPP deflated	76	77
Number of industries	35	56
Industry classification	ISIC v3	ISIC v4
Factor inputs		
Hours	✓	✓
Capital	✓	✓
...Nominal current cost	✓	✓
...Investment	✓	
...Capital deflators	✓	

Note: Both vintages contain data on value added by country and industry as well as value added deflators and factor prices for inputs for which data is available. The 2013 vintage includes incomplete data for 2008-2011 that we do not use in our analysis. Share of world GDP reported in percentage of dollar-denominated world value added from World Bank (2018). The 2016 vintage contains incomplete capital data, especially capital deflators. We construct them by merging data from OECD (2017b) and extrapolating from the 2013 vintage for variables unavailable. See the Appendix for details.

Table 2: Summary of global ALP growth accounting: 1996-2014

SEA vintage			2013				2016				
line	description	notation	1996 - 2000	2001 - 2004	2005 - 2007	All	2001 - 2004	2005 - 2007	2008 - 2010	2011 - 2014	All
1.	World GDP growth	$\dot{v}$	3.33	2.51	3.70	3.15	2.31	3.65	0.91	2.56	2.37
2.	World hours growth	$\dot{l}$	1.18	2.44	0.39	1.40	1.16	0.85	-0.07	3.38	1.46
3.	World ALP growth	$\dot{alp}$	2.15	0.07	3.31	1.75	1.15	2.80	0.98	-0.82	0.90
	Reallocation of hours	$\left(1-s_i^L\right)\left(\dot{l}_i-\dot{l}\right)$									
4.	...within countries		0.07	0.13	0.37	0.17	0.17	0.25	-0.06	0.23	0.16
5.	...across countries		-0.05	-0.84	0.24	-0.24	-0.40	0.22	-0.29	-0.74	-0.34
	Misallocation of hours	$s_i^L\left(\dot{l}_i-\dot{l}\right)$									
6.	...within countries		0.07	-0.02	0.15	0.06	0.03	0.08	0.08	0.09	0.07
7.	...across countries		-0.08	-1.32	0.35	-0.39	-0.60	0.27	-0.44	-1.07	-0.51
8.	*Country-industry ALP growth*	$\dot{alp}_i$	2.14	2.11	2.20	2.15	1.94	1.98	1.70	0.67	1.53

Note: Lines in this table correspond to parts of equation (17). Reported are contributions to average annual growth rates in percentage points over various subperiods.

Table 3: Contribution of country-industry specific ALP growth, by country/region: 1996-2014

SEA vintage	2013				2016				
Country/region	1996 - 2000	2001 - 2004	2005 - 2007	All	2001 - 2004	2005 - 2007	2008 - 2010	2011 - 2014	All
Advanced	1.77	1.78	1.21	1.63	1.66	0.92	0.57	0.30	0.89
United States	0.75	1.01	0.42	0.76	0.92	0.38	0.54	-0.00	0.46
Great Britain	0.11	0.13	0.10	0.11	0.13	0.05	0.03	0.01	0.06
Japan	0.31	0.25	0.19	0.26	0.27	0.12	-0.08	0.06	0.11
Euro Area	0.33	0.23	0.30	0.29	0.21	0.23	0.04	0.16	0.16
Other Advanced	0.27	0.16	0.20	0.21	0.13	0.14	0.04	0.07	0.10
Emerging	0.38	0.33	1.00	0.51	0.27	1.06	1.12	0.36	0.66
Brazil	0.04	-0.00	0.02	0.02	-0.02	-0.00	0.27	-0.05	0.04
China	0.30	0.28	0.53	0.35	0.23	0.67	0.65	0.59	0.52
India	0.06	0.02	0.17	0.07	0.05	0.13	0.12	-0.11	0.04
Russia	-0.02	0.04	0.11	0.03	0.05	0.09	0.09	0.02	0.06
Other Emerging	-0.00	-0.01	0.17	0.04	-0.04	0.17	-0.01	-0.09	-0.00
Total	2.14	2.11	2.20	2.15	1.94	1.98	1.70	0.67	1.53

Note: Reported are contributions by country/region to line 8 in Table 2 in percentage points over various subperiods.

Table 4: Summary of global TFP growth accounting without markups: 1996-2014

SEA vintage			2013				2016				
line	description	notation	1996 - 2000	2001 - 2004	2005 - 2007	All	2001 - 2004	2005 - 2007	2008 - 2010	2011 - 2014	All
1.	World GDP growth	$\dot{v}$	3.33	2.51	3.70	3.15	2.31	3.65	0.91	2.56	2.37
2.	Aggregate capital growth	$s^K \dot{k}$	0.98	0.94	1.26	1.04	1.54	1.50	1.18	1.18	1.35
3.	Aggregate hours growth	$s^L \dot{l}$	0.71	1.44	0.23	0.83	0.67	0.48	-0.04	1.89	0.82
4.	World TFP growth	$t\dot{f}p$	1.65	0.13	2.21	1.28	0.13	1.64	-0.23	-0.51	0.19
	Misallocation of capital	$s_i^K \left(\dot{k}_i - \dot{k}\right)$									
5.	…within countries		0.63	0.20	0.31	0.40	0.16	0.25	0.14	0.18	0.18
6.	…across countries		0.13	0.09	0.13	0.11	0.06	0.11	0.14	0.09	0.10
	Misallocation of hours	$s_i^L \left(\dot{l}_i - \dot{l}\right)$									
7.	…within countries		0.07	-0.02	0.15	0.06	0.03	0.08	0.08	0.09	0.07
8.	…across countries		-0.08	-1.32	0.35	-0.39	-0.60	0.27	-0.44	-1.07	-0.51
9.	*Country-industry TFP growth*		0.91	1.18	1.28	1.09	0.45	0.91	-0.17	0.19	0.34

Note: Lines in this table correspond to parts of equation (11). Reported are contributions to average annual growth rates in percentage points over various subperiods. Results with no markups.

Table 5: Summary of global TFP growth accounting *with* markups: 1996-2014

SEA vintage			2013				2016				
line	description	notation	1996 - 2000	2001 - 2004	2005 - 2007	All	2001 - 2004	2005 - 2007	2008 - 2010	2011 - 2014	All
1.	World GDP growth	$\dot{v}$	3.33	2.51	3.70	3.15	2.31	3.65	0.91	2.56	2.37
2.	Aggregate capital growth	$s^K\dot{k}$	0.79	0.74	0.80	0.78	0.89	0.86	0.75	0.63	0.78
3.	Aggregate hours growth	$s^L\dot{l}$	0.71	1.44	0.23	0.83	0.67	0.48	-0.04	1.89	0.82
4.	World TFP growth	$\dot{tfp}$	1.84	0.32	2.67	1.54	0.77	2.30	0.19	0.04	0.77
	Misallocation of capital	$s_i^K\left(\dot{k}_i-\dot{k}\right)$									
5.	...within countries		0.23	0.06	0.11	0.15	0.08	0.14	0.07	0.06	0.09
6.	...across countries		-0.02	-0.03	-0.05	-0.03	0.09	0.04	0.16	0.18	0.12
	Misallocation of hours	$s_i^L\left(\dot{l}_i-\dot{l}\right)$									
7.	...within countries		0.07	-0.02	0.15	0.06	0.03	0.08	0.08	0.09	0.07
8.	...across countries		-0.08	-1.32	0.35	-0.39	-0.60	0.27	-0.44	-1.07	-0.51
9.	Shifts in markups	$\frac{\mu_i}{1+\mu_i}\dot{y}_i$	0.51	0.39	0.94	0.58	0.46	0.85	0.29	0.59	0.55
10.	*Country-industry TFP growth*		1.13	1.25	1.17	1.18	0.70	0.91	0.03	0.18	0.45

Note: Lines in this table correspond to parts of equation (11). Reported are contributions to average annual growth rates in percentage points over various subperiods. Results with markups.

Table 6: Summary of global PPP-TFP growth accounting *with* markups: 1996-2014

SEA vintage			2013				2016				
line	description	notation	1996 - 2000	2001 - 2004	2005 - 2007	All	2001 - 2004	2005 - 2007	2008 - 2010	2011 - 2014	All
1.	World GDP growth	$\dot{v}$	5.42	5.33	8.02	6.04	5.07	7.91	3.33	5.59	5.45
2.	Aggregate capital growth	$s^K \dot{k}$	0.75	0.71	0.77	0.74	0.87	0.87	0.79	0.69	0.80
3.	Aggregate hours growth	$s^L \dot{l}$	0.75	1.39	0.21	0.83	0.65	0.43	-0.03	1.82	0.79
4.	World TFP growth	$\dot{tfp}$	3.92	3.24	7.04	4.47	3.57	6.62	2.57	3.09	3.87
	Misallocation of capital	$s_i^K \left(\dot{k}_i - \dot{k}\right)$									
5.	…within countries		0.21	0.07	0.15	0.15	0.09	0.17	0.05	-0.00	0.07
6.	…across countries		0.11	0.10	0.11	0.11	0.30	0.45	0.76	0.68	0.54
	Misallocation of hours	$s_i^L \left(\dot{l}_i - \dot{l}\right)$									
7.	…within countries		0.08	-0.19	0.36	0.06	0.15	0.34	0.25	0.27	0.25
8.	…across countries		-0.06	-0.93	0.23	-0.28	-0.38	0.19	-0.28	-0.70	-0.33
9.	Shifts in markups	$\frac{\mu_i}{1+\mu_i} \dot{y}_i$	0.60	0.60	1.46	0.81	0.69	1.18	0.55	0.77	0.79
10.	*Country-industry TFP growth*		2.99	3.59	4.72	3.62	2.71	4.29	1.25	2.07	2.55

Note: Lines in this table correspond to parts of equation (11). Reported are contributions to average annual growth rates in percentage points over various subperiods. Results with markups.

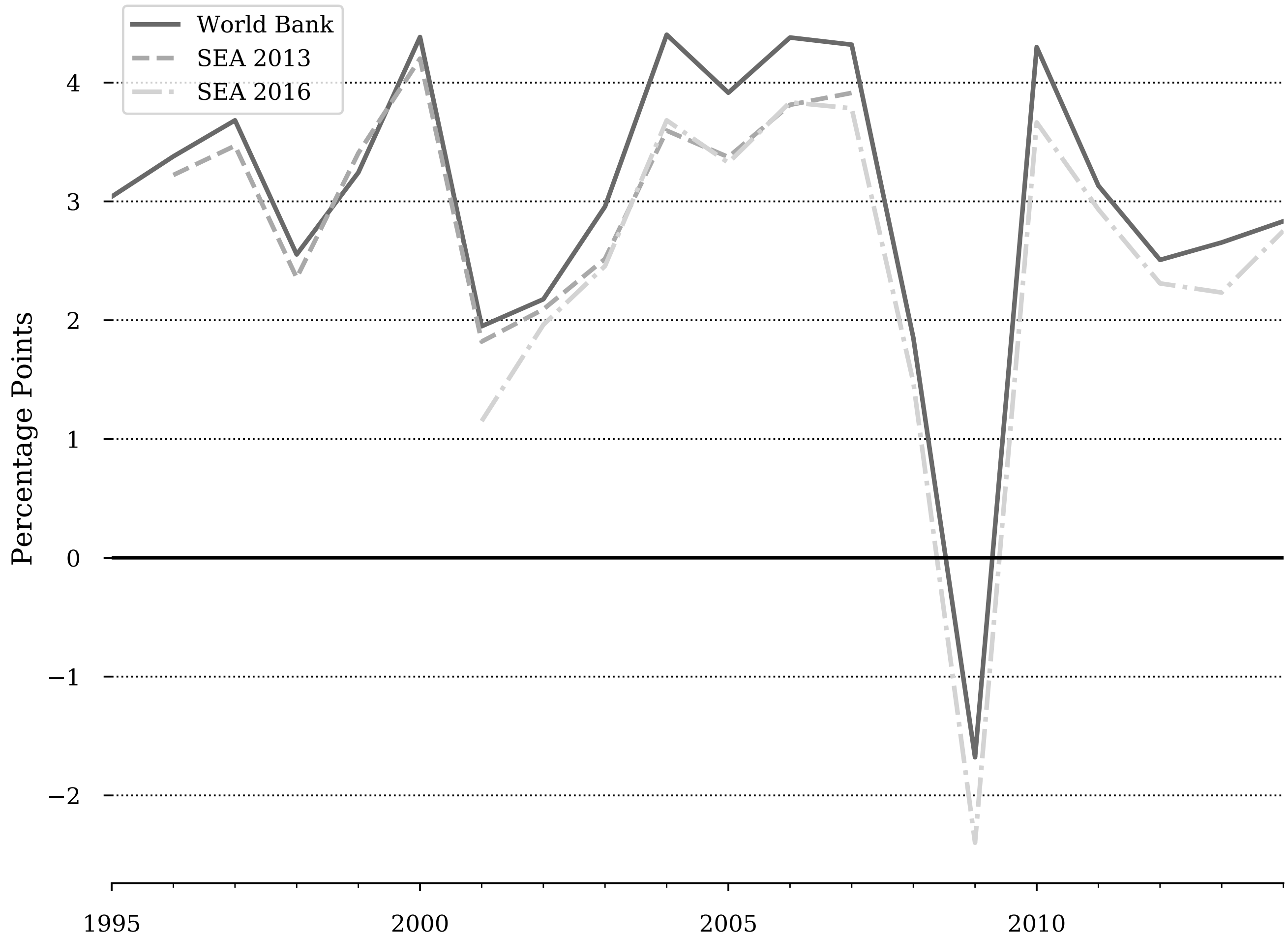

Figure 1: Growth in world real GDP in WIOD-SEA and World Development Indicators (WDI)

Source: Timmer (2012) and World Bank (2018).

Note: World real GDP growth is constructed as dollar-denominated value-added share weighted average of real GDP or real country-industry value-added growth.

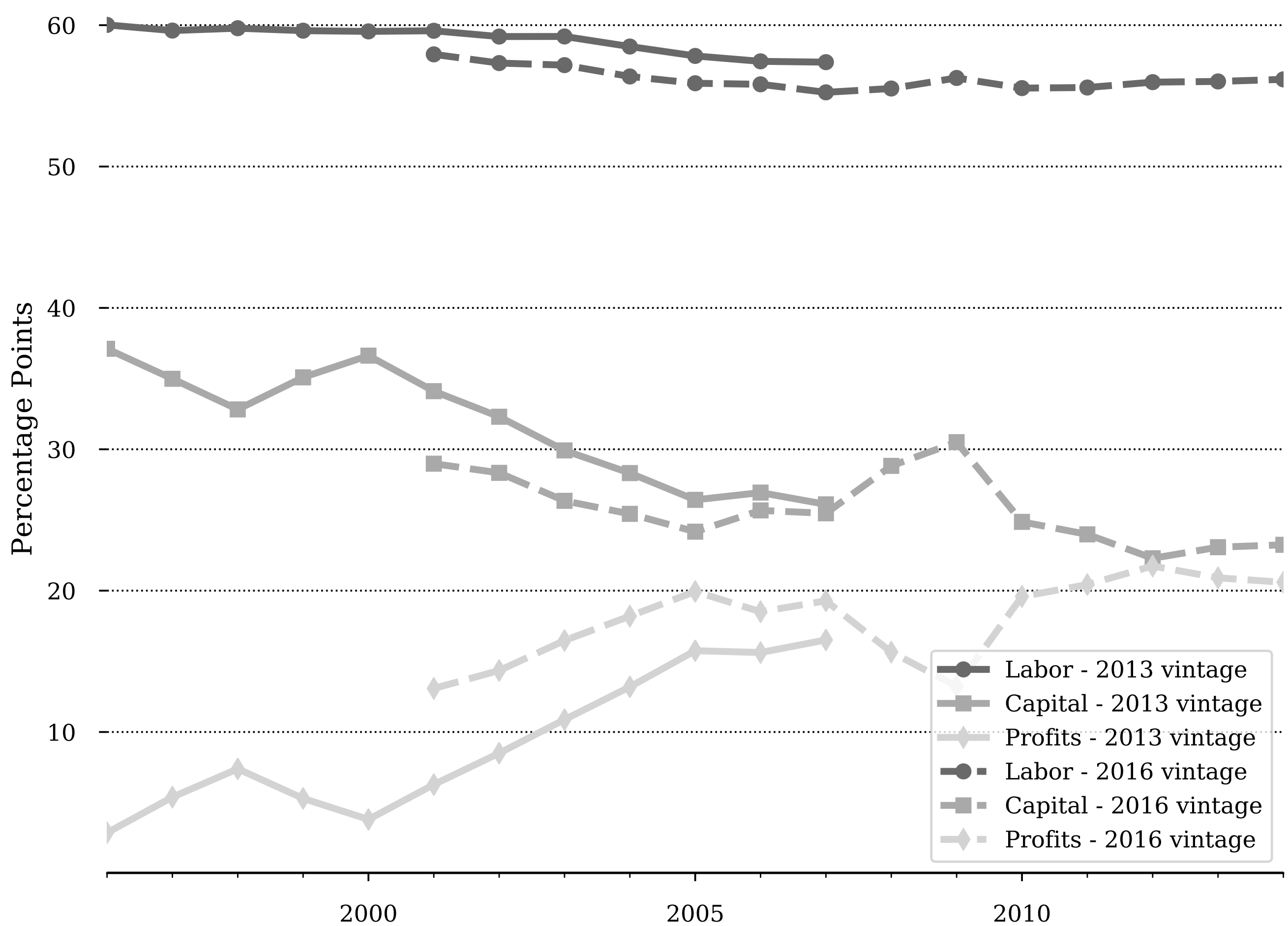

Figure 2: World factor shares for both vintages of WIOT

Source: Timmer (2012), OECD (2017b), and authors' calculations.

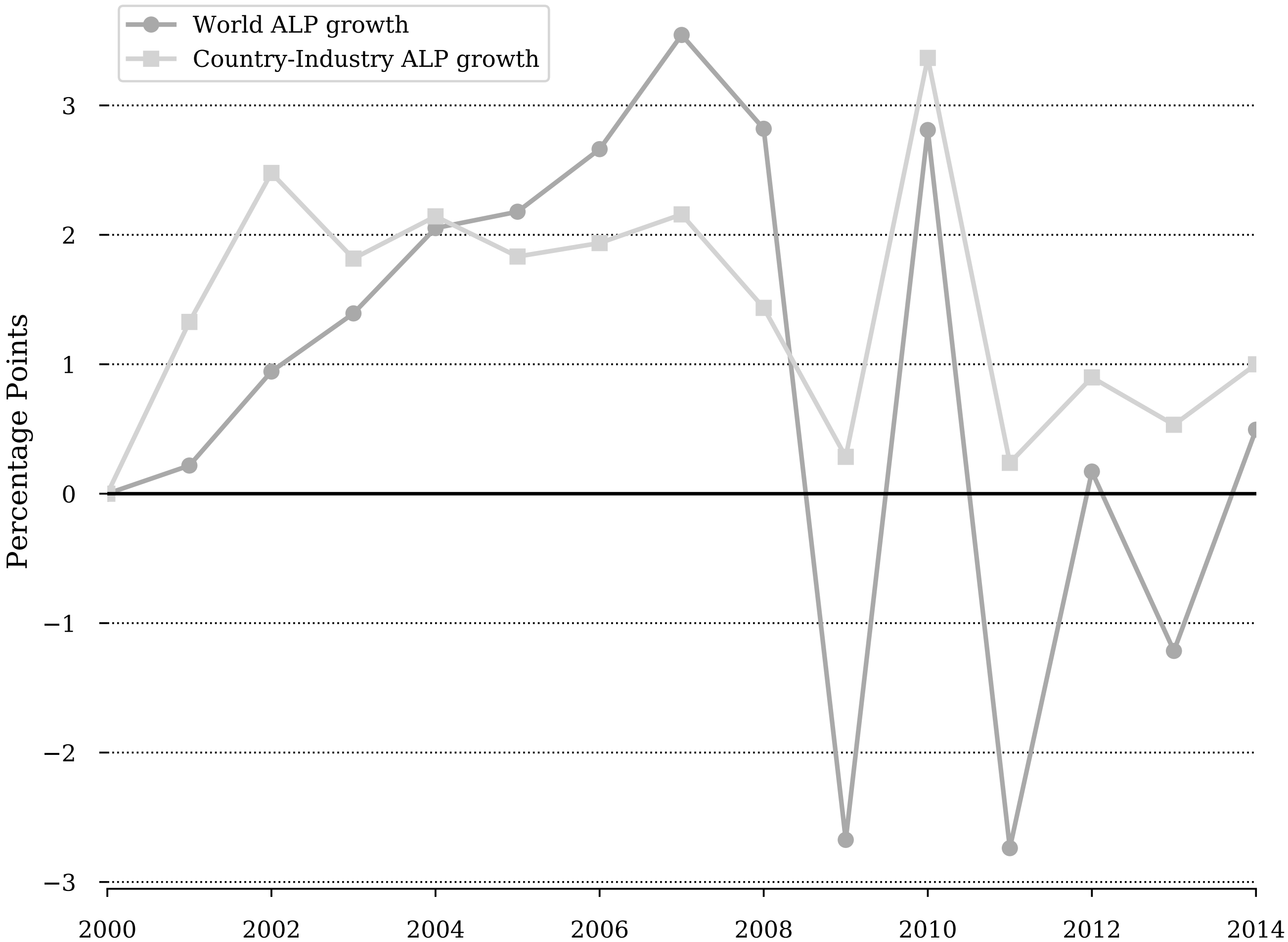

Figure 3: ALP growth: World vs. country-industry component, vintage 2016.
Source: Timmer (2012), OECD (2017b), and authors' calculations.

A Accounting for within- and across-country contributions

As mentioned in the main text, we split up the contribution of shifts in misallocation into with-country component and across-country one. We elaborate here how we do this. We focus on equation (11), but the same calculations can be applied to misallocation term in (17) as well.

Remember that the index i in equation (11) represents a country-industry pair. We rewrite this equation again with a new indexation: i for industry and c for country:

$$\begin{aligned} \dot{v} &= \sum_c \sum_i \frac{1}{(1+\mu_{ci})} s^D_{ci} \dot{z}_{ci} + s^K \dot{k} + s^L \dot{l} \\ &+ \sum_c \sum_i s^D_{ci} \frac{\mu_{ci}}{(1+\mu_{ci})} \dot{y}_{ci} + \sum_c \sum_i s^V_{ci} s^K_{ci} \left(\dot{k}_{ci} - \dot{k}\right) + \sum_c \sum_i s^V_{ci} s^L_{ci} \left(\dot{l}_{ci} - \dot{l}\right). \end{aligned} \tag{18}$$

We can now split up the capital and labor misallocation terms into within- and across-country component. For example, labor misallocation term can be written as

$$\sum_c \sum_i s^V_{ci} s^L_{ci} \left(\dot{l}_{ci} - \dot{l}\right) = \sum_c s^V_c \sum_i \frac{s^V_{ci} s^L_{ci}}{s^V_c} \left(\dot{l}_{ci} - \dot{l}_c\right) + \sum_c s^V_c s^L_c \left(\dot{l}_c - \dot{l}\right), \tag{19}$$

where

$$s^L_c = \left(\frac{\sum_i s^V_{ci} s^L_{ci}}{s^V_c}\right), \text{ and } s^V_c = \sum_i s^V_{ci}. \tag{20}$$

Equation (19) splits up the labor misallocation terms into two parts: within-country misallocation of labor which is the first term on the RHS, and across-country component which is the second term. A positive within-country misallocation of labor states that hours are growing faster in industries that on average have higher labor share and contribute more to the country GDP. Higher labor share means that the wages are on average higher in these industries which indicates higher marginal product of labor. Hence, a positive term means that there are productivity gains from changes in the misallocation of labor within the country.

Similarly, a positive across-country misallocation means that hours are growing faster in countries with higher labor share and contribute more to world GDP. This will result in less misallocation of labor and contribute positively to world TFP growth. The capital misallocation term can be split up in a similar way.

B Detailed results and data

B.1 Detailed results

B.1.1 Comparison with World-Bank aggregates

Figure B.1 shows how nominal GDP in our data, measured in current US$, lines up with world GDP. The short-dashed line shows the level of nominal GDP in our sample countries in the 2013 vintage of the data. The other dashed line is the 2016 vintage of the data. Both of these lines are below the World GDP solid line, reflecting that our sample of countries covers about 80 percent of global economic activity (in dollars). The 2016 vintage is a bit higher in the overlapping period because of the inclusion of Croatia, Norway, and Switzerland.

Our time series for PPP-deflated world GDP growth lines up closely with that published by the World Bank in World Bank (2018). This is evident in Figures B.2 and B.3, which show the World GDP-PPP and its growth in our data versus that of the World Bank.

B.1.2 Value-added and factor shares by country and industry

Dollar-denominated value-added shares for the different periods by country and industry are reported in Tables B.1 and B.3, respectively. Similar PPP-weighted shares are listed in Tables B.2 and B.4, respectively. Profit shares by industry are reported in Table B.5.

B.1.3 Detailed contributions to world ALP and TFP growth

The contributions of country-industry TFP growth, $\dot{z}_i$, by country/region for calculations based on dollar-weighted world GDP without taking into account markups are listed in B.6, while these contributions with markups are in B.7. The contribution of shifts in misallocation due to markups by region is reported in Table B.8 while the same contribution by industry can be found in Table B.9.

B.2 Data

B.2.1 Countries and industries

The countries in each of the vintages as well as in the sample for PPP results are listed in Table B.10. Throughout, we present these results for a set of regions that are the same across both vintages. The regions are listed in Table B.11. The industries were classified into major categories, listed in Table B.12, in order to be consistent with the North American Industry Classification System (NAICS).

B.2.2 Main variables used for our analysis

- **Gross Value Added**: This is the gross value added at current basic prices (in millions of national currency). The volume index which is normalized to 100 in 1995 and the price level normalized to 100 in 1995 are provided in the tables. The volume index of gross value added is the foundation of GDP growth calculation. We use the exchange rates provided in WIOD to express the nominal values in current U.S. Dollars. These exchange rates, however, are not PPP adjusted.

- **Labor**: Number of employees (thousands) and total hours worked by persons engaged (millions) provide information on the growth in hours along with misallocation of labor across countries and industries. It should be mentioned that the data on hours worked in China were imputed for the period 2008-2014 from the International Labor Organization (ILO). In SEA 2013, data on labor compensation (in millions of national currency) and total hours worked are decomposed based on skill level of the labor into three broad groups: low-, medium- and high-skill. Labor skill types are classified on the basis of educational attainment levels as defined in the International Standard Classification of Education (ISCED): low-skilled (ISCED categories 1 and 2), medium-skilled (ISCED 3 and 4) and high-skilled (ISCED 5 and 6). This decomposition, however, is absent in SEA 2016.

- **Capital**: Data on the current cost replacement value of the capital stock (in millions of national currency) and nominal gross fixed capital formation (in millions of national currency) along with the volume and price index of the latter is used to calculate capital deepening and misallocation of capital across countries and industries. For the 2013 vintage gross fixed capital formation and its associated volume index are used to calculate the implicit capital price deflator which is then used to construct a volume index for the real capital stock. For the 2016 vintage, the current cost replacement value of the capital stock by country-industry is deflated by a constructed capital price deflator. For country-industry combinations for which these deflators are available in OECD (2017b), these deflators are taken from the STAN database for the industry at the lowest level of aggregation that contains the industry in our data. For country-industry combinations for which the capital price deflator is not available in STAN, we use the implicit capital price deflator from the closest corresponding industry in the 2013 vintage and then extrapolate it assuming a constant growth rate for the years 2008-2014.

- **Profits**: Profits are calculated as value added minus compensation minus capital service flows. The latter are calculated assuming an external rate of return equal to the U.S. corporate 10-yr BBB rate. We use the exchange rate to express the capital price deflator in each country in U.S. dollars. This allows us to calculate the capital price inflation in U.S. dollars, i.e. π^K_{USD}. Capital service flows for each country-industry combination are then calculated as

$$\left(i_{BBB} - \pi^K_{USD} + \delta_i\right) P^K_i K_i \tag{21}$$

  Here, i_{BBB} is the nominal BBB 10-yr corporate bond rate and δ_i is the average capital depreciation rate implied by the 2013 vintage capital data. In addition, $P^K_i K_i$ is the nominal replacement value of the capital stock. For the empirical implementation we have smoothed out fluctuations in π^K_{USD} by using the average over vintage sample.

B.2.3 Construction of capital deflators for 2016 vintage

A major source of discrepancies between the 2013 and 2016 vintages is differences in the nominal replacement value of the capital stocks. For the 2013 vintage, when available, they are taken from EU and US KLEMS data. For the 2016 vintage, when available, they are taken from the OECD STAN database. Other values are imputed. However, even those that are taken from these two data sources seem to be very different.

We have merged the the capital deflators from STAN into our data for the 2016 vintage. They are consistent with the nominal replacement values used and, for the countries for which we can obtain them, make our growth rate of the capital stock consistent with OECD STAN. For the other countries, we extrapolated the capital deflators from the 2013 vintage for the years we have missing data.

Depreciation rates are calculated by industry for the 2013 and applied to both the 2013 and 2016 vintages of the data.

B.2.4 Construction of PPP-deflated value-added

In this section, we explain in more detail how we constructed a measure of PPP-deflated value added by double-deflating the benchmark PPP relative prices constructed by Timmer *et al.* (2007) and Inklaar & Timmer (2014).

PPP benchmark prices

The PPP benchmark tables report relative prices of industry gross output for industries and countries in the dataset. The numeraire good is US GDP in 2005, i.e. the relative price of US GDP in the benchmark table is 1. This means the relative price reported, $\mathcal{P}_{i,t}$, is the number of U.S. dollars in 2005 per unit of output in country-industry i in 2005 relative to the number of U.S. dollars in 2005 per unit of U.S. GDP. It is useful to consider this in mathematical form

$$\mathcal{P}_{i,t} = \frac{\$/GO_{i,t}}{\$/USGDP_t} = \frac{USGDP_t}{GO_{i,t}} \text{ for } t = 2005. \tag{22}$$

The first step is to calculate a time series for $\mathcal{P}_{i,t}$ for $t \neq 2005$. This can be done by using the time series for the price index for gross output in country-industry i in year t, i.e. $P_{i,t}$, as well as the U.S. GDP deflator, $\mathcal{P}_t$.

Using these two time series, we can construct

$$\mathcal{P}_{i,t} = \mathcal{P}_{i,2005} \frac{P_{i,t}/P_{i,2005}}{\mathcal{P}_t/\mathcal{P}_{2005}}. \tag{23}$$

This gives us a time series of PPP conversion rates of the real gross output values into U.S. GDP.

Dollars to PPP, denominated in US GDP

The conversion factor derived above then allows us to convert nominal gross output in country-industry i in year t, i.e. $P_{i,t}Y_{i,t}$, into units of U.S. GDP. Let $Y^*_{i,t}$ be output in country-industry i in year t measured in PPP units of U.S. GDP in the same period, then we can calculate it through

$$Y^*_{i,t} = \frac{P_{i,t}Y_{i,t}}{\mathcal{P}_{i,t}} \frac{1}{\mathcal{P}_t} = \frac{P_{i,t}Y_{i,t}}{P^*_{i,t}}, \text{ where } P^*_{i,t} = \mathcal{P}_{i,t}\mathcal{P}_t. \tag{24}$$

This equation means the following. The inverse of $\mathcal{P}_{i,t}$ converts dollars of nominal gross output of country-industry i in year t into dollars of nominal U.S. GDP in year t according to the PPP adjustment. Dividing these dollars by the U.S. GDP deflator then gives the quantity of U.S. GDP produced in the sector.

Now, this allows us to calculate PPP adjusted *gross output*. However, what we really want to calculate is PPP adjusted *value added*. To obtain this, we need to do an additional calculation.

Value added in terms of PPP

To PPP adjust value added, we basically PPP adjust the nominal gross output and intermediate inputs terms in the definition of value added. That is, nominal value added of country-industry i in year t is the difference between nominal gross output and the nominal value of intermediate inputs.

$$P^V_{i,t}V_{i,t} = P_{i,t}Y_{i,t} - \sum_{i'} P_{i',t}M_{i',t}. \tag{25}$$

Now PPP adjusted value added of sector i during year t, i.e. $V^*_{i,t}$, is obtained by PPP adjusting each of the individual nominal components. That is,

$$V^*_{i,t} = \frac{P_{i,t}Y_{i,t}}{P^*_{i,t}} - \sum_{i'} \frac{P_{i',t}M_{i',j',t}}{P^*_{i',t}}. \tag{26}$$

The implicit PPP deflator of value added of sector i in year t is then given by

$$P^{V*}_{i,t} = \frac{P^V_{i,t}V_{i,t}}{V^*_{i,t}}. \tag{27}$$

The calculation of (26) involves figuring out the intermediate inputs from all over the world using the WIOT and this requires using the input-output tables.

The other problem is that we cannot PPP adjust all intermediate inputs. One way of dealing with it is to use the same PPP deflator for the intermediate inputs for which we have no data compared to those for which we have data. The PPP deflator of the intermediate inputs that are covered is calculated using

$$P^{M*}_{i,t} = \sum_{i'} \frac{P_{i',t}M_{i',t}}{\sum_{i''} P_{i'',t}M_{i'',t}} P^*_{i',t}. \tag{28}$$

where i' and j' cover the intermediate inputs for which PPP adjusted deflators are measured. We then use this to deflate all the nominal intermediate inputs.

So, practically, we calculate $P^{M*}_{i,t}$ for each sector i and year t for all the intermediate inputs for which we have PPP adjusted gross output deflators. We then deflate *all* nominal intermediate inputs by this deflator to calculate PPP adjusted value added. We then calculate the implied PPP adjusted value-added deflator, (27).

This then allows us to calculate all the PPP adjusted data that we need for our analysis.

Table B.1: Dollar-denominated value-added shares, by country/region: 1996-2014

SEA vintage	2013				2016				
Country/region	1996 - 2000	2001 - 2004	2005 - 2007	All	2001 - 2004	2005 - 2007	2008 - 2010	2011 - 2014	All
Advanced	0.88	0.87	0.83	0.86	0.88	0.84	0.78	0.71	0.81
United States	0.33	0.37	0.33	0.34	0.37	0.33	0.29	0.27	0.32
Great Britain	0.05	0.05	0.05	0.05	0.05	0.06	0.05	0.04	0.05
Japan	0.17	0.14	0.11	0.15	0.13	0.10	0.09	0.08	0.10
Euro Area	0.24	0.22	0.24	0.23	0.23	0.24	0.24	0.20	0.23
Other Advanced	0.09	0.09	0.10	0.09	0.10	0.11	0.11	0.12	0.11
Emerging	0.13	0.14	0.16	0.14	0.14	0.16	0.22	0.29	0.20
Brazil	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.04	0.03
China	0.04	0.05	0.06	0.05	0.05	0.06	0.10	0.14	0.09
India	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02
Russia	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.03	0.02
Other Emerging	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.04
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Note: Reported are contributions by country/region in percentage points over various subperiods.

Table B.2: PPP-denominated value-added shares, by country/region: 1996-2014

SEA vintage	2013				2016				
Country/region	1996 - 2000	2001 - 2004	2005 - 2007	All	2001 - 2004	2005 - 2007	2008 - 2010	2011 - 2014	All
Advanced	0.72	0.69	0.65	0.69	0.70	0.65	0.60	0.55	0.62
United States	0.27	0.26	0.25	0.26	0.27	0.25	0.23	0.21	0.24
Great Britain	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Japan	0.10	0.09	0.08	0.09	0.08	0.08	0.07	0.06	0.07
Euro Area	0.22	0.21	0.19	0.21	0.22	0.20	0.18	0.16	0.19
Other Advanced	0.09	0.09	0.09	0.09	0.09	0.08	0.08	0.08	0.08
Emerging	0.28	0.32	0.36	0.31	0.31	0.35	0.40	0.45	0.37
Brazil	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
China	0.11	0.14	0.17	0.13	0.14	0.17	0.21	0.25	0.19
India	0.05	0.06	0.06	0.06	0.05	0.06	0.07	0.08	0.06
Russia	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03
Other Emerging	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Note: Reported are contributions by country/region in percentage points over various subperiods.

Table B.3: Dollar-denominated value-added shares, by industry: 1996-2014

SEA vintage	2013				2016				
Industry	1996 - 2000	2001 - 2004	2005 - 2007	All	2001 - 2004	2005 - 2007	2008 - 2010	2011 - 2014	All
Agriculture	0.05	0.04	0.05	0.05	0.04	0.05	0.06	0.07	0.06
Construction	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Nondurables manuf	0.13	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11
Durables manuf	0.06	0.06	0.06	0.06	0.07	0.07	0.06	0.07	0.07
Trade Trans Utilities	0.20	0.20	0.19	0.20	0.19	0.19	0.19	0.19	0.19
FIRE	0.16	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16
Business services	0.09	0.10	0.10	0.10	0.14	0.14	0.14	0.13	0.14
Education Healthcare	0.08	0.08	0.09	0.08	0.08	0.08	0.09	0.08	0.08
Hospitality	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03
Personal services	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03
Government	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09
Households	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Note: Reported are contributions by industry in percentage points over various subperiods.

Table B.4: PPP-denominated value-added shares, by industry: 1996-2014

SEA vintage	2013				2016				
Industry	1996 - 2000	2001 - 2004	2005 - 2007	All	2001 - 2004	2005 - 2007	2008 - 2010	2011 - 2014	All
Agriculture	0.09	0.08	0.07	0.08	0.09	0.07	0.06	0.06	0.07
Construction	0.07	0.06	0.06	0.07	0.06	0.06	0.04	0.03	0.05
Nondurables manuf	0.15	0.14	0.15	0.15	0.13	0.14	0.17	0.20	0.16
Durables manuf	0.05	0.06	0.07	0.06	0.06	0.08	0.10	0.12	0.09
Trade Trans Utilities	0.17	0.19	0.19	0.18	0.19	0.20	0.19	0.19	0.19
FIRE	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.14
Business services	0.08	0.09	0.09	0.09	0.12	0.12	0.12	0.11	0.12
Education Healthcare	0.08	0.08	0.08	0.08	0.08	0.07	0.06	0.06	0.07
Hospitality	0.03	0.03	0.02	0.03	0.03	0.02	0.02	0.02	0.02
Personal services	0.04	0.04	0.03	0.04	0.03	0.02	0.02	0.02	0.02
Government	0.06	0.06	0.06	0.06	0.07	0.06	0.06	0.06	0.06
Households	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Note: Reported are contributions by industry in percentage points over various subperiods.

Table B.5: Profits as a percentage of world GDP, by industry: 1996-2014

SEA vintage	2013				2016				
Industry	1996 - 2000	2001 - 2004	2005 - 2007	All	2001 - 2004	2005 - 2007	2008 - 2010	2011 - 2014	All
Agriculture	0.63	0.85	1.40	1.06	1.20	1.86	1.86	2.49	2.02
Construction	0.55	0.71	1.02	0.82	0.67	0.99	0.84	1.04	0.97
Nondurables manuf	1.83	2.17	3.02	2.72	2.49	2.98	2.47	2.80	3.06
Durables manuf	0.49	0.35	0.74	0.67	0.68	1.05	0.63	0.70	0.95
Trade Trans Utilities	2.33	3.01	4.01	3.58	3.82	4.50	3.91	4.86	4.88
FIRE	-2.10	1.23	3.65	1.47	4.49	5.46	4.52	6.96	6.27
Business services	0.73	0.79	1.19	1.08	1.57	1.79	1.44	1.57	1.97
Education Healthcare	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hospitality	0.39	0.49	0.55	0.52	0.59	0.63	0.48	0.48	0.61
Personal services	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Households	-0.00	-0.00	-0.00	-0.00	0.01	0.01	0.01	0.01	0.01
Total	4.96	9.72	15.96	12.25	15.53	19.24	16.16	20.92	20.74

Note: Reported are contributions by industry in percentage points over various subperiods.
Profits in Education/Healthcare, Personal care, Government, and Households are set to zero by construction.

Table B.6: Contribution of country-industry specific TFP growth, by country/region: 1996-2014

SEA vintage	2013				2016				
Country/region	1996 - 2000	2001 - 2004	2005 - 2007	All	2001 - 2004	2005 - 2007	2008 - 2010	2011 - 2014	All
Advanced	0.64	0.82	0.47	0.66	0.29	0.33	-0.45	0.10	0.08
United States	0.22	0.51	-0.02	0.26	0.16	0.00	0.06	-0.02	0.05
Great Britain	0.03	0.06	0.05	0.04	0.09	0.04	-0.00	0.01	0.04
Japan	0.06	0.12	0.17	0.10	-0.03	0.18	-0.19	0.10	0.02
Euro Area	0.18	0.07	0.18	0.15	0.05	0.13	-0.25	0.05	0.00
Other Advanced	0.15	0.06	0.09	0.11	0.02	-0.02	-0.07	-0.04	-0.03
Emerging	0.26	0.35	0.80	0.44	0.15	0.59	0.27	0.09	0.24
Brazil	0.01	-0.00	-0.02	-0.00	-0.01	-0.04	-0.02	-0.14	-0.06
China	0.21	0.29	0.56	0.33	0.15	0.45	0.24	0.29	0.27
India	0.03	0.01	0.08	0.04	0.01	0.05	0.02	-0.13	-0.02
Russia	-0.03	0.03	0.06	0.02	0.04	0.06	0.04	0.03	0.04
Other Emerging	0.04	0.02	0.12	0.05	-0.04	0.07	-0.01	0.04	0.01
Total	0.91	1.18	1.28	1.09	0.45	0.91	-0.17	0.19	0.34

Note: Reported are contributions by country/region to line 10 in Table 4 in percentage points over various subperiods. Results without markups.

Table B.7: Contribution of country-industry specific TFP growth, by country/region: 1996-2014

SEA vintage	2013				2016				
Country/region	1996 - 2000	2001 - 2004	2005 - 2007	All	2001 - 2004	2005 - 2007	2008 - 2010	2011 - 2014	All
Advanced	0.92	0.99	0.63	0.88	0.52	0.42	-0.22	0.10	0.22
United States	0.27	0.55	0.09	0.32	0.28	0.06	0.16	-0.09	0.10
Great Britain	0.05	0.07	0.06	0.06	0.08	0.04	-0.03	0.03	0.03
Japan	0.23	0.20	0.21	0.22	0.05	0.20	-0.15	0.09	0.05
Euro Area	0.20	0.09	0.17	0.16	0.06	0.09	-0.16	0.08	0.03
Other Advanced	0.17	0.08	0.10	0.12	0.05	0.03	-0.04	-0.01	0.01
Emerging	0.21	0.24	0.53	0.30	0.17	0.49	0.25	0.06	0.23
Brazil	0.00	-0.01	-0.01	-0.01	-0.01	-0.04	0.02	-0.09	-0.03
China	0.19	0.21	0.31	0.23	0.11	0.37	0.15	0.28	0.22
India	0.03	0.01	0.08	0.04	0.02	0.04	0.04	-0.08	0.00
Russia	-0.02	0.02	0.05	0.01	0.02	0.05	0.03	-0.02	0.02
Other Emerging	0.01	0.01	0.10	0.03	0.03	0.07	0.01	-0.03	0.02
Total	1.13	1.25	1.17	1.18	0.70	0.91	0.03	0.18	0.45

Note: Reported are contributions by country/region to line 10 in Table 5 in percentage points over various subperiods. Results with markups.

Table B.8: Contribution of markups to world GDP growth, by country/region: 1996-2014

SEA vintage	2013				2016				
Country/region	1996 - 2000	2001 - 2004	2005 - 2007	All	2001 - 2004	2005 - 2007	2008 - 2010	2011 - 2014	All
Advanced	0.36	0.18	0.42	0.31	0.32	0.46	-0.04	0.25	0.24
United States	0.22	0.10	0.18	0.17	0.14	0.15	-0.06	0.17	0.10
Great Britain	0.03	0.03	0.04	0.03	0.01	0.01	0.03	-0.01	0.01
Japan	-0.00	-0.02	-0.01	-0.01	-0.01	-0.01	-0.02	-0.00	-0.01
Euro Area	0.06	0.04	0.11	0.06	0.11	0.19	-0.02	0.01	0.07
Other Advanced	0.05	0.03	0.10	0.06	0.07	0.12	0.03	0.08	0.07
Emerging	0.15	0.19	0.53	0.26	0.14	0.40	0.33	0.34	0.30
Brazil	0.01	0.00	0.02	0.01	0.01	0.04	0.04	0.03	0.03
China	0.04	0.10	0.31	0.13	0.08	0.14	0.19	0.14	0.14
India	0.02	0.02	0.05	0.03	0.03	0.05	0.05	0.05	0.04
Russia	0.00	0.03	0.06	0.02	0.03	0.07	0.03	0.04	0.04
Other Emerging	0.08	0.04	0.09	0.07	-0.01	0.10	0.02	0.08	0.05
Total	0.51	0.39	0.94	0.58	0.46	0.85	0.29	0.59	0.55

Note: Reported are contributions by country/region to line 9 in Table 5 in percentage points over various subperiods.

Table B.9: Contribution of markups to world GDP growth, by industry: 1996-2014

SEA vintage	2013				2016				
Industry	1996 - 2000	2001 - 2004	2005 - 2007	All	2001 - 2004	2005 - 2007	2008 - 2010	2011 - 2014	All
Agriculture	0.02	0.02	0.04	0.03	0.02	0.03	0.04	0.10	0.05
Construction	0.02	0.02	0.05	0.03	0.02	0.06	0.02	0.05	0.04
Nondurables manuf	0.08	0.07	0.19	0.10	0.05	0.14	0.04	0.09	0.08
Durables manuf	0.05	0.04	0.10	0.06	0.04	0.09	0.03	0.03	0.04
Trade Trans Utilities	0.16	0.15	0.23	0.17	0.13	0.22	0.07	0.15	0.14
FIRE	0.08	0.05	0.21	0.10	0.17	0.20	0.06	0.13	0.14
Business services	0.07	0.02	0.09	0.06	0.02	0.08	0.02	0.04	0.04
Education Healthcare	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hospitality	0.01	0.01	0.02	0.02	0.01	0.02	0.00	0.01	0.01
Personal services	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Households	0.00	0.00	0.00	-0.00	0.00	0.00	-0.00	0.00	0.00
Total	0.51	0.39	0.94	0.58	0.46	0.85	0.29	0.59	0.55

Note: Reported are contributions by country/region to line 9 in Table 5 in percentage points over various subperiods. Results with markups.

Table B.10: List of countries in each vintage of SEA and the ones that have PPP data

	Country	SEA 2013	SEA 2016	PPP
1.	Australia	✓	✓	✓
2.	Austria	✓	✓	✓
3.	Belgium	✓	✓	✓
4.	Bulgaria	✓	✓	✓
5.	Brazil	✓	✓	✓
6.	Canada	✓	✓	✓
7.	Switzerland		✓	
8.	China	✓	✓	✓
9.	Cyprus	✓	✓	✓
10.	Czech Republic	✓	✓	✓
11.	Germany	✓	✓	✓
12.	Denmark	✓	✓	✓
13.	Spain	✓	✓	✓
14.	Estonia	✓	✓	✓
15.	Finland	✓	✓	✓
16.	France	✓	✓	✓
17.	United Kingdom	✓	✓	✓
18.	Greece	✓	✓	✓
19.	Croatia		✓	
20.	Hungary	✓	✓	✓
21.	Indonesia	✓	✓	✓
22.	India	✓	✓	✓
23.	Ireland	✓	✓	✓
24.	Italy	✓	✓	✓
25.	Japan	✓	✓	✓
26.	South Korea	✓	✓	✓
27.	Lithuania	✓	✓	✓
28.	Luxembourg	✓	✓	✓
29.	Latvia	✓	✓	✓
30.	Mexico	✓	✓	✓
31.	Malta	✓	✓	✓
32.	Netherlands	✓	✓	✓
33.	Norway		✓	
34.	Poland	✓	✓	✓
35.	Portugal	✓	✓	✓
36.	Romania	✓	✓	✓
37.	Russia	✓	✓	✓
38.	Slovakia	✓	✓	✓
39.	Slovenia	✓	✓	✓
40.	United States	✓	✓	✓
41.	Turkey	✓	✓	✓
42.	Taiwan	✓	✓	
43.	United States	✓	✓	✓

Table B.11: Country Classification

Region	Country
Euro Area	Germany, France, Austria, Italy, Belgium, Cyprus, Spain, Estonia, Finland, Greece, Ireland, Lithuania, Luxembourg, Latvia, Malta, Netherlands, Portugal, Slovakia, Slovenia
Other Advanced	Canada, South Korea, Taiwan, Australia, Switzerland, Denmark, Sweden, Norway, Bulgaria, Czech Republic, Croatia, Hungary, Poland, Romania
Other Emerging	Indonesia, Turkey, Mexico

Table B.12: Industry Classification

Major sector	ISIC v3 industries included[1]
Agriculture	Agriculture, Forestry, Fishing and Hunting, Mining
Construction	Construction
Nondurable manufacturing	Manufacturing
Durable manufacturing	Manufacturing
Trade, transportation and utilities	Wholesale Trade, Retail Trade, Transportation and Warehousing, Utilities
Finance, insurance and real estate (FIRE)	Finance and Insurance, Real Estate Rental and Leasing
Business services	Information, Professional, Scientific, and Technical Services, Management of Companies and Enterprises
Education and healthcare	Educational Services, Health Care and Social Assistance
Hospitality	Accommodation and Food Services
Personal services	Arts, Entertainment, and Recreation, Other Services, Administrative and Support and Waste Management and Remediation Services
Government	Public Administration
Households	

[1] For WIOD vintage 2016 ISIC v4 industries are aggregated to ISIC v3 using the crosswalk provided in the data documentation (Gouma *et al.* , 2018).

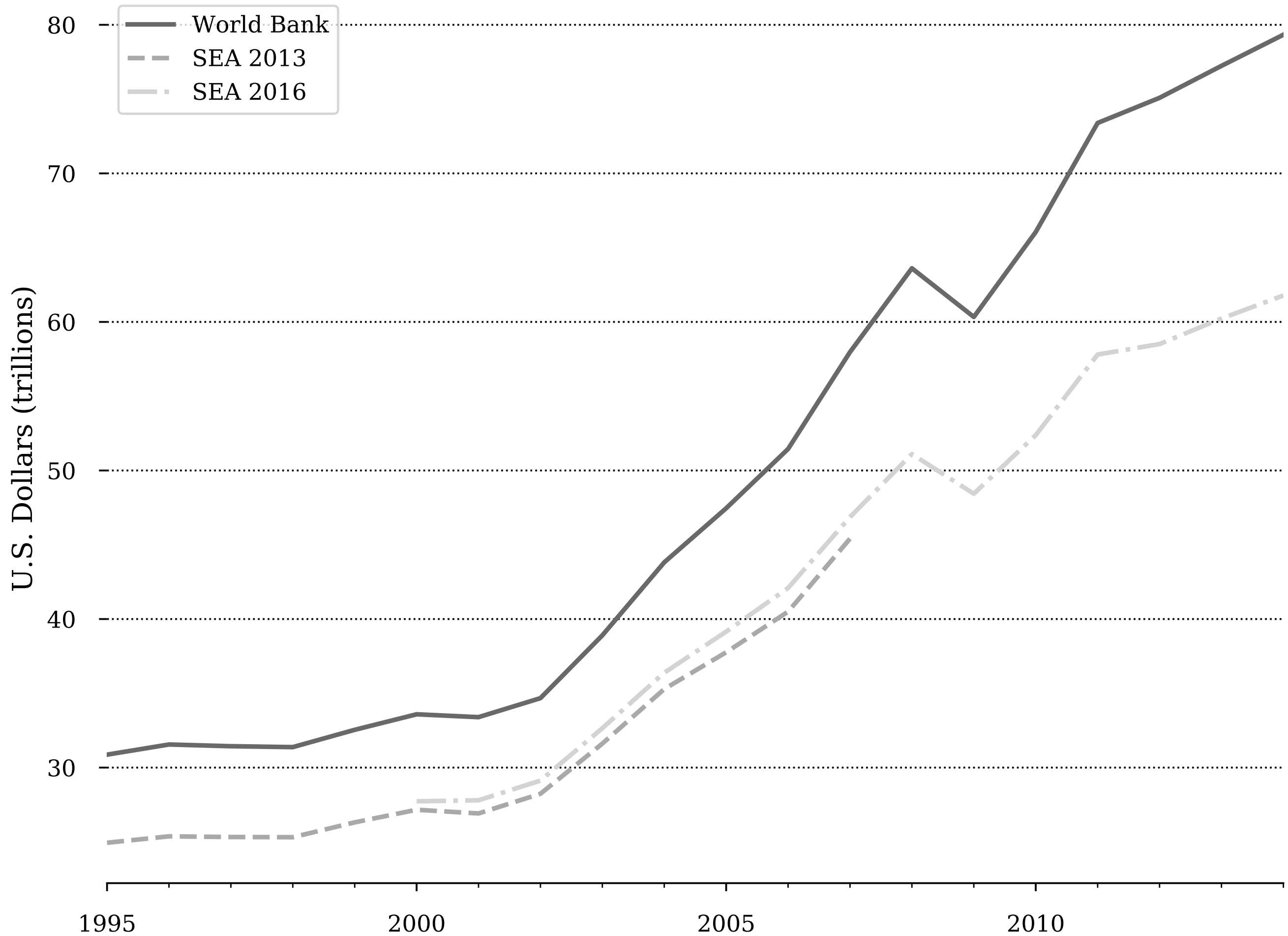

Figure B.1: Nominal world GDP in WIOD-SEA and WDI

Source: Timmer (2012) and World Bank (2018).

Note: SEA data is total nominal value added for all industries and countries in both vintages of the WIOD. All measures are reported in current U.S. $.

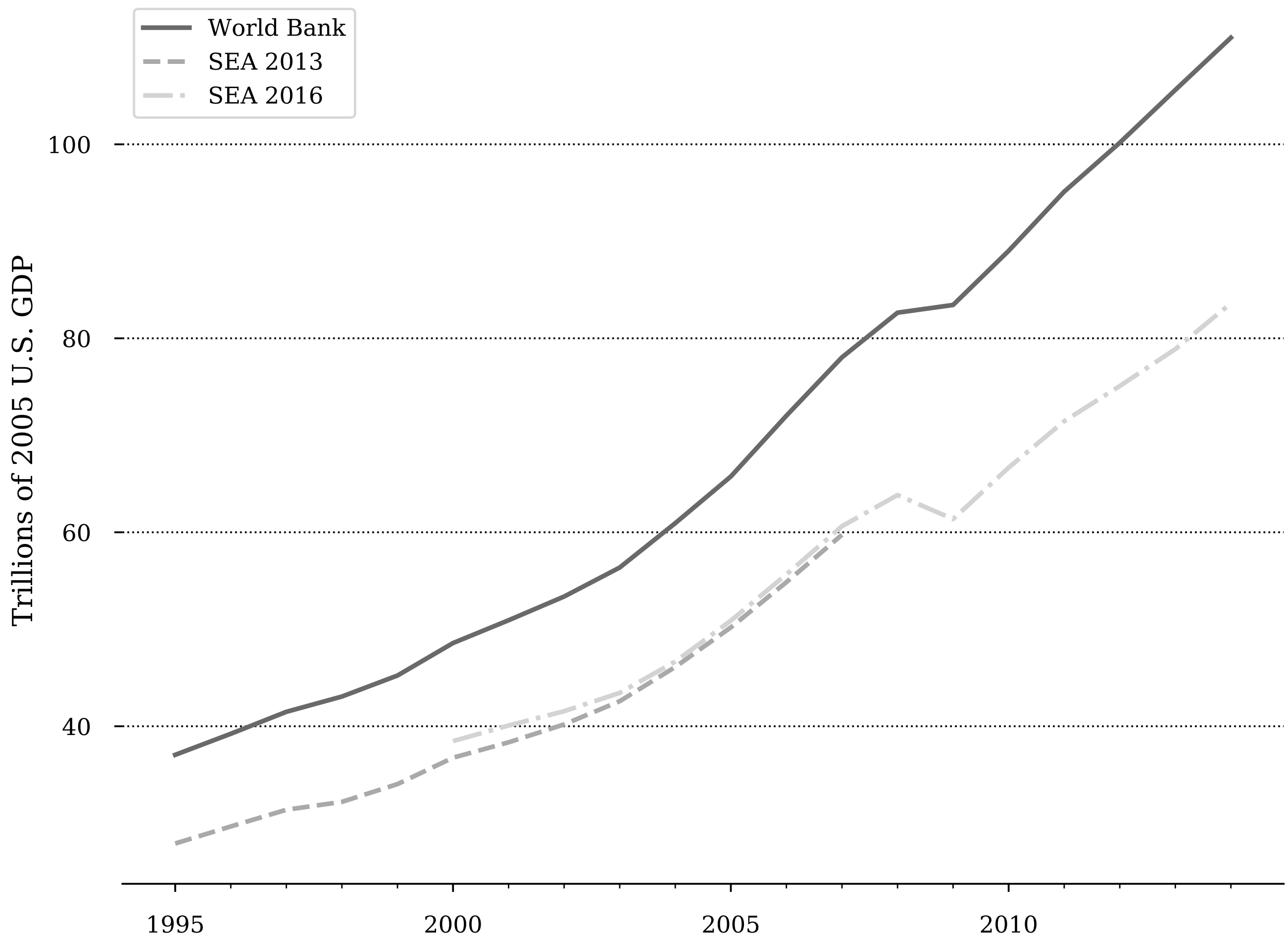

Figure B.2: World GDP PPP in WIOD-SEA and WDI

Source: Timmer (2012), and World Bank (2018), and authors' calculations.
Note: SEA data is total value added PPP for all industries and countries in both vintages of the WIOD. All measures are reported in U.S. $ of 2005 U.S. GDP.

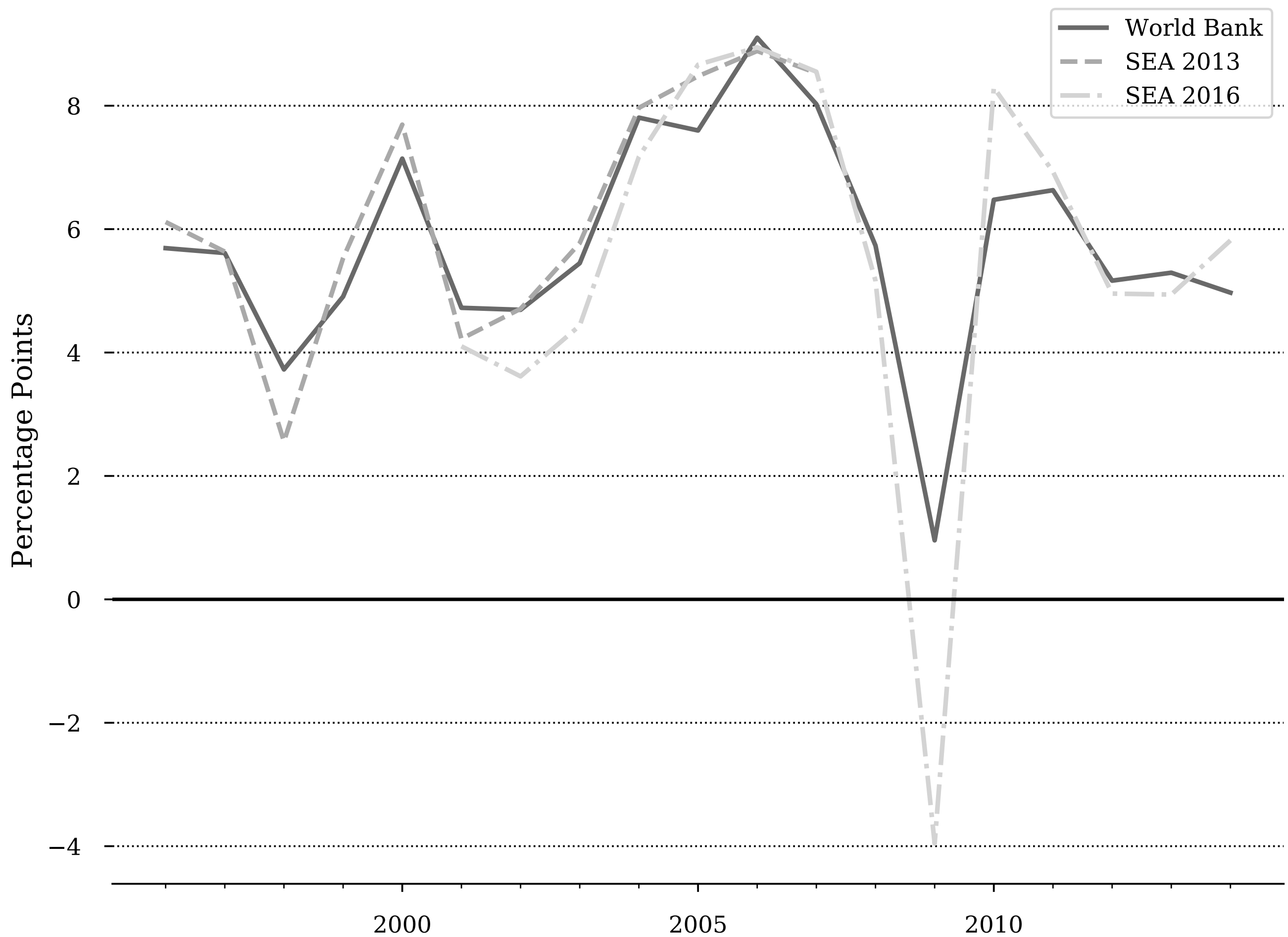

Figure B.3: Growth in world GDP PPP in WIOD-SEA and WDI

Source: Timmer (2012), and World Bank (2018), and authors' calculations.

Note: World GDP PPP growth is constructed as real PPP-adjusted value-added share weighted average of nominal GDP or real country-industry value-added PPP growth.