# DISCUSSION PAPER SERIES

DP17452

## World Productivity: 1996 - 2014

John Fernald, Mehrdad Esfahani and Bart Hobijn

**MACROECONOMICS AND GROWTH**

CEPR

ISSN 0265-8003

# World Productivity: 1996 - 2014

*John Fernald, Mehrdad Esfahani and Bart Hobijn*

Discussion Paper DP17452
Published 09 July 2022
Submitted 06 July 2022

Centre for Economic Policy Research
33 Great Sutton Street, London EC1V 0DX, UK
Tel: +44 (0)20 7183 8801
www.cepr.org

# World Productivity: 1996 - 2014


## Abstract

We use a new growth accounting method to quantify the drivers of world total factor productivity (TFP) growth during 1996-2014 and uncover four main results. World productivity growth is volatile from year to year. This mainly reflects reallocation of labor across country-industries. The contribution of country-industry level productivity growth to world productivity is relatively constant over time. This constancy masks that the increased importance of emerging economies offset a productivity slowdown in advanced economies; after 2008, this offsetting effect dissipated and world TFP growth declined. These conclusions are robust to the inclusion of markups in the analysis.



JEL Classification: F43, O47, O50

Keywords: Growth accounting, Productivity, World Economy



John Fernald - fernaldjg@gmail.com
*INSEAD, Federal Reserve Bank of San Francisco and CEPR*

Mehrdad Esfahani - mehrdad.esfahani@asu.edu
*Arizona State University*

Bart Hobijn - bart.hobijn@chi.frb.org
*Federal Reserve Bank of Chicago*



Acknowledgements
We thank seminar participants at several academic and policy institutions for helpful comments and feedback. We also like to thank Patryk Perkowski for his excellent research assistance. Mehrdad Esfahani acknowledges financial support from the Center for the Study of Economic Liberty (CSEL). The views expressed in this paper are those of the authors and do not necessarily reflect the position of the Federal Reserve Bank of Chicago, the Federal Reserve Bank of San Francisco, the Federal Reserve System, or CSEL.

# World Productivity: 1996 - 2014*

Mehrdad Esfahani — Arizona State University
John G. Fernald — INSEAD and FRBSF
Bart Hobijn — FRB Chicago

June 25, 2022

**Abstract**

We use a new growth accounting method to quantify the drivers of world total factor productivity (TFP) growth during 1996-2014 and uncover four main results. World productivity growth is volatile from year to year. This mainly reflects reallocation of labor across country-industries. The contribution of country-industry level productivity growth to world productivity is relatively constant over time. This constancy masks that the increased importance of emerging economies offset a productivity slowdown in advanced economies. After 2008, this offsetting effect dissipated and world TFP growth declined. These conclusions are robust to the inclusion of markups in the analysis.

**Keywords:** Growth accounting, productivity, world economy.

**JEL codes:** F43, O47, O50.

*Correspondence: mehrdad.esfahani@asu.edu, john.fernald@insead.edu and bart.hobijn@chi.frb.org. We thank seminar participants at several academic and policy institutions for helpful comments and feedback. We also like to thank Patryk Perkowski for his excellent research assistance. Mehrdad Esfahani acknowledges financial support from the Center for the Study of Economic Liberty (CSEL). The views expressed in this paper are those of the authors and do not necessarily reflect the position of the Federal Reserve Bank of Chicago, the Federal Reserve Bank of San Francisco, the Federal Reserve System, or CSEL.

# 1 Introduction

We trace growth in world total factor productivity from 1996-2014 to its industry sources, using data on more than 36 industries and 40 countries. "World productivity" appears in models of economic growth and innovation (e.g., 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, as well as by factor reallocation and markups.

Our results provide a clear narrative regarding global Total Factor Productivity (TFP). First, world productivity growth is highly volatile from year-to-year and even over multi-year periods. Second, the bulk of the volatility in world productivity growth is due to the (net) reallocation of labor across countries. Mechanically, labor reallocation is negative for world productivity growth if labor grows faster in low-wage country-industries. Third, the contribution of underlying productivity growth at the country-industry level (that is, the weighted average of productivity growth across the country-industry combinations in our data) is much less volatile than world TFP. Fourth, the productivity slowdown in advanced economies in the early 2000s was offset by an acceleration in emerging markets, resulting in relatively constant world productivity growth until the Great Recession.[1] After that, productivity growth in emerging economies also slowed and world productivity growth sagged.

This narrative is not affected by the inclusion of markups in our calculations. Even though the markups we impute are large and rise over time, they only modestly impact measured industry-level productivity growth. Instead, they primarily affect the direct contribution of capital (because the markup-corrected share of capital in revenue is lower) as well as the quantified effect of capital reallocation on world

[1] See, for example, Fernald (2015), ECB (2017), and Fernald & Inklaar (2020) for studies that quantify the productivity slowdown in advanced economies.

productivity growth. These shifts are not central to the main points described above.

In order to document this narrative, we make a methodological contribution and construct a new dataset to apply our new method. Our methodological contribution is that we develop a new global growth-accounting decomposition. It generalizes the one in Jorgenson *et al.* (1987) in that it separates (world) GDP growth not only into parts due to country-industry specific technology, hours growth, capital input growth, and factor reallocation, but also quantifies the impact of markups due to shifts in economic activity across countries and sectors.

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

The second strand of the literature, based on the methodology pioneered by Domar (1962), Hulten (1978), and (especially) Jorgenson *et al.* (1987), studies productivity growth using industry-level data.[2] These studies analyze the industry origins of productivity growth and the importance of the factor reallocation, but only at the country level or for a few countries. This second strand of the literature does not account for markup distortions in output markets. In the presence of markups of price over marginal cost, the TFP changes quantified in these studies are, in general, not changes in technology.

The third strand corrects country-industry TFP changes for markups (Hall, 1986; Basu & Fernald, 1997, 2002; Baqaee & Farhi, 2019). If firms have different markups of price over marginal cost, then society, in general, values resources differently in different uses. Reallocating resources towards more socially valued uses then raises

[2]Studies in this literature include Fernald (2015) 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.

world TFP, even if country-industry technology doesn't change. Intuitively, sectors with markups have inefficiently low levels of output. Hence, shifting economic activity towards these sectors alleviates these markup distortions and contributes positively to GDP growth. We account for this effect by quantifying the markup-weighted reallocation of economic activity based on relative output growth across sectors.[3]

The data we use are two vintages (2013 and 2016) of the World Input-Output Database (WIOD), described in Timmer (2012) and Timmer *et al.* (2015); we extend the data in several ways. The WIOD contain input-output and productivity data for more than 40 countries and 36 industries from 1996-2014. The country-industry combinations in our data produce about 80 percent of World GDP measured in dollars over the years in the sample. Industry-level capital services are missing from the 2016 vintage of the data. We address this shortcoming by constructing the missing capital services data. We also extend recent work by Barkai (2020) and Karabarbounis & Neiman (2018) and 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; a sizeable role for labor reallocation; relatively smooth country-industry productivity; and the productivity slowdown—are robust to different measurement assumptions. They hold under the Solow assumption of perfect competition (price equals marginal cost, Jorgenson *et al.*, 1987), and for TFP calculated using our markup estimates.[4]

[3]A more ambitious approach is to further decompose output growth in these sectors in terms of their labor and capital inputs, intermediate purchases from other sectors, and technology. As we discuss in 2.3, because of markups on intermediate purchases, the decomposition is not unambiguous: it requires additional, specific assumptions about the shape of the production function and/or where marginal industry output goes. Our decomposition is also closely related to Hsieh & Klenow (2009). Our growth accounting requires little structure other than cost-minimization. We are then able to analyze observed shifts and reallocations, taking as given the (potentially) distorted equilibrium. But without additional structure (e.g., on the demand side of the economy), we cannot do counterfactuals the way Hsieh & Klenow (2009) can. Fernald & Neiman (2011) also discuss links between growth-accounting approaches and the Hsieh & Klenow (2009) approach in a two-sector setting.

[4]In the appendix we show they also hold when Average Labor Productivity (ALP) is used as the measure of productivity and when output shares are measured in country-industry specific PPP deflators (Timmer *et al.*, 2007) rather than U.S. dollars.

Our approach is as follows. As a benchmark, we start with the decomposition based on Jorgenson *et al.* (1987). We then explain how the factor reallocation and markup terms, in our alternative accounting identity, can be interpreted as resulting from wedges in the factor and product markets. We are deliberately agnostic about the sources of these wedges and do not provide a specific normative interpretation. In the final section of the paper we discuss different reasons why such wedges could exist, both in terms of misallocation as well as other deviations from the core assumptions that result in market efficiency. This is particularly pertinent for the reallocation of labor term that plays a central role in our results.

# 2 Global growth accounting

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 factor reallocation and markups.

Our decomposition draws on a long literature, starting with Domar (1962) and Hulten (1978), tracing aggregate productivity to its industry sources. Hulten considered the case where factor prices are equalized across industries. Jorgenson *et al.* (1987) go a step further in allowing factor-price differences across industries.[5] Basu & Fernald (2002), Baqaee & Farhi (2019), and Baqaee & Farhi (2021) extend the Jorgenson and Hulten results to a setup with 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

[5] Jorgenson *et al.* (1987) make an even more substantive contribution in developing a comprehensive U.S. KLEMS dataset that allows them to implement their decomposition. Every KLEMS dataset, including the WIOD that we use, builds on that seminal contribution.

the impact of particular wedges in product and factor markets. It is important to recognize that, in the presence of such wedges, there is no unique decomposition. 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 wedges in factor and product markets. The latter is in the form of markups.

The specific decomposition we use here is designed to do so. We discuss how wedges result in terms related to factor reallocation and markups. Throughout the next three sections, we focus on the positive interpretation of these terms as reflecting the impact of changes in allocations on world GDP growth resulting from these wedges. In the final section of the paper we discuss both the narrow interpretation of these wedges as the results of misallocation as well as those resulting from other deviations from the core assumptions that yield efficiency in the competitive allocation. Throughout the first part, we use the terms wedges and distortions interchangeably.

## 2.1 Producer level

We analyze the static cost-minimizing decisions of producers to purchase inputs, and on how those decisions are affected by technology and factor prices. The (world) economy has $n$ sectors, indexed by $i = 1 \ldots n$. Each sector reflects a particular country-industry combination.

The producers in each sector take technology, $Z_i$, as given.[6] Producers pay $R_i$ to rent capital, $W_i$ to hire workers, and $\left(1 + \tau_i^j\right) P_j$ to purchase intermediate inputs of product $j$ (so $P_j$ is the net price received by the producer of product $j$). Any (implicit or explicit) taxes on capital or labor usage are incorporated into the $W_i$ and $R_i$. Such taxes would affect the interpretion of some of the effects, but not their derivations.

Producers choose factor inputs, $\left\{K_i, L_i, \{M_{i,j}\}_{j=1}^{n}\right\}$, to minimize cost:

[6] $Z_i$, and all variables below, have time subscripts that we suppress for readability.

$$R_iK_i + W_iL_i + \sum_j \left(1+\tau_i^j\right) P_jM_{i,j}, \tag{1}$$

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

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

Producers in sector $i$ charge a price, $P_i$, that includes a potential net markup, $\mu_i$, over marginal cost. In other words, if $MC_i$ is marginal cost, then $(1+\mu_i) = P_i/MC_i$.

The envelope theorem tells us that the Lagrange multiplier in the cost-minimization problem equals marginal cost. Hence, we can write firms' intratemporal cost-minimizing first-order conditions for capital, labor, and intermediate inputs as

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

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

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

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

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

As is standard since Solow (1957), we differentiate the production function to express output growth, $\dot{y}_i$, as the output-elasticity-weighted growth in factor inputs plus the contribution of technological progress. We follow Hall (1990) and use (4) to substitute for the output elasticities (normalizing the elasticity with respect to technology to one, $F_i^Z Z_i/F_i = 1$). This yields

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

With zero profits, payments to factors of production exhaust revenue and factor shares sum to one. They sum to less than one if there are pure economic profits. We have suppressed time subscripts, but factor shares and the markup can vary with time.

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

Concretely, 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, $\dot{z}_i$ is no longer (in general) a measure of technology change, so its economic interpretation is less clear.

Aggregate output is a value-added concept, which nets out intermediate-input use. So 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).

Rearranging (5), we obtain

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

Combining the equation with (6) yields the following expression for industry value added growth:

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

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, $s_i^L = W_i L_i/(P_i^V V_i)$.

The second and third terms in equation (8) show that growth in value added depends on share-weighted growth in capital, 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 value added also grows through the growth of profits, captured by the first term in the above equation. Gross output growth in sectors with markups reduces the distortion caused by the markups that result in an under-supply of goods and services in these industries (Basu & Fernald, 2002).

Throughout this paper, our decomposition includes the first term in (8) as capturing this effect of markups. However, output growth, $\dot{y}_i$ itself in turn depends on the growth of technology, capital, labor, and intermediate inputs. So, in principle one can work through the inter-industry relationships to split this into terms related to not only industry $i$'s technology, capital, and labor growth, but also those of other industries through the direct and indirect deliveries of intermediates. But making the results economically interpretable requires specific assumptions about the marginal allocation of changes in inputs and in production in each of the sectors. In order not have our results depend on these assumptions we refrain from doing so.

## 2.2 Aggregate growth accounting

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

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

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

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

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

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

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 output growth to the contributions 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.

Aggregate productivity is typically defined in terms of aggregate inputs. For example, aggregate labor input is given by the sum of hours across country-industries, $L = \sum_i L_i$. To get a representation in terms of these aggregate inputs, we add and subtract growth in aggregate capital and labor as well as in a measure of "average" gross output growth, $\dot{\bar{y}}$ (defined below). The resulting decomposition, which we will use for our analysis of world productivity, is

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

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

$$s^K = \sum_i s_i^V s_i^K, \text{ where } s_i^K = \frac{R_i K_i}{P_i^V V_i} \text{ and } s^L = \sum_i s_i^V s_i^L, \text{ where } s_i^L = \frac{W_i L_i}{P_i^V V_i}. \tag{12}$$

These shares include any implicit or explicit tax wedges in factor costs. For example, labor costs are from the point of view of employers. $s^D = \sum_i s_i^D$ is the aggregate Domar weight (which exceeds one), $\dot{\bar{y}} = \sum_i s_i^D \dot{y}_i$ is Domar-weighted gross-output growth and $\frac{\bar{\mu}}{1+\bar{\mu}} = \frac{1}{s^D} \sum_i s_i^D \frac{\mu_i}{1+\mu_i}$ measures average markups.

Equation (11) allows us to account for the drivers of growth in real value added in the world economy. The first three terms in the first line are the direct effect of technology and the contributions of growth of aggregate capital and labor. The final term in the first line can be interpreted as the average effect of changes in markup distortions in product markets, which Hall (1986) and Hall (1990) emphasized. As the first-order conditions (in elasticity form) (4) show, the output elasticity of each factor, including intermediate inputs, exceeds its revenue share.

The terms in the second line account for reallocations of productive resources in the world economy among country-industries with different markups or that face different factor costs. The first term captures the weighted covariance between output growth and markups. (As a covariance, the weighted average $\dot{y}$ is rescaled by $\frac{1}{s^D}$; that rescaling controls for the fact that the Domar weight $s^D$ exceeds one). This term captures the fact that aggregate output grows if industries with higher markups (and, therefore, a higher wedge between marginal rates of transformation and marginal rates of substitution) grow faster. Firms with monopoly power underproduce relative to the social optimum; as Basu & Fernald (2002) point out, shifting resources towards firms with higher-than-average markups means shifting resources towards where they have a higher social value, which increases aggregate output.

The final two terms reflect reallocations of capital and labor input. To understand these terms better, consider a rearrangement of the labor-reallocation term; the intuition for the capital-reallocation term is analogous. First, define the cross-sectional (across countries and industries) world average gross hourly wage in a given year as $\overline{W} = \left(\sum_i W_i L_i\right)/L$. Second, note that, since world hours are the simple sum across country-industries, growth in world hours is

$$\dot{l} = \sum_i \left(\frac{L_i}{L}\right)\dot{l}_i = \sum_i \left(\frac{\overline{W}L_i}{\overline{W}L}\right)\dot{l}_i. \tag{13}$$

In the definition of labor reallocation, we use (13) to substitute for $\dot{l}$. We note that $s_i^V s_i^L = \frac{W_i L_i}{PV}$ and the aggregate labor share is $s^L = \frac{\overline{W}L}{PV} = \sum_i \frac{W_i L_i}{PV}$. We find:

$$\begin{aligned} \sum_i s_i^V s_i^L \left(\dot{l}_i - \dot{l}\right) &= \sum_i \left(\frac{\left(W_i - \overline{W}\right)L_i}{PV}\right)\dot{l}_i & (14) \\ &= \frac{1}{PV}\sum_i \left(W_i - \overline{W}\right) dL_i. & (15) \end{aligned}$$

Thus, mechanically, the labor reallocation term reflects the covariance of country-industry (gross) wages and changes in labor input (where $dL_i \equiv L_i\dot{l}_i$). If wage differences do not covary with labor input changes, then labor reallocation is zero.

In Section 4, we find this labor reallocation term is quantitatively important, both on average and for volatility. The reason is that wages differ substantially across countries. From the first-order conditions, wage differences correspond to differences in marginal products. Section 5 discusses normative interpretations of this term.

## 2.3 Discussion of alternative aggregation equations

Our decomposition in equation (11) differs from others in the literature. We discuss the key differences here. Our starting point is the observation that alternative decompositions can all be interpreted as accounting identities. That is, all of them are equally "correct" in an accounting sense, in that all of them decompose the aggregate data perfectly. As noted in Section 2.1, this requires that the technology residuals $z_i$'s be calculated using the same $\mu_i$'s used in the rest of the decomposition. Some decompositions also add additional structure in order to allow further interpretation of the terms. Importantly, if the benchmark assumptions are not correct, the various terms may not have a clear economic interpretation.

Hulten (1978) derives the baseline neoclassical case with an efficient allocation and no distortions in product and factor markets. In (11), that is the case where all net markups are zero (for all $i$, $\mu_i = 0$) and all country-industries face the same factor prices (e.g., for labor, $W_i = \overline{W}$ for all $i$).

Jorgenson *et al.* (1987) retain the no-markup assumption, but allow for factor-market distortions. This is the special case of (11) in which all markups are zero, but the factor reallocation terms are not. If there are, in fact, markups, then the missing markup terms in (11) will affect the measured capital share (and thus capital's contribution to growth), the capital reallocation term, and the country-industry technology term. The labor terms are not affected.

Where we differ from other papers is how we handle the existence of markups. With markups, there is no unique decomposition of aggregate output into its industry sources, because the effect on output depends on how the extra output is allocated across industries. The first-order conditions in (3) show that markups create a wedge between the "cost" of a factor and the value of its marginal product.[7] 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.

Basu & Fernald (2002) contain the first industry-to-aggregate sources-of-growth decomposition with markups. To split aggregate output growth into parts due to capital, labor, and technology, they impose assumptions about how marginal output is allocated. They addressed the ambiguity that arises with markups by explicitly (p. 979) deciding their decomposition should be correct in the context of then-typical representative-agent models with imperfect competition (e.g., Rotemberg & Woodford (1995)). Those models assume that gross output and intermediate inputs are used in fixed proportions.[8] If, in fact, this Leontief assumption does not hold, then the Basu-Fernald identity has an additional term for the reallocation of intermediate inputs. This term is interpretable in the context of the symmetric Basu (1995) model. Other studies, e.g. Petrin & Levinsohn (2013), Osotimehin (2019) and, more recently, Baqaee & Farhi (2019, 2021), have made different assumptions about this allocation rule. For example, Baqaee & Farhi take as their benchmark for measuring aggregate technology the case where, following an industry technology shock, all uses of industry output expand in equal multiplicative proportions.

In contrast, our decomposition in (11) does not make any assumptions about this marginal allocation rule. As a result, it does not split the effect of markups up

[7] It is the *value* of the marginal product ($P_i \partial F_i / \partial J_i$, for any input $J_i$) that matters for aggregate output, not just the marginal revenue product ($\frac{P_i}{1+\mu_i} \partial F_i / \partial J_i$). The reason is that aggregate output is valued using prices (marginal rates of substitution).

[8] If intermediate inputs and gross output are used in fixed proportions ($\dot{y}_i = \dot{m}_i = (\sum_j \tilde{s}_i^j \dot{m}_{i,j}) / \tilde{s}_i^M$ where $\tilde{s}_i^M = \sum_j \tilde{s}_i^j$), then it is straightforward to show that industry value-added growth can be written so that it does depend just on primary input growth; there is a "value-added' markup multiplying share-weighted primary input growth that exceeds the gross-output markup $\mu_i$. Otherwise, intermediate input changes also affect industry value added (see Basu & Fernald (1995)). This illustrates why it is necessary to make assumptions about where marginal output goes.

into parts due to technology and factor input growth across the different sectors in the world economy. Instead, (11) isolates each distortion (markups and factor-price differentials) into distinct terms in the decomposition.[9]

We view this generality as a virtue, since we do not require strong assumptions. However, it comes at the cost of not having a complete sources-of-growth analysis tracing movements in aggregate output to country-industry capital, labor, and TFP.

# 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.[10] Two vintages of the WIOD have been released, one in 2013 and one in 2016. We calculate results using both of them.

To implement our continuous-time equations, we use Tornquist approximations. Growth rates of all variables are log-changes, and time-varying factor shares for any given year $t$ are the average share in years $t$ and $t-1$.

## 3.1 Comparison across vintages and with other data sources

The two vintages differ somewhat in the industries, countries, and years covered. The two vintages contain an overlapping period from 2000-2007. We use this period in the

[9] One additional difference between our analysis and that in Baqaee & Farhi (2019, 2021) is that we do not transform all "distortions" (including differential factor prices) into markups. This turns out to be important, because the effects of markups and differential factor prices 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 (2019) is related to conventional growth accounting results.

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

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 compares the two vintages of the WIOD that we use. 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 is largely comparable across vintages. The 2016 vintage contains three additional countries, namely Norway, Switzerland, and Croatia. These countries are relatively small, so the average share of world GDP covered is similar in the two vintages. At times, we aggregate our results into regions or country blocks.

We also present results for major sectors of the economy. Each sector comprises ISIC industries for which the WIOD data are 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.[11]

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 is constructed in the two vintages.[12] Second, the 2016 vintage does not contain data on capital price deflators. We supplement the available WIOD data and construct such deflators using data from OECD (2017).

For the overlapping years, aggregates from the two vintages line up closely, as well as with world-level aggregates from the World Bank (2018).[13] Figure 1 shows that real GDP growth in the WIOD data mimics that of world GDP.[14] World GDP accelerates

[11] Regions, country blocks, major sectors are listed in Tables D.14 and D.15 in Appendix D.2.

[12] We discuss these differences in more detail in Appendix D.2.

[13] 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. $\tau_i^j$ in our theoretical framework. Of course, our data also do not cover all countries in the world.

[14] See Appendix D.1.1 for a comparison of nominal GDP measures.

after 2000 up until the Great Recession in 2008. Global economic activity shrank in 2008, before accelerating again during the recovery phase of 2009-2014. In the World Bank (2018) data, world real GDP growth is a bit higher after 2002, because our sample of countries does not include some fast-growing emerging economies.

So, our sample covers more than 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 Mapping decomposition to data

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 inputs and markups.

*Gross output and value added*: Nominal gross output, $P_i Y_i$, nominal value added, $P_i^V V_i$, along with quantity and price indexes are directly reported. The growth in real gross output, $\dot{y}_i$, and real value added $\dot{v}_i$ can be calculated directly.

*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. $W_i L_i$ is also directly reported.

*Markups and payments to capital*: To implement our growth accounting equation, (11), we require markups for all industries. Relatedly, we need capital shares based on required payments to capital, which do not include pure profits. We estimate required payments to capital and infer the level of markups, $\mu_i$, in a similar manner to Barkai (2020) and Karabarbounis & Neiman (2018).

The part of nominal value added that is not paid to labor consists of required payments to capital plus pure economic profits. Denoting profits by $\Pi_i$, we can write

$$P_i^V V_i - W_i L_i = R_i K_i + \Pi_i. \quad (16)$$

We first estimate required payments to capital, $R_i K_i$, and then impose constant returns to scale to back out a markup consistent with the implied profit rate.[15] First, we follow Jorgenson (1963) to estimate a required return on capital, $R_i$, by assuming that the nominal capital service flows equal a real cost of capital multiplied by the nominal replacement value of the capital stock. The cost of capital consists of a nominal return on capital corrected for depreciation and capital price inflation. We use the 10-yr BBB U.S. nominal corporate bond rate as the nominal rate.[16]

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. Under this assumption, profits equal $\Pi_i = (\mu_i/(1+\mu_i))\, P_i Y_i$. [17]

## 3.3 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 shares in

[15] Recent literature (e.g., Karabarbounis & Neiman (2018)) points out that "profits" potentially include payments for unmeasured capital, notably intangible capital, as well as pure economic profits. Hence, if the accounting identity in (16) 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. Even our measures of standard capital do not include land or inventories. As a result, we are bound to find higher profit estimates than datasets that do include these types of capital.

[16] Qualitative results are similar using the 10-year U.S. treasury yield, e.g. Schmelzing (2017).

[17] Baqaee & Farhi (2019) use direct estimates of firm-level markups from De Loecker *et al.* (2020). The magnitude of these estimates hinges on what is assumed to make up variable costs for firms (Traina (2018)); estimates are also not available for all countries. More importantly, in our aggregate growth accounting framework such firm-level markups would not be the right measure: They would also be non-zero in the case of Hopenhayn & Rogerson (1993), where industry technology has constant returns to scale and the market allocation is efficient, even though firms charge a markup to cover entry costs or fixed operating costs. Hall (1990) and Basu & Fernald (1997) estimate industry returns to scale and markups jointly, but their data-intensive approach is not possible with 1400 industries in 40 countries. The constant-returns-to-scale assumption is not innocuous here. For example, Ruzic & Ho (2021) find that in U.S. manufacturing, profit rates rose in the 1990s and 2000s despite roughly constant markups, because returns to scale fell (from increasing to constant).

world value-added (in current U.S. dollars).

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.

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.

The other shares that matter for our analysis 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). However, the decline in the labor share pales in comparison to the movements in the factor shares of capital and profits. Just like Barkai (2020) for the United States, we find that the capital share in world GDP has declined substantially, 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 in our estimates 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.

# 4 Results

We use the two WIOD vintages to construct annual estimates of each of the components of equation (11). The key takeaways from this section are that (i) world productivity growth is volatile from year to year or over multi-year periods; (ii) Reallocation, particularly labor reallocation, explains the bulk of the high-frequency volatility in world productivity; (iii) Underlying country-industry productivity growth is relatively smooth; and (iv) the productivity slowdown in advanced economies was first masked by high productivity growth in India and China and only showed up in world TFP growth since the Great Recession.

As a baseline, we start with a restricted decomposition that assumes no-markups, which amounts to a global version of Jorgenson *et al.* (1987). We then drop the no-markup assumption and present the results for the general decomposition implied by (11). Our key takeaways are robust to whether or not markups are included.

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 for a direct comparison of results. We focus primarily on the qualitative results that both vintages have in common, rather than on the precise numbers.[18]

### World TFP growth without accounting for markups

Following Jorgenson *et al.* (1987), we implement equation (11) assuming net markups are zero everywhere. Table 2 shows the results by subperiod for the two vintages. The rows correspond to components of equation (11). 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 the contribution of aggregate capital growth, $s^K \dot{k}$, to world GDP growth for the subperiods in our data. There is a substantial discrepancy between

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

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, $1 - s^L$) in the 2016 vintage, as shown in Figure 2.

Line 3 shows the contribution of growth in world hours to world GDP growth. Comparing the 2001-2004 and 2005-2007 periods across vintages, one can see the discrepancy in hours growth across vintages that we discussed in Subsection 3.1. Specifically, the contribution of world growth in hours in the 2016 vintage was 0.77 percentage point lower from 2001-04 than in the 2013 vintage, but then was 0.25 percentage point higher from 2005-07.

These revisions of both the capital and labor contributions between vintages, though large, do not substantially affect the key takeaways from this section. Lines 4, 8, and 14 show the first three takeaways. Line 4 reveals the first one, that world TFP growth is volatile across the five subperiods that we consider. It is highly procyclical with the world business cycle, as captured by world GDP growth.

Line 8 shows our second takeaway, that the bulk of the volatility in world TFP growth arises from labor reallocation. Lines 9 and 10 show that this is mainly due to the reallocation of hours across countries as opposed to within countries.[19] As equation (14) shows, this term reflects the covariance between wage levels and hours growth. In line 8, the term is, on average, negative because labor has typically increased faster in country-industries with lower-than-average gross wages—notably, emerging markets, which saw higher population and economic growth rates over this period. Moreover, during recessions in industrialized countries, as in 2001 and 2008, the hours growth gap between industrialized and emerging economies is larger and, as a result, labor reallocation contributes more negatively to world GDP growth.

Line 14 shows the third takeaway: The country-industry component of TFP growth, $\sum_i \frac{1}{(1+\mu_i)} s_i^D \dot{z}_i$, is much less volatile than world TFP growth. Country-industry

[19] Appendix A details how we decompose terms into within- and across-country.

TFP growth was relatively strong prior to 2008, and then (looking at the 2016 vintage) declined markedly. Country-industry TFP growth was modestly negative from 2008-10 and was only weakly positive from 2011-2014.

In addition to these three takeaways, Table 2 shows sizable effects of capital reallocation (capital's analogue to the labor reallocation term (14)). Lines 6 and 7 of Table 2 are positive, implying 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. Most capital reallocation occurs between industries *within* countries (Line 6) rather than *across* countries (Line 7). Capital reallocation is largely due to two sectors: trade, transportation, and utilities as well as business services. Capital reallocation across countries accounts for a much smaller part of world GDP growth.

Though these results based in Jorgenson *et al.* (1987) are a useful benchmark, our estimates imply that profits make up a substantial, and increasing, fraction of world GDP. These results ignore this evidence. So, we now redo our decomposition accounting for the role of markups.

### World TFP growth with markups

Table 3 shows that our first three main results also hold when we explicitly account for markups. As in Table 2, this can be seen from line 4, which shows the volatility in world TFP; line 8 (which is identical to line 8 of Table 2), which shows the volatility of labor reallocation; and line 14, which shows that country-industry TFP is relatively smooth up until the Great Recession.

Still, even if the main takeaways remain, there are some notable differences. First, a substantial part of the growth contribution of aggregate capital from Table 2 is attributable to markups in Table 3. This can be seen by comparing Line 2 in the former with Lines 2 and 11 in the latter. The reason is that, without markups, capital's weight was $(1 - s^L)$. With markups and profits, however, this weight is split between capital and profits, $s^K + s^\Pi$. 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 account for markups, it is also remarkably constant, with a mean of 0.78, across subperiods and vintages. 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 2 almost disappear.

Compared with Table 2, the lower contribution of aggregate capital growth results in somewhat higher world TFP growth in line 4 of Table 3. That said, world TFP growth remains quite volatile across subperiods and slows substantially after 2007.

A second, and big, difference between the results with and without markups is the implied contribution of capital reallocation, reported in Lines 5 through 7 of the respective tables. After accounting for markups in Table 3, the measured effect of capital reallocation *within* countries (line 6) is small, particularly in the 2016 vintage. Intuitively, suppose a country-industry had a large markup. When we didn't account for the markup, then the large apparent economic profits were attributed to the user cost of capital, $R_i$, in order to make the accounting identity (16) hold. Hence, much of the apparent contribution of capital reallocation in the no-markup Table 2 reflected that sectors with high profit rates (rather than high user costs) had relatively fast capital growth. That is, we were conflating markups with differences in capital rental rates (and implied marginal products of capital). With or without markups, the effect of changes in the *cross-country* reallocation of capital (line 7) remains negligible.[20]

Lines 11 through 13 of Table 3 report the impact of markups on world GDP

[20]The reader might wonder why there is any capital reallocation term left, given we assume the same nominal return everywhere. The user-cost differences reflect differences in the levels and growth rates of capital deflators, which in part arises from the mix of types of capital (which we are not able to control for). Similarly, there are cross-country differences in average depreciation rates.

growth. These shifts add around half a percentage point annually to world GDP growth over the period we consider (Line 11). The bulk of this is due to changes in the average markup distortion (Line 12). Our detailed results indicate that the effect of shifts in markups across sectors (Line 13) on world GDP growth is mainly due to manufacturing, trade, and FIRE in China and the United States.

Finally, Line 14 of Table 3 lists the part of world GDP growth accounted for by country-industry specific TFP growth. The picture here is very similar to the no-markup case in Table 2. Before 2008 the contribution of country-industry specific TFP growth to world productivity was relatively constant at around 1.2 percent. After that, country-industry specific TFP growth declined to near zero during global financial crisis and recovered only modestly afterwards.

It is striking that allowing for markups makes so little difference to line 14, even though the country-industry technology is measured differently in the presence of markups. Rather, the effect of markups in line 11 largely comes out of a reduced contribution from capital (line 2) and within-country capital reallocation (line 6).

Figure 3 summarizes our first and third main takeaways graphically. It shows the time series of the estimates of World TFP growth by vintage and its country-industry components. For both vintages World TFP growth is much more volatile than its country-industry components.

The low volatility in the country-industry components before the Great Recession masks a shift in technology growth from advanced economies to emerging economies. This can be seen from Table 4, which splits Line 14 up by country. For both vintages of the WIOD, the table shows a marked reduction in the contribution of country-industry productivity growth of industrialized countries to World GDP growth that is offset by increase of the contribution of emerging economies, especially China. Since the Great Recession, growth in country-industry productivity has been markedly slower, dragged down by the contributions of both advanced and emerging economies.

# 5 Interpreting markup and factor reallocation terms

So far, we have interpreted the reallocation terms in equation (11) in a positive, or descriptive, way. Mechanically, as noted earlier, labor reallocation reflects the covariance of wage levels with labor input growth. But markups and differences in factor prices are often taken as evidence against allocative efficiency. This consideration suggests a normative interpretation of the markup and factor-reallocation terms.

From a normative point of view, the reallocation and markup terms can be interpreted as deviations from the benchmark efficient allocation considered by Hulten (1978). In the context of our analysis, efficiency requires five main assumptions that we now discuss: (*i*) No markups in product markets; (*ii*) no wedges between factor prices and marginal revenue products; (*iii*) comparable units of measurement of different types of capital and labor inputs; (*iv*) perfect tradability of output of all sectors; and (*v*) perfect mobility of production factors.

We now revisit each of the terms in (11) and discuss how they can be interpreted as deviations from one or more of these five assumptions. Deviations from the first two have clear normative implications in terms of misallocation. Deviations from the third and fourth suggest that the apparent labor reallocation might arise from measurement issues. The fifth suggests that the labor reallocation might not have a clear normative implication at all.

### (*i*) Markups and product market distortions

The last term in the first line and the first term on the second line of (11) capture the effects of markups. In a direct growth accounting sense, these terms capture the fact that, with markups, the revenue-share-weighted growth in primary inputs doesn't capture the full productive effect of capital, labor, and intermediate input usage.

Clearly, markups are also related to static efficiency and welfare. Markups most obviously lead to static efficiency losses by, for example, distorting the labor-leisure choice; or by distorting producers's choices about the use of intermediate versus primary inputs. Note also that we quantify the impact of resource changes starting from an already distorted allocation. In that case, output in sectors with high markups is relatively undersupplied. The markup term on the second line of (11) captures that output growth in sectors with markups alleviates this distortion.

Of course, the full dynamic general equilibrium effects of markups and the tradeoff between static markup distortions and dynamic Schumpeterian gains from innovation are complicated. We take the path of markups and technological change, $Z_i$, as given and without considerably more structure, which goes beyond the scope of this paper, we cannot quantify the full endogenous effects of markups.[21]

### *(ii)* Wedges between factor prices and marginal revenue products

In addition to markups, a second deviation from baseline efficiency considerations is wedges between factor prices and marginal revenue products, $(\frac{P_i}{1+\mu_i}\partial F_i/\partial J_i)$.

Equation (15) showed that labor reallocation reflects the covariance between compensation per hour worked paid by employers and hours growth. In order for this covariance to be non-zero, there must be cross-industry variation in compensation per hour, $W_i$. Taxes, or other wedges, are one potential source of such variation. For example, a labor income tax paid by the employer would cause a wedge between the employers' cost of employee compensation and the take-home wages of workers.

For example, suppose that wages differ by country-industry because of differential taxes on labor, $\tau_i^L$. Then $W_i = W\left(1+\tau_i^L\right)$ and $\overline{W(1+\tau^L)} = W\left(1+\overline{\tau^L}\right)$. Labor reallocation is then

$$\sum_i s_i^V s_i^L \left(\dot{l}_i - \dot{l}\right) = s_L \sum_i \left(\frac{\tau_i^L - \overline{\tau^L}}{1+\overline{\tau^L}}\right)\left(\dot{l}_i - \dot{l}\right). \tag{17}$$

[21] Edmond *et al.* (2018) discuss the costs of markups in the context of a fully-specified model, and provide references to this literature.

It reflects the change in output due to the shift in the distribution of hours across industries towards industries with higher distortionary taxes and, hence, a higher gross wage. For given markups, the value of the marginal product (the right-hand side of the first-order condition (3)) rises if the gross wage rises (the left-hand side).[22]

Similarly, in principle, cross-industry differences in distortionary taxes on capital income show up in the capital reallocation term. That said, the way we measure markups may suppress this effect because we impose that the internal rate of return in all sectors is equal to the BBB corporate bond rate (without a capital tax correction, which we lack the data to implement). Thus, in our calculations with markups in Table 3, cross-industry variation in capital taxes will be captured by the markup terms.

A final set of distortions are those that affect factor demands for intermediate inputs, i.e. $\tau_i^j$. We do not explicitly account for them because they have been taken out during data construction. The reason is that the value added measures in the WIOD are at basic prices and are calculated using intermediate input costs measured at purchaser prices, i.e. the equivalent of $\left(1+\tau_i^j\right) P_j$. The reallocation terms of labor and capital that we find can be interpreted as capturing wedges in capital and labor markets conditional on the intermediate input demands that have been affected by $\tau_i^j$.

### *(iii)* Comparable units of measurement of different types of labor

A quite different interpretation of the labor reallocation term is that it could reflect cross-country differences in worker skills. Because of data limitations, our baseline unit of measurement of the labor input is hours worked. Suppose total hours don't

[22] The value of the marginal product also depends on the markup, as captured in the markup terms in (11). Labor reallocation completely accounts for the change in output if there are no net markups ($\mu_i = 0$), as well as no changes in country-industry technology $z_i$, aggregate $L$ or $K$, or in the distribution of $K_i$: $\dot{l} = \dot{k} = 0$, and for all $i$, $\dot{z}_i = \dot{k}_i = 0$. With these assumptions, the only change in the economy is in the distribution of $L_i$ across country-industries.

change, but the hours shift towards higher marginal product locations (as measured using wages). Then this "reallocation" increases output, despite no change in total inputs or in technology. Subsection ($ii$) interpreted the wage and marginal productivity differentials at face value, and so a reflection of inefficiency.

However, any efficiency interpretation of labor reallocation assumes that the efficiency units of labor per hour are the same across country-industry combinations. A plausible alternative explanation, with a very different normative interpretation, is that the large labor reallocation term arises from worker productivity differences—most saliently, arising from differences in educational attainment—that are "embodied" in workers. There are large differences in human capital across countries.[23]

Though we are not able to fully account for such human capital differences, we are able to implement a crude human capital adjustment in the 2013 vintage of WIOD (through 2007). This vintage provides information on industry labor hours and compensation based on three broad skill groups (low-, medium-, high-skilled).[24] These data allow for a simple accounting of cross-country differences in skill distributions. First we look at the sources of variations in wages based on skill group and decompose the variance of wages into within country, cross-country, and cross-skill variances.[25] The results are reported in Table 5. Similar to the previous studies of wages across countries, most of the variation in wages come from cross-skill variations. This points to the importance of skill composition for wages across countries.

To incorporate different types of labor in our decomposition, we treat the hours worked by each of these skill groups as a separate factor of production, $L_i^\tau$, where $\tau \in \{L, M, H\}$. The production function from equation (2) becomes

[23] See for example, Klenow & Rodriguez-Clare (1997), Prescott (1997), Hall & Jones (1999), Hendricks (2002), Caselli (2005), Schoellman (2011), and Hendricks & Schoellman (2017).

[24] 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).

[25] The details of the mathematical derivation are in Appendix B.

$$Y_i = F_i \left( K_i, L_i^L, L_i^M, L_i^H, \{M_{i,j}\}_{j=1}^n, Z_i \right). \tag{18}$$

The resulting decomposition of aggregate TFP growth differs from the ones we presented before in three ways. First, aggregate growth of the labor input is measured as a share-weighted average of growth in hours of each skill group. Second, this redefinition also affects our measures of aggregate and industry TFP, since each type of labor is effectively treated as a separate input.[26] Finally, and most importantly, labor reallocation in this case is a weighted average of labor reallocation across the three types of labor.[27]

Table 6 shows the results of the decomposition with three skill types. Three things stand out from this table. First of all, comparing line 3 with that in Table 3, shows that accounting for the skill distribution increases the contribution of hours growth to World GDP. This indicates that labor quality has been growing over time. For the full 1996-2007 period shown in Table 6, the gap is about 0.7 percent per year. This reflects the rising educational attainment around the world over this period.

Second, the earlier finding regarding the importance of cross-country labor reallocation is robust to this extension. Comparing Lines 7 and 11 shows that, as before, the volatility of world TFP growth is mainly driven by the cross-country labor reallocation term; country-industry TFP growth (Line 21) remains very smooth. The cross-country labor reallocation term not only fluctuates a lot, but lines 16 through 19 show that its contribution to world TFP growth is almost always negative for each skill group. Thus, even within skill groups, hours typically grow faster in countries with relatively low wages.

[26] The production function in (18) allows for shifts in the contribution of labor "composition," or "quality." For example, suppose that total hours are constant, but the composition shifts towards the high skilled. Since the high-skilled wage is higher, effective share-weighted labor input increases. For industry TFP, the contribution from hours shifting (at least on average) to the high skilled was previously attributed to technology.

[27] We defer the details of this decomposition to Appendix C.

Third, the magnitude of the labor reallocation term is larger in Table 6 than in Table 3. This is because the inclusion of the three skill levels increases the weight of country-industry wage differentials for high-skilled workers relative to the other two skill groups. This is the group for which wage differentials are the highest.

To see why this is the case, it is important to realize that controlling for human capital (skills) can cause the labor reallocation effect to become either less or more negative. This is because there are two reasons why wages might be lower in one country than another. First, the low-wage country might have relatively more low-skilled labor. Second, within skill categories, wages might be lower in the low-wage country. In the data, both explanations appear to hold.

Suppose there are two countries, and that within skill categories, wages are equalized across countries. One country has more low-skilled workers, so it is (on average) a low-wage country as well. Since workers with the same skills earn the same wage in both countries, there is now, by construction, no labor-reallocation effect within skill groups. When we disaggregate by skills, the overall labor-reallocation term is the sum of labor reallocation within skill groups—so it is also zero. However, if we do *not* disaggregate by skill groups, we would measure a negative labor reallocation effect when (total) labor hours grow faster in the low-skilled (low average-wage) country.

In the second case, however, the reallocation effect can easily become *more* negative when we disaggregate labor. Suppose both low- and high-skilled workers are paid less in the low-wage country. Suppose also that there is no overall labor growth but that, over time, some workers in the low-wage country gain skills and become high-skilled. Hence, within the low-wage country, low-skilled labor falls while high-skilled labor grows. In the high-wage country, there is no change in the number of low- or high-skilled workers. In this example, high-skilled labor is growing relatively fast in the low-wage country, so there is a negative high-skilled labor reallocation term. On the other hand, there is a positive low-skilled reallocation term, since low-skilled workers are growing relatively fast in the high-wage country.

For all three skill groups, the cross-country wage differentials are an order of magnitude larger than those within countries. As a result, the across-country reallocation of labor terms are much larger than those within-country in Table 6 as well as in Tables 2 and 3.

Of course, the three skill groups are crude – capturing only broad buckets of years of schooling, and with no controls for the quality of education – and might thus not fully capture cross-country differences in skill mix. However, evidence from individual-level data with more refined skill measures is consistent with our main finding that the labor reallocation terms are not solely driven differences in observed worker skills. It shows that workers with a given skill level earn higher wages (and are more productive) in some country-industries than in others. For example, Hendricks (2002), Schoellman (2011), Hendricks & Schoellman (2017), and Hendricks & Schoellman (2022) use the wages of immigrants before and after migration to quantify cross-country differences in wages per unit of human capital. These studies show that, after controlling for selection, wage gains from migrating to the U.S. are large. They are larger for workers who earned lower wages in the country of origin than for workers with high wages in those countries and vary between a factor of 2 to 4.[28]

Thus, if wages per unit of human capital reflect marginal products of labor measured in constant quality units, then our observation that hours grow faster in countries with lower wages implies that hours grow faster in countries with lower wages per unit of human capital. Hence, correcting for human capital does not overturn our qualitative conclusion that the reallocation of labor is a drag on world TFP growth as well as being a substantial source of volatility.

[28]This comes from table 3 on page 13 of Hendricks & Schoellman (2022).

### (*iv*) Imperfect tradability of output and deviations from PPP

Our results so far are based on world output being measured in current dollars. This is the appropriate measure if all output is perfectly tradable and Purchasing Power Parity (PPP) holds. To allow for deviations from PPP, we calculated a set of results with PPP-deflated industry value added, using deflators constructed using data from Timmer *et al.* (2007) for the base year. The main qualitative results we discussed in the last section also hold for this data that is corrected for PPP deviations.[29]

The most notable impact of using PPP-weighted results is that labor reallocation is less important. A portion of cross-country labor reallocation in the dollar-weighted results in Table 3 reflects economic activity shifting to sectors with an international cost advantage. These are industries with low relative wages compared to relative productivity levels—most obviously, manufacturing in China and India.

However, our results imply that deviations from PPP account for only about a third of the total impact of labor reallocation reported in Table 3. Thus, even after adjusting for PPP, labor reallocation remains a drag on world GDP growth as well as being an important source of volatility in world TFP.

### (*v*) Imperfect mobility of production factors

In our efficient global benchmark, to equate the marginal product of labor across country-industry combinations, labor needs to be perfectly mobile. So, the large labor reallocation term arising from wage differentials could reflect barriers to cross-border mobility. Most obviously, because of immigration restrictions, workers cannot freely cross borders to arbitrage wage and productivity differences. Such movements, if they were possible, would raise world productivity, since labor would grow in high-wage (high-productivity) country-industries and shrink in low-wage ones. For given

[29] Table D.9 contains a summary of the results. A detailed description of the methodology is in the Appendix D.2.4.

global labor input, these movements would thus raise global output as well.

Conceptually, this is similar 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 car manufacturing is much higher in Germany than that in Mexico. This means that, from a global perspective, there is a misallocation of production factors from the point of view of maximizing global output. World GDP would increase if we could move resources, including workers, from Mexican to German car manufacturing.

However, the normative interpretation of wage differentials arising from labor immobility are unclear. For example, suppose the lack of worker mobility across regions and countries reflects worker preferences. Even within a zone with free labor mobility, such as the European Union, a given worker may prefer to live in a particular location because of family, friends, language, culture, geography, or other non-pecuniary reasons; they are willing to accept a lower wage to do so. In this case, moving the worker would raise productivity and output, but it would not be Pareto efficient because the worker would be worse off in non-pecuniary ways. This might be one reason why, even within the EU, the labor reallocation term is not zero.[30]

Moreover, the welfare interpretation of legal impediments to labor mobility are also unclear. There is no presumption that allowing free factor mobility would necessarily increase the social welfare function for both the source country, and the recipient, of the factor flows. Thus, one should arguably consider locational taste differences and cross-border mobility barriers as fundamental to the world economy, rather than

[30] See Table D.10 in the Appendix for detailed results for the EU.

an impediment to economic growth. In that case, the labor reallocation term would not reflect misallocation but rather measure the output effect of reallocation of labor in the world economy. Even if the welfare interpretation is unclear, it is still an important driver of fluctuations in world GDP and TFP growth.

# 6 Conclusion

We provide new global growth-accounting results from a novel growth decomposition that nests standard decompositions but allows for markups as well as factor "wedges". We implement this decomposition using data on 35 or more industries and 40 or more countries from 1996-2014.

Empirically, we find four main results: (i) world productivity is volatile from year to year and even over multi-year periods; (ii) labor reallocation is the primary source of this volatility, as well as being a persistent drag on growth; (iii) the average rate of productivity growth across country-industries is comparatively smooth; and (iv) Before the Great Recession the contribution of country-industry growth was relatively constant because the productivity slowdown in Advanced Economies was offset by an increased contribution of productivity growth in emerging economies. The latter dissipated after the Great Recession and world TFP growth slowed down. These takeaways apply whether or not we control for markups, or we adjust for PPP.

Our results provide new insights into at least two other recent literatures. First, a growing recent literature examines the role of markups and rising profits. We extend Barkai (2020) to emerging markets. Interestingly, although profits and markups are quantitatively important, the broad narrative about global productivity is robust to whether we control for markups or not.

Second, a sizable strand of literature has highlighted the slowdown in recent decades in advanced-economy productivity growth. We provide broader context for this finding: At a global level, the advanced-economy slowdown in country-industry productivity growth in the 2000s is offset until the Great Recession by a rising contribution from emerging markets. World productivity growth (and world country-industry productivity growth) only consistently slows after the Great Recession.

The quantitative importance of labor reallocation arises from the well-known heterogeneity in wages around the world. Labor input has typically grown faster in low-wage/low marginal-product locations, creating a persistent drag of around 1/2 percent per year for world productivity growth. But over time, the cross-sectional covariance of wages and hours growth varies substantially which, in turn, leads to considerable variability in world productivity.

Thus, our analysis shows how important it is to do growth accounting on a global scale to understand shifts in the center of gravity of global productivity growth. With the rise of emerging economies in Asia, this global perspective has become increasingly essential.

## References

Baqaee, David, & Farhi, Emmanuel. 2021 (March). *A Short Note on Aggregating Productivity*. Working Paper 25688. National Bureau of Economic Research.

Baqaee, David Rezza, & Farhi, Emmanuel. 2019. Productivity and Misallocation in General Equilibrium. *The Quarterly Journal of Economics*, **135**(1), 105–163.

Barkai, Simcha. 2020. Declining Labor and Capital Shares. *The Journal of Finance*, **75**(5), 2421–2463.

Basu, Susanto. 1995. Intermediate Goods and Business Cycles: Implications for Productivity and Welfare. *American Economic Review*, **85**(3), 512–31.

Basu, Susanto, & Fernald, John. 2002. Aggregate productivity and aggregate technology. *European Economic Review*, **46**(6), 963–991.

Basu, Susanto, & Fernald, John G. 1995. Are apparent productive spillovers a figment of specification error? *Journal of Monetary Economics*, **36**(1), 165 – 188.

Basu, Susanto, & Fernald, John G. 1997. Returns to Scale in U.S. Production: Estimates and Implications. *Journal of Political Economy*, **105**(2), 249–283.

Caselli, Francesco. 2005. Chapter 9-Accounting for Cross-Country Income Differences. Handbook of Economic Growth, vol. 1, Part A. Elsevier.

Caselli, Francesco, & Coleman, Wilbur John. 2006. The World Technology Frontier. *The American Economic Review*, **96**(3), pp. 499–522.

Cette, Gilbert, Fernald, John, & Mojon, Benoit. 2016. The pre-Great Recession slowdown in productivity. *European Economic Review*, **88**(C), 3–20.

Conference Board. 2015. Total Economy Database. *www.conference-board.org/data/economydatabase [Last Accessed: 05/30/15]*.

Das, Deb Kusum, Erumban, Abdul A., Aggarwal, Suresh, & Sengupta, Sreerupa. 2016. Productivity growth in India under different policy regimes. *Page 234–280 of:* Jorgenson, Dale W., Fukao, Kyoji, & Timmer, Marcel P. (eds), *The World Economy: Growth or Stagnation?* Cambridge University Press.

De Loecker, Jan, Eeckhout, Jan, & Unger, Gabriel. 2020. The Rise of Market Power and the Macroeconomic Implications. *The Quarterly Journal of Economics*, **135**(2), 561–644.

Domar, Evsey D. 1962. On Total Productivity and All That. *Journal of Political Economy*, **70**(6), 597–608.

ECB. 2017. *The Slowdown in Euro Area Productivity in a Global Context.* ECB Economic Bulletin 3/2017. European Central Bank.

Edmond, Chris, Midrigan, Virgiliu, & Xu, Daniel Yi. 2018 (July). *How Costly Are Markups?* NBER Working Papers 24800. National Bureau of Economic Research, Inc.

Feenstra, Robert C., Inklaar, Robert, & Timmer, Marcel P. 2015. The Next Generation of the Penn World Table. *American Economic Review*, **105**(10), 3150–3182.

Fernald, John, & Inklaar, Robert. 2020. Does Disappointing European Productivity Growth Reflect a Slowing Trend? Weighing the Evidence and Assessing the Future. *International Productivity Monitor*, **38**, 104–135.

Fernald, John, & Neiman, Brent. 2011. Growth Accounting with Misallocation: Or, Doing Less with More in Singapore. *American Economic Journal: Macroeconomics*, **3**(2), 29–74.

Fernald, John G. 2015. Productivity and Potential Output before, during, and after the Great Recession. *NBER Macroeconomics Annual*, **29**(1), 1–51.

Gouma, Reitze, Chen, Wen, Woltjer, Pieter, & Timmer, Marcel. 2018. *WIOD Socio-Economic Accounts 2016 Sources and Methods.*

Hall, Robert E. 1986. Market Structure and Macroeconomic Fluctuations. *Brookings Papers on Economic Activity*, **2**, 285–322.

Hall, Robert E. 1990. Invariance Properties of Solow's Productivity Residual. *Pages 71–112 of:* Diamond, Peter (ed), *Growth, Productivity, Unemployment: Essays to Celebrate Robert Solow's Birthday.* Cambridge, MA: MIT Press.

Hall, Robert E., & Jones, Charles I. 1999. Why do Some Countries Produce So Much More Output Per Worker than Others? *The Quarterly Journal of Economics*, **114**(1), 83–116.

Hendricks, Lutz. 2002. How Important Is Human Capital for Development? Evidence from Immigrant Earnings. *The American Economic Review*, **92**(1), 198–219.

Hendricks, Lutz, & Schoellman, Todd. 2017. Human Capital and Development Accounting: New Evidence from Wage Gains at Migration. *The Quarterly Journal of Economics*, **133**(2), 665–700.

Hendricks, Lutz, & Schoellman, Todd. 2022. Skilled Labor Productivity and Cross-country Income Differences. *Conditionally accepted: American Economic Journal: Macroeconomics*.

Hopenhayn, Hugo, & Rogerson, Richard. 1993. Job Turnover and Policy Evaluation: A General Equilibrium Analysis. *Journal of Political Economy*, **101**(5), 915–938.

Hsieh, Chang-Tai, & Klenow, Peter J. 2009. Misallocation and Manufacturing TFP in China and India. *The Quarterly Journal of Economics*, **124**(4), 1403–1448.

Hsieh, Chang-Tai, & Moretti, Enrico. 2019. Housing Constraints and Spatial Misallocation. *American Economic Journal: Macroeconomics*, **11**(2), 1–39.

Hulten, Charles R. 1978. Growth Accounting with Intermediate Inputs. *Review of Economic Studies*, **45**(3), 511–518.

Inklaar, Robert, & Timmer, Marcel P. 2014. The Relative Price of Services. *Review of Income and Wealth*, **60**(4), 727–746.

Jorgenson, Dale W. 1963. Capital Theory and Investment Behavior. *The American Economic Review*, **53**(2), pp. 247–259.

Jorgenson, Dale W., Gollop, Frank M., & Fraumeni, Barbara M. 1987. *Productivity and U.S. economic growth*. Harvard economic studies. Harvard University Press.

Karabarbounis, Loukas, & Neiman, Brent. 2014. The Global Decline of the Labor Share. *The Quarterly Journal of Economics*, **129**(1), 61–103.

Karabarbounis, Loukas, & Neiman, Brent. 2018. Accounting for Factorless Income. *In: NBER Macroeconomics Annual 2018, volume 33.* NBER Chapters. National Bureau of Economic Research, Inc.

Klenow, Peter, & Rodriguez-Clare, Andres. 1997. The Neoclassical Revival in Growth Economics: Has It Gone Too Far? *Pages 73–114 of: NBER Macroeconomics Annual 1997, Volume 12.* NBER Chapters. National Bureau of Economic Research, Inc.

OECD. 2017. *STAN Industry ISIC Rev. 4.*

Oliner, Stephen D., & Sichel, Daniel E. 2000. The Resurgence of Growth in the Late 1990s: Is Information Technology the Story? *Journal of Economic Perspectives*, **14**(4), 3–22.

Osotimehin, Sophie. 2019. Aggregate Productivity and the Allocation of Resources Over the Business Cycle. *Review of Economic Dynamics*, **32**, 180–205.

Petrin, Amil, & Levinsohn, James. 2013. Measuring aggregate productivity growth using plant-level data. *The RAND Journal of Economics*, **43**(4), 705–725.

Prescott, Edward C. 1997. *Needed: a theory of total factor productivity.* Staff Report 242. Federal Reserve Bank of Minneapolis.

Rao, D. S.P., & van Ark, Bart. 2013. *Europe's Productivity Performance in Comparative Perspective: Trends, Causes and Projections.* Cheltenham, UK: Edward Elgar Publishing. Chap. 11.

Rotemberg, Julio J, & Woodford, Michael. 1995. Dynamic General Equilibrium Models with Imperfectly Competitive Product Markets. *In:* Cooley, Thomas (ed), *Frontiers of Business Cycle Research.* Princeton, N.J.: Princeton University Press.

Ruzic, Dimitrije, & Ho, Sui-Jade. 2021. Returns to Scale, Productivity Measurement, and Trends in U.S. Manufacturing Misallocation. *The Review of Economics and Statistics*, 10, 1–47.

Schmelzing, Paul. 2017 (Oct.). *Eight Centuries of the Risk-Free Rate: Bond Market Reversals From the Venetians to the 'VAR Shock'*. Bank of England working papers 686. Bank of England.

Schoellman, Todd. 2011. Education Quality and Development Accounting. *The Review of Economic Studies*, **79**(1), 388–417.

Solow, Robert M. 1957. Technical Change and the Aggregate Production Function. *The Review of Economics and Statistics*, **39**(3), 312–320.

Timmer, Marcel, Ypma, Gerard, & van Ark, Bart. 2007. PPPs for Industry Output: A New Dataset for International Comparisons. *Working Paper*.

Timmer, Marcel P. 2012. The World Input-Output Database (WIOD): Contents, Sources, and Methods. *WIOD Working Paper*, **10**.

Timmer, Marcel P., Dietzenbacher, Erik, Los, Bart, Stehrer, Robert, & de Vries, Gaaitzen J. 2015. An Illustrated User Guide to the World Input–Output Database: the Case of Global Automotive Production. *Review of International Economics*, **23**(3), 575–605.

Traina, James. 2018 (February). *Is Aggregate Market Power Increasing? Production Trends Using Financial Statements*. Tech. rept. 17. Stigler Center New Working Paper Series.

World Bank. 2018. *World Development Indicators*.

Xu, Chenggang. 2011. The Fundamental Institutions of China's Reforms and Development. *Journal of Economic Literature*, **49**(4), 1076–1151.

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 (2017) and extrapolating from the 2013 vintage for variables unavailable. See the Appendix for details.

Table 2: 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) | World 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) | World 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 | $\dot{tfp}$ | 1.65 | 0.12 | 2.21 | 1.28 | 0.11 | 1.67 | -0.23 | -0.50 | 0.20 |
| 5) | Reallocation of capital | $\sum_i s_i^V s_i^K(\dot{k}_i - \dot{k})$ | 0.76 | 0.28 | 0.43 | 0.52 | 0.22 | 0.36 | 0.29 | 0.26 | 0.28 |
| 6) | ...within countries | | 0.63 | 0.20 | 0.30 | 0.40 | 0.16 | 0.25 | 0.14 | 0.18 | 0.18 |
| 7) | ...across countries | | 0.13 | 0.09 | 0.13 | 0.11 | 0.06 | 0.11 | 0.14 | 0.09 | 0.10 |
| 8) | Reallocation of hours | $\sum_i s_i^V s_i^L(\dot{l}_i - \dot{l})$ | -0.01 | -1.34 | 0.50 | -0.33 | -0.56 | 0.35 | -0.36 | -0.97 | -0.44 |
| 9) | ...within countries | | 0.07 | -0.02 | 0.15 | 0.06 | 0.03 | 0.08 | 0.08 | 0.09 | 0.07 |
| 10) | ...across countries | | -0.08 | -1.32 | 0.35 | -0.39 | -0.6 | 0.27 | -0.44 | -1.07 | -0.51 |
| 11) | Shifts in markups | $\sum_i s_i^D \frac{\mu_i}{1+\mu_i}\dot{y}_i$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 12) | ...Shifts in average markups | $\frac{\bar{\mu}}{1+\bar{\mu}}\dot{\bar{y}}$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 13) | ...Output shifts | $\sum_i s_i^D \frac{\mu_i}{1+\mu_i}(\dot{y}_i - \dot{\bar{y}})$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 |
| 14) | Country-industry TFP growth | $\sum_i s_i^D \frac{1}{1+\mu_i}\dot{z}_i$ | 0.91 | 1.18 | 1.28 | 1.09 | 0.46 | 0.96 | -0.16 | 0.21 | 0.36 |

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. These are results with no markups. Hence, lines 11-13 are all zero.

Table 3: 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) | World 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) | World 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 | $t\dot{f}p$ | 1.84 | 0.32 | 2.67 | 1.54 | 0.76 | 2.32 | 0.21 | 0.05 | 0.77 |
| 5) | Reallocation of capital | $\sum_i s_i^V s_i^K(\dot{k}_i - \dot{k})$ | 0.21 | 0.03 | 0.06 | 0.11 | 0.17 | 0.18 | 0.23 | 0.24 | 0.20 |
| 6) | ...within countries | | 0.23 | 0.06 | 0.11 | 0.14 | 0.07 | 0.14 | 0.07 | 0.06 | 0.08 |
| 7) | ...across countries | | -0.02 | -0.03 | -0.05 | -0.03 | 0.09 | 0.04 | 0.16 | 0.18 | 0.12 |
| 8) | Reallocation of hours | $\sum_i s_i^V s_i^L(\dot{l}_i - \dot{l})$ | -0.01 | -1.34 | 0.50 | -0.33 | -0.56 | 0.35 | -0.36 | -0.97 | -0.44 |
| 9) | ...within countries | | 0.07 | -0.02 | 0.15 | 0.06 | 0.03 | 0.08 | 0.08 | 0.09 | 0.07 |
| 10) | ...across countries | | -0.08 | -1.32 | 0.35 | -0.39 | -0.6 | 0.27 | -0.44 | -1.07 | -0.51 |
| 11) | Shifts in markups | $\sum_i s_i^D \frac{\mu_i}{1+\mu_i}\dot{y}_i$ | 0.51 | 0.39 | 0.94 | 0.58 | 0.46 | 0.85 | 0.29 | 0.59 | 0.55 |
| 12) | ...Shifts in average markups | $\frac{\bar{\mu}}{1+\bar{\mu}}\dot{\bar{y}}$ | 0.30 | 0.25 | 0.73 | 0.39 | 0.45 | 0.86 | 0.18 | 0.68 | 0.55 |
| 13) | ...Output shifts | $\sum_i s_i^D \frac{\mu_i}{1+\mu_i}(\dot{y}_i - \dot{\bar{y}})$ | 0.21 | 0.13 | 0.21 | 0.19 | 0.02 | -0.01 | 0.11 | -0.09 | -0.00 |
| 14) | Country-industry TFP growth | $\sum_i s_i^D \frac{1}{1+\mu_i}\dot{z}_i$ | 1.13 | 1.24 | 1.17 | 1.18 | 0.7 | 0.93 | 0.04 | 0.19 | 0.46 |

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 4: 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 |
| 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 | 0.04 | 0.20 | -0.15 | 0.09 | 0.05 |
| Euro Area | 0.20 | 0.09 | 0.18 | 0.16 | 0.06 | 0.10 | -0.16 | 0.08 | 0.03 |
| Other advanced | 0.17 | 0.08 | 0.10 | 0.12 | 0.06 | 0.04 | -0.03 | -0.00 | 0.02 |
| Brazil | 0.00 | -0.01 | -0.01 | -0.01 | -0.01 | -0.04 | 0.02 | -0.08 | -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 | 0.08 | 0.01 | -0.03 | 0.02 |
| Total | 1.13 | 1.24 | 1.17 | 1.18 | 0.7 | 0.93 | 0.04 | 0.19 | 0.46 |

Note: Reported are contributions by country/region to line 10 in Table 3 in percentage points over various subperiods. Results with markups.

Table 5: Summary of decomposition of the variations of wages, percentage of total wage variation

| | notation | 1996-2000 | 2001-2004 | 2005-2007 |
|---|---|---|---|---|
| inter-industry wage variations | $\left(\frac{W_{c,\tau}}{W}\right)^2 \left(\frac{\sigma_{i,c,\tau}}{W_{c,\tau}}\right)^2$ | 2.54 | 2.52 | 2.96 |
| ... low skill | | 0.44 | 0.45 | 0.49 |
| ... medium skill | | 0.70 | 0.67 | 0.79 |
| ... high skill | | 1.39 | 1.40 | 1.68 |
| cross-country wage variations | $\left(\frac{W_{\tau}}{W}\right)^2 \left(\frac{\sigma_{c,\tau}}{W_{\tau}}\right)^2$ | 16.70 | 17.03 | 15.47 |
| ... low skill | | 0.55 | 0.52 | 0.50 |
| ... medium skill | | 3.18 | 3.08 | 2.90 |
| ... high skill | | 12.97 | 13.43 | 12.07 |
| cross-skill wage variations | $\left(\frac{\sigma_{\tau}}{W}\right)^2$ | 80.83 | 80.52 | 81.64 |
| ... low skill | | 28.28 | 28.10 | 28.54 |
| ... medium skill | | 27.03 | 26.93 | 27.36 |
| ... high skill | | 25.53 | 25.50 | 25.74 |
| world wage variations | $\left(\frac{\sigma}{W}\right)^2$ | 100.00 | 100.00 | 100.00 |

Table 6: Summary of global TFP growth accounting *with* markups and labor quality: 1996-2007

| line | description | notation | 1996-2000 | 2001-2004 | 2005-2007 | All |
|---|---|---|---|---|---|---|
| 1) | World GDP growth | $\dot{v}$ | 3.33 | 2.51 | 3.70 | 3.15 |
| 2) | World capital growth | $s^K\dot{k}$ | 0.79 | 0.74 | 0.80 | 0.78 |
| 3) | World hours growth across skills | $s^{L\tau}\dot{l}^\tau$ | 1.53 | 2.17 | 0.88 | 1.58 |
| 4) | ...low-skilled | | -0.02 | 0.14 | -0.04 | 0.03 |
| 5) | ...medium-skilled | | 0.73 | 0.82 | 0.16 | 0.62 |
| 6) | ...high-skilled | | 0.82 | 1.21 | 0.76 | 0.94 |
| 7) | World TFP growth | $t\dot{f}p$ | 1.01 | -0.41 | 2.02 | 0.79 |
| 8) | Reallocation of capital | $\sum_i s_i^V s_i^K(\dot{k}_i - \dot{k})$ | 0.21 | 0.03 | 0.06 | 0.11 |
| 9) | ...within countries | | 0.23 | 0.06 | 0.11 | 0.14 |
| 10) | ...across countries | | -0.02 | -0.03 | -0.05 | -0.03 |
| 11) | Reallocation of hours | $\sum_i \sum_\tau s_i^V s_i^{L\tau}(\dot{l}_i^\tau - \dot{l}^\tau)$ | -0.63 | -1.88 | 0.01 | -0.89 |
| 12) | within countries | | -0.01 | -0.11 | 0.09 | -0.02 |
| 13) | ...low-skilled | | 0.00 | -0.01 | 0.03 | 0.00 |
| 14) | ...medium-skilled | | -0.01 | -0.06 | 0.04 | -0.02 |
| 15) | ...high-skilled | | -0.00 | -0.03 | 0.02 | -0.01 |
| 16) | across countries | | -0.62 | -1.78 | -0.08 | -0.87 |
| 17) | ...low-skilled | | -0.17 | -0.26 | -0.03 | -0.16 |
| 18) | ...medium-skilled | | -0.35 | -0.81 | 0.09 | -0.39 |
| 19) | ...high-skilled | | -0.11 | -0.71 | -0.14 | -0.32 |
| 20) | Shifts in markups | $\sum_i s_i^D \frac{\mu_i}{1+\mu_i}\dot{y}_i$ | 0.51 | 0.39 | 0.94 | 0.58 |
| 21) | Country-industry TFP growth | $\sum_i s_i^D \frac{1}{1+\mu_i}\dot{z}_i$ | 0.93 | 1.06 | 1.01 | 0.99 |

Note: Lines in this table correspond to parts of equation (37). Reported are contributions to average annual growth rates in percentage points over various subperiods. Results with markups. Line 20) is the same as line 11) in Table 3 and lines 12) and 13) of that Table would also apply as a split of that line 20) in this table. They are not reported for brevity.

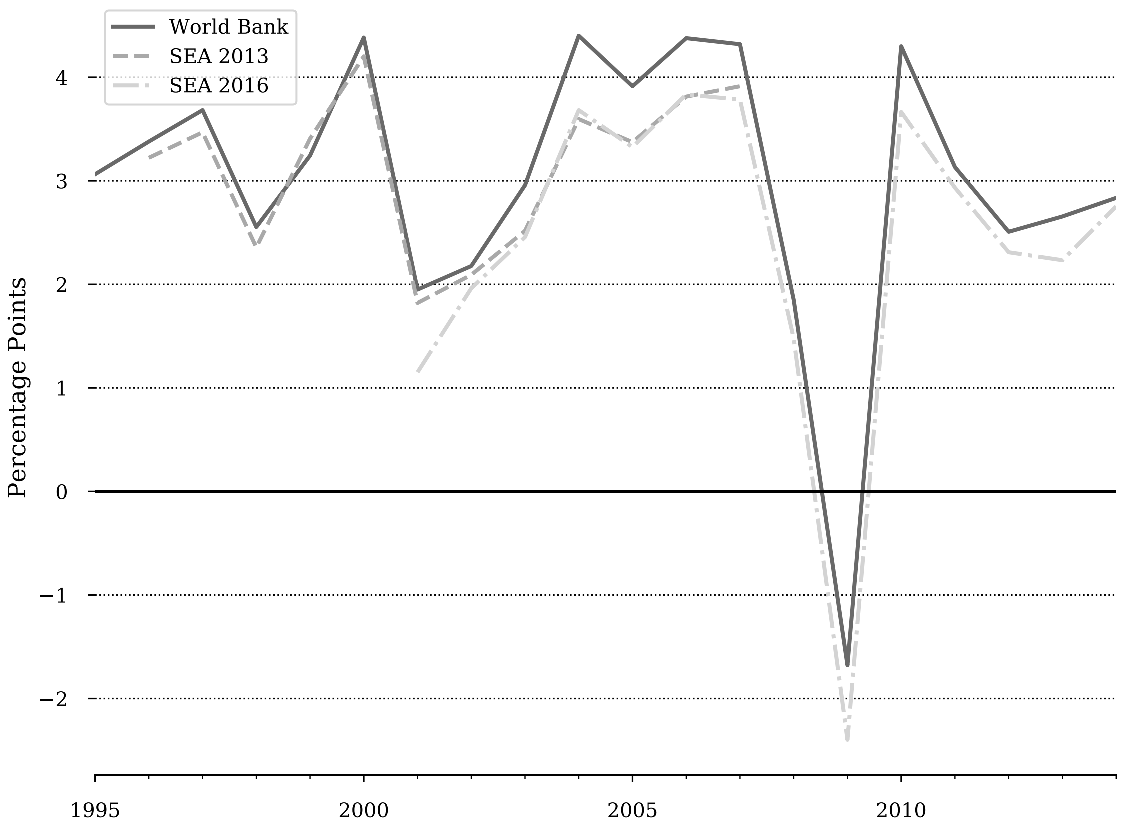


Figure 1: Growth in world real GDP in WIOD-SEA and World Development Indicators (WDI)

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.

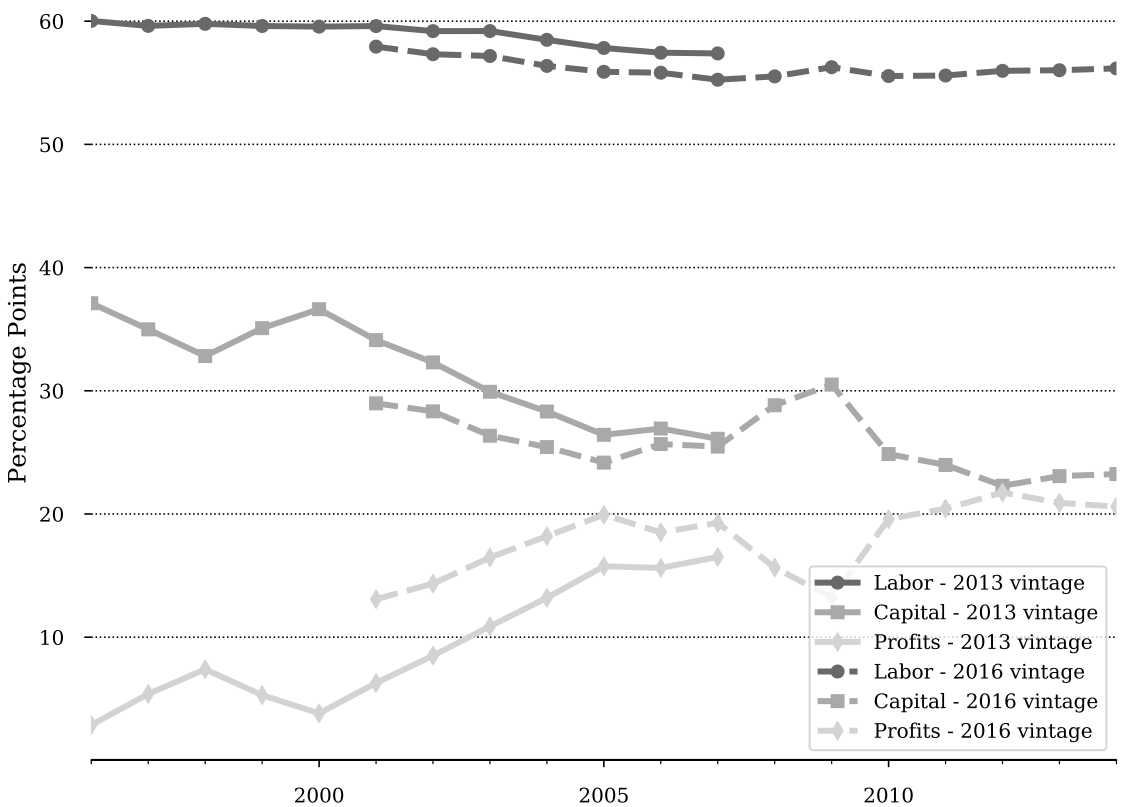


Figure 2: World factor shares for both vintages of WIOT

Note: Solid line is 2013 vintage and dashed line is 2016 vintage.
Source: Timmer (2012), OECD (2017), and authors' calculations.

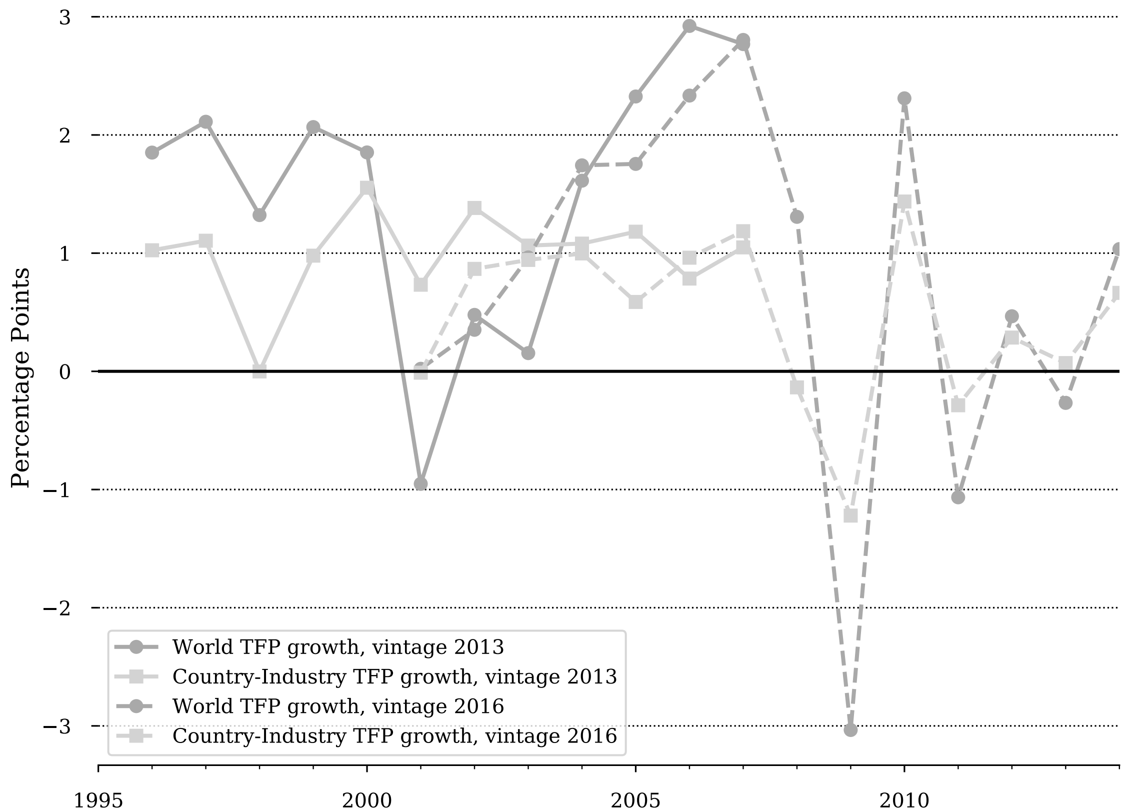


Figure 3: TFP growth: World vs. country-industry component, vintage 2016.
Note: Solid line is 2013 vintage and dashed line is 2016 vintage.
Source: Timmer (2012), OECD (2017), and authors' calculations.

# A Accounting for within- and across-country contributions

As mentioned in the main text, we split up the contribution of reallocation terms into with-country component and across-country one. We elaborate here how we do this, focusing on equation (11).

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:

$$\begin{aligned} \dot{v} &= \sum_c \sum_i \frac{1}{(1+\mu_{ci})} s^D_{ci} \dot{z}_{ci} + s^K \dot{k} + s^L \dot{l} \\ &+ \sum_c \sum_i s^D_{ci} \frac{\mu_{ci}}{(1+\mu_{ci})} \dot{y}_{ci} + \sum_c \sum_i s^V_{ci} s^K_{ci} \left( \dot{k}_{ci} - \dot{k} \right) + \sum_c \sum_i s^V_{ci} s^L_{ci} \left( \dot{l}_{ci} - \dot{l} \right). \end{aligned} \tag{19}$$

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

$$\sum_c \sum_i s^V_{ci} s^L_{ci} \left( \dot{l}_{ci} - \dot{l} \right) = \sum_c s^V_c \sum_i \frac{s^V_{ci} s^L_{ci}}{s^V_c} \left( \dot{l}_{ci} - \dot{l}_c \right) + \sum_c s^V_c s^L_c \left( \dot{l}_c - \dot{l} \right), \tag{20}$$

where

$$s^L_c = \left( \frac{\sum_i s^V_{ci} s^L_{ci}}{s^V_c} \right), \text{ and } s^V_c = \sum_i s^V_{ci}. \tag{21}$$

Equation (20) splits up the labor reallocation terms into two parts: within-country reallocation of labor which is the first term on the RHS, and across-country component which is the second term. A positive within-country reallocation 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 reallocation of labor within the country.

Similarly, a positive across-country reallocation means that hours are growing faster in countries with higher labor share and contribute more to world GDP. The capital reallocation term can be split up similarly.

# B ANOVA of wages

To quantify the importance of cross-country wage differentials versus within-country cross-industry wage differentials, we can do an ANOVA. Define the average global wage as

$$W_t = \sum_i \frac{W_i L_i}{L} = \sum_i \omega_i W_i, \text{ where } L = \sum_i L_i,\ \omega_i = \frac{L_i}{L} \tag{22}$$

We will decompose the variance of this average wage across country-industry combinations. This variance is given by

$$\sigma^2 = \sum_i \omega_i \left(W_i - W\right)^2 = \sum_i \omega_i W_i^2 - W^2. \tag{23}$$

We split this variance into within-country, $c$, variation and between-country variation in the following way. Let the average wage paid in country $c$ to skill-level $\tau$ be equal to

$$W_{c,\tau} = \sum_{i\in c} \frac{W_{i,\tau} L_{i,\tau}}{L_{c,\tau}} = \sum_{i\in c} \omega_{i,\tau} W_{i,\tau}, \text{ where } L_{c,\tau} = \sum_{i\in c} L_{i,\tau},\ \omega_{i,\tau} = \frac{L_{i,\tau}}{L_{c,\tau}}, \tag{24}$$

and let the average hourly wage paid to workers with skill level $\tau$ be

$$W_\tau = \sum_i \frac{W_{c,\tau} L_{c,\tau}}{L_\tau} = \omega_{c,\tau} W_{c,\tau}, \text{ where } \omega_{c,\tau} = \frac{L_{c,\tau}}{L_\tau},\ \omega_\tau = \frac{L_\tau}{L}, \text{ and } L_\tau = \sum_i L_{i,\tau}. \tag{25}$$

We can then write

$$\sigma^2 = \sum_\tau \sum_c \sum_{i \in c} \omega_i \left[ (W_{i,\tau} - W_{c,\tau}) + (W_{c,\tau} - W_\tau) + (W_\tau - W) \right]^2 \tag{26}$$

$$= \sum_\tau \sum_c \sum_{i \in c} \omega_i \left[ (W_{i,\tau} - W_{c,\tau})^2 + (W_{c,\tau} - W_\tau)^2 + (W_\tau - W)^2 \right] + \tag{27}$$

$$2 \sum_\tau \sum_c \sum_{i \in c} \omega_i \left[ (W_{i,\tau} - W_{c,\tau}) (W_{c,\tau} - W_\tau) + (W_{i,\tau} - W_{c,\tau}) (W_\tau - W) \right] + \tag{28}$$

$$2 \sum_\tau \sum_c \sum_{i \in c} \omega_i \left[ (W_{c,\tau} - W_\tau) (W_\tau - W) \right] \tag{29}$$

$$= \sum_\tau \sum_c \sum_{i \in c} \omega_i \left[ (W_{i,\tau} - W_{c,\tau})^2 + (W_{c,\tau} - W_\tau)^2 + (W_\tau - W)^2 \right] \tag{30}$$

$$= \sum_\tau \omega_\tau \sum_c \frac{\omega_{c,\tau}}{\omega_\tau} \sum_{i \in c} \frac{\omega_{i,\tau}}{\omega_{c,\tau}} (W_{i,\tau} - W_{c,\tau})^2 + \sum_\tau \omega_\tau \sum_c \frac{\omega_{c,\tau}}{\omega_\tau} (W_{c,\tau} - W_\tau)^2 + \sum_\tau (W_\tau - W)^2 \tag{31}$$

$$= \sigma^2_{i,c,\tau} + \sigma^2_{c,\tau} + \sigma^2_\tau. \tag{32}$$

The problem is that the above measure is dependent on units of observation, which actually change over time. So, we need a transformation that gets rid off that. For that we, use the square of coefficient of variation, $\frac{\sigma}{\mu}$. So, that yields

$$\left( \frac{\sigma}{W} \right)^2 = \left( \frac{W_{c,\tau}}{W} \right)^2 \left( \frac{\sigma_{i,c,\tau}}{W_{c,\tau}} \right)^2 + \left( \frac{W_\tau}{W} \right)^2 \left( \frac{\sigma_{c,\tau}}{W_\tau} \right)^2 + \left( \frac{\sigma_\tau}{W} \right)^2. \tag{33}$$

The alternative is to use shares and calculate at each point in time

$$1 = \frac{\sigma^2_{i,c,\tau}}{\sigma^2} + \frac{\sigma^2_{c,\tau}}{\sigma^2} + \frac{\sigma^2_\tau}{\sigma^2} \tag{34}$$

and then average these shares over time and report them in the table.

We can do this for every year and determine what fraction of the variation in wages is due to within country differences and what fraction is due to cross-country differences. We can also relate this to percentage differences in wages.

## C Growth accounting with labor skill levels

Let $\tau \in \{L, M, H\}$ denotes the three labor inputs based on skill. Our raw accounting identity is the following (equation (10) in the main text):

$$\dot{v} = \sum_i \frac{1}{(1+\mu_i)} s_i^D \dot{z}_i + \sum_i s_i^V s_i^K \dot{k}_i + \sum_i s_i^V s_i^L \dot{l}_i + \sum_i s_i^D \frac{\mu_i}{(1+\mu_i)} \dot{y}_i. \tag{35}$$

Before rearranging this equation to get equation (11), we can manipulate the labor term to reflect labor quality. Assuming we have three categories for labor (Low, Medium, and High skilled), the above equation would be:

$$\dot{v} = \sum_i \frac{1}{(1+\mu_i)} s_i^D \dot{z}_i + \sum_i s_i^V s_i^K \dot{k}_i + \sum_i \sum_{\tau \in \{L,M,H\}} s_i^V s_i^{L\tau} \dot{l}_i^\tau + \sum_i s_i^D \frac{\mu_i}{(1+\mu_i)} \dot{y}_i. \tag{36}$$

We now add and subtract aggregate share-weighted factor growth to this equation. For labor, there are three types of aggregate workers, so we add and subtract $\sum_{\tau \in \{L,M,H\}} s^{L\tau} \dot{l}^\tau = \sum_{\tau \in \{L,M,H\}} \sum_i s_i^V s_i^{L\tau} \dot{l}^\tau$. We arrive at the modified version of the main equation:

$$\begin{aligned} \dot{v} &= \sum_i \frac{1}{(1+\mu_i)} s_i^D \dot{z}_i + s^K \dot{k} + \sum_{\tau \in \{L,M,H\}} s^{L\tau} \dot{l}^\tau \\ &+ \sum_i s_i^D \frac{\mu_i}{(1+\mu_i)} \dot{y}_i + \sum_i s_i^V s_i^K \left( \dot{k}_i - \dot{k} \right) + \sum_{\tau \in \{L,M,H\}} \sum_i s_i^V s_i^{L\tau} \left( \dot{l}_i^\tau - \dot{l}^\tau \right). \end{aligned} \tag{37}$$

The final term is the change in labor reallocation. It is now the weighted average of labor reallocation across the three types of labor. Aggregate and industry TFP also change, because we now allow for shifts in the contribution of aggregate labor quality. For aggregate TFP, these shifts show up in the share-weighted growth in labor input in the final term on the first line. For industry TFP, we were previously attributing to technology a part of each industry's growth that is due to labor shifting among education groups.

To see the contribution of labor quality more explicitly, note that the aggregate labor share, $s^L$, is the sum of the labor shares across the three types of labor, $\sum_{\tau\in\{L,M,H\}} s^{L\tau}$. Hence, following Jorgenson *et al.* (1987), we can write the contribution-of-aggregate-labor term in the first line as the sum of share-weighted hours growth plus the change in aggregate labor quality:

$$\sum_{\tau\in\{L,M,H\}} s^{L\tau}\dot{l}^{\tau} = s^L\dot{l} + \sum_{\tau\in\{L,M,H\}} s^{L\tau}\left(\dot{l}^{\tau} - \dot{l}\right) \tag{38}$$

Returning to the labor reallocation term, it will be useful for intuition to express it a different way. First, define the average wage for each type of worker as $W^{\tau} = \left(\sum_i W_i^{\tau} L_i^{\tau}\right)/L^{\tau}$. Second, note that growth in hours of type $\tau$ is

$$\dot{l}^{\tau} = \sum_i \left(\frac{L_i^{\tau}}{L^{\tau}}\right)\dot{l}_i^{\tau} = \sum_i \left(\frac{W^{\tau}L_i^{\tau}}{W^{\tau}L^{\tau}}\right)\dot{l}_i^{\tau}. \tag{39}$$

We can now return to the definition of the labor reallocation term, and substitute in for $\dot{l}^{\tau}$. We find:

$$\begin{aligned}\sum_{\tau\in\{L,M,H\}}\left(\left(\sum_i s_i^V s_i^{L\tau}\dot{l}_i^{\tau}\right) - s^{\tau}\dot{l}^{\tau}\right) &= \sum_{\tau\in\{L,M,H\}}\left(\sum_i \frac{W_i^{\tau}L_i^{\tau}}{PV}\dot{l}_i^{\tau} - \sum_i \frac{W^{\tau}L_i^{\tau}}{PV}\dot{l}_i^{\tau}\right)\\ &= \sum_{\tau\in\{L,M,H\}}\sum_i\left(\frac{\left(W_i^{\tau}-W^{\tau}\right)L_i}{PV}\right)\dot{l}_i^{\tau}\end{aligned} \tag{40}$$

Our earlier intuition for labor reallocation was that, if labor grows faster in country-industries where it has a higher than average wage, then this is an improvement in reallocation. Other things equal, that shift boosts growth in output and aggregate TFP. With multiple types of labor, the nuance is that the shift has to take place within a given type of labor. This difference may matter in the data. For example, suppose we see a shift in the data from labor in advanced economies to labor in emerging markets. A part of cross-country wage differential in our earlier equation presumably reflects differences in the mix of skills across countries–so we need to compare the shifts within skill groups.[31]

# D Detailed results and data

## D.1 Detailed results

### D.1.1 Comparison with World-Bank aggregates

Figure D.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 D.2 and D.3, which show the World GDP-PPP and its growth in our data versus that of the World Bank.

[31]The same intuition holds for capital reallocation. Capital reallocation reflects differential user costs across country-industries for computers, or for machine tools, or for office buildings. The reason we think the capital-reallocation term should be small with an external user cost is that the user cost differences should presumably be small. Of course, there could still be differences to the extent we treat the capital-gains term as country-industry specific, or if there are differential tax wedges.

### D.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 D.1 and D.3, respectively. Similar PPP-weighted shares are listed in Tables D.2 and D.4, respectively. Profit shares by industry are reported in Table D.5.

### D.1.3 Detailed contributions to world 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 D.6, while these contributions with markups are in Table 4. The contribution of shifts in markups by region is reported in Table D.7 while the same contribution by industry can be found in Table D.8.

### D.1.4 Results for TFP with PPP-deflated data and for the ALP

**PPP value-added share weighted results** A striking takeaway from our results in the main text is that labor reallocation explains much of the volatility in world TFP, as well as being a consistent drag on world growth. For this result, we valued world output using current dollars. A natural question is whether these findings reflect true differences in labor's marginal productivity across countries, or rather the effects of exchange rates? Table D.9 addresses this question by quantifying the impact of deviations from PPP on the decomposition in equation (11). Here, country-industry value-added shares are measured in terms of 2005 PPP dollars rather than current U.S. dollars. Although the specific numbers are quite different, our qualitative results are robust to deviations from PPP.

Line 1 of Table D.9 shows that PPP-weighted world GDP grows much faster than current-dollar-weighted GDP growth. The reason is that PPP value-added shares in world GDP tend to be higher than dollar shares for emerging economies; these economies tend to grow faster than average. The growth rate also appears somewhat more volatile. In contrast, comparing lines 2 and 3 with the same lines in Table 3, the contributions of aggregate capital and labor growth are not much changed.[32]

World TFP growth, reported in Line 4, is higher for the PPP-weighted case than for the dollar-weighted case. This follows from having faster growth in GDP (line 1) along with roughly similar contributions from capital and labor (lines 2 and 3). World TFP growth remains highly volatile across subperiods as well as slows down after 2007.

Comparing Lines 4 and 14 of Table D.9 we find that fluctuations in PPP-deflated world TFP growth are much larger than those in country-industry PPP-deflated TFP growth. This is similar to what we found for dollar-weighted ALP and TFP growth as well (and was our first two takeaways). 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.

Deviations from PPP do have a marked impact on the contributions of capital and labor reallocation, especially across countries, to world GDP growth. The impact of the cross-country capital reallocation in Line 7 of Table D.9 is large compared to that in Table 3, in which it was negligible. This potentially reflects that capital flows across the world to equate dollar-denominated returns on investment across country-industry combinations. Equating these dollar-denominated returns is not the same as equating physical marginal products.

For the changes in labor reallocation we find the opposite. Labor reallocation is less important when we consider the PPP-weighted results in Table D.9. A portion of cross-country labor reallocation in the dollar-weighted results in Table 3 reflects economic activity shifting to sectors with an international cost advantage. These are industries with low relative wages compared to relative productivity levels—most

[32]The numbers do not match exactly since our sample changed slightly due to PPP data availability. See Table D.13 in Appendix D.2 for more details.

obviously, manufacturing in China and India.

The labor reallocation results imply that deviations from PPP only account for about a third of the total impact of labor reallocation reported in the earlier tables. Thus, even after adjusting for PPP, labor reallocation remains a drag on world GDP growth as well as being an important source of volatility in world TFP.

Finally, shifts in markups (line 11) contribute slightly more to world GDP growth when PPP-deflated than current-dollar weighted. This is largely due to markups in (Chinese) manufacturing.

**World labor productivity growth** A popular way to measure productivity is to do a decomposition that uses the most reliably measured components. Namely, we are going to 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 $\sum_i s_i^V \dot{l}$. Using these expressions, and subtracting and adding $\sum_i s_i^V \dot{l}_i$, we can write world ALP growth as

$$a\dot{l}p = \dot{v} - \dot{l} \;\; = \;\; \sum_i s_i^V a\dot{l}p_i + \sum_i s_i^V \left(\dot{l}_i - \dot{l}\right) \tag{41}$$

Here, the first term on the right-hand side is the contribution of country-industry specific ALP growth. The second term reflects shifts in hours growth across country-industries. Some algebraic manipulation shows that the second term can be written as $\sum_i \left(\frac{L_i}{L}\right)\left(\frac{P_i^V V_i/L_i}{P^V V/L} - 1\right)\dot{l}_i$,[33] which will, in general, be nonzero if nominal value added per hour worked differs across country-industries. 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 or

[33] To see this, note that, since $\sum_i s_i^V = \sum_i \frac{P_i^V V}{P^V V} = 1$ and $\dot{l} = \sum_i (L_i \,/\, L)\,\dot{l}_i$, we can write the second term on the right-hand-side of (41) as $\sum_i \left(\frac{P_i^V V}{P^V V} - L_i/L\right)\dot{l}_i = \sum_i \left(\frac{L_i}{L}\right)\left(\frac{P_i^V V_i/L_i}{P^V V/L} - 1\right)\dot{l}_i$.

markups). For this reason, it is useful to decompose the shift-in-hours term into two pieces:

$$\sum_i s_i^V \left(\dot{l}_i - \dot{l}\right) = \sum_i s_i^V s_i^L \left(\dot{l}_i - \dot{l}\right) + \sum_i s_i^V \left(1 - s_i^L\right) \left(\dot{l}_i - \dot{l}\right). \quad (42)$$

The first piece is the labor-reallocation term from equation (11); as discussed in Section 5, this term may be non-zero if there are wage differences across country-industries. In case of a statically efficient allocation of resources, this term would be zero. The second piece is a residual, reflecting other differences in factor shares or markups that may affect nominal value-added per hour (which might or might not be efficient).

In this section, we implement the world ALP decomposition in equation (41). We begin graphically with Figure D.4, which illustrates the three key takeaways that we highlighted throughout our analysis. This is figure is basically the ALP version of Figure 3.

First, the dark lines in the figure show the substantial volatility in world ALP growth, $\dot{v} - \dot{l}$. Second, the light lines show 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 (41) shows that the difference between the two lines reflects shifts in hours across industries with different levels of labor productivity, $\sum_i s_i^V \left(\dot{l}_i - \dot{l}\right)$. This effect includes the contribution of labor reallocation, $\sum_i s_i^V s_i^L \left(\dot{l}_i - \dot{l}\right)$. The third takeaway is the year-to-year volatility of this labor reallocation term, which explains much of the difference between the volatile world ALP growth and the smooth country-industry labor productivity growth.

Table D.11 shows the detailed subperiod numbers for the two vintages. The rows correspond to components of equation (41). 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 we discussed in Subsection 3.1. Specifically, world growth in hours in the 2016 vintage was about 1-1/4 percentage points lower from 2001-04 than in the 2013 vintage, but then was about 1/2 percentage point higher from 2005-07. These revisions, though large, do not substantially affect the key takeaways from this section.

Lines 3, 4, and 8 show the key takeaways from implementing equation (41). Line 3 shows World ALP growth, which is output growth (line 1) less hours growth (line 2). Lines 4 and 8 decompose this growth into (line 8) the part that reflects country-industry ALP growth, $\sum_i s_i^V \dot{alp}_i$; and (line 4) the part that reflects shifts in hours across country-industries, $\sum_i s_i^V \left(\dot{l}_i - \dot{l}\right)$. By construction, line 3 is the sum of lines 4 and 8.

Line 3 shows the first key takeaway: World ALP growth is volatile across the five subperiods that we distinguish. During the expansion of the late 1990's, world ALP growth was above 2 percent. Growth 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, turning sharply negative.

Line 8 shows the second key takeaway, which is the relatively smooth evolution of ALP growth at a country-industry level, $\sum_i s_i^V \dot{alp}_i$. Indeed, country-industry ALP 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, from lines 4 and 5, is that the bulk of the variation in world ALP growth arises from substantial volatility in the effects of shifting hours, notably labor reallocation. This follows from the first two takeaways, given that the contribution of shifting hours (line 4) is, as an accounting identity, the difference between the volatile growth rate of world ALP growth and the relatively smooth contribution of country-industry specific ALP.

As discussed in section 5, this shift-in-hours term reflects the cross-sectional covariance of labor growth and nominal value added per hour. Those differences could be efficient—reflecting, say, technological heterogeneity in factor shares across industries. Or they could be related to wedges, such as markups or labor taxes. For this reason, line 5 of Table D.11 breaks out labor reallocation, $\sum_i s_i^V s_i^L \left(\dot{l}_i - \dot{l}\right)$. This piece, as discussed in Section 5, reflects the cross-sectional covariance of wages and labor growth. This labor-reallocation term in line 5 carries over to the TFP decompositions in the main text.

Within labor reallocation, what turns out to be quantitatively most important is reallocations 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, where wages are lower, 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. This cross-country term was slightly positive during the expansion in developed economies from 2005-2007. In contrast, the term was more negative in periods when there was a bigger wedge in hours growth between emerging and developed economies, as in 2001-2004, 2008-2010, and 2011-2014. Note also, from line 6, that shifts in the within-country reallocation of labor contribute little to world GDP growth.

Table D.12 decomposes the 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 (e.g., Cette *et al.*, 2016). 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.

## D.2 Data

### D.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 D.13. Throughout, we present these results for a set of regions that are the same across both vintages. The regions are listed in Table D.14. The industries were classified into major categories, listed in Table D.15, in order to be consistent with the North American Industry Classification System (NAICS).

### D.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 (2017), 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. $\pi^K_{USD}$. Capital service flows for each country-industry combination are then calculated as

$$\left(i_{BBB} - \pi^K_{USD} + \delta_i\right) P^K_i K_i \tag{43}$$

Here, $i_{BBB}$ is the nominal BBB 10-yr corporate bond rate and $\delta_i$ 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 $\pi^K_{USD}$ by using the average over vintage sample.

### D.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.

### D.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

$$\mathcal{P}_{i,t} = \frac{\$/GO_{i,t}}{\$/USGDP_t} = \frac{USGDP_t}{GO_{i,t}} \text{ for } t = 2005. \tag{44}$$

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

$$\mathcal{P}_{i,t} = \mathcal{P}_{i,2005} \frac{P_{i,t}/P_{i,2005}}{\mathcal{P}_t/\mathcal{P}_{2005}}. \tag{45}$$

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

$$Y^*_{i,t} = \frac{P_{i,t}Y_{i,t}}{\mathcal{P}_{i,t}} \frac{1}{\mathcal{P}_t} = \frac{P_{i,t}Y_{i,t}}{P^*_{i,t}}, \text{ where } P^*_{i,t} = \mathcal{P}_{i,t}\mathcal{P}_t. \tag{46}$$

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.

$$P_{i,t}^{V}V_{i,t} = P_{i,t}Y_{i,t} - \sum_{i'} P_{i',t}M_{i',t}. \tag{47}$$

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,

$$V_{i,t}^{*} = \frac{P_{i,t}Y_{i,t}}{P_{i,t}^{*}} - \sum_{i'} \frac{P_{i',t}M_{i',j',t}}{P_{i',t}^{*}}. \tag{48}$$

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

$$P_{i,t}^{V*} = \frac{P_{i,t}^{V}V_{i,t}}{V_{i,t}^{*}}. \tag{49}$$

The calculation of (48) 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

$$P_{i,t}^{M*} = \sum_{i'} \frac{P_{i',t}M_{i',t}}{\sum_{i''} P_{i'',t}M_{i'',t}} P_{i',t}^{*}. \tag{50}$$

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 $P_{i,t}^{M*}$ 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, (49).

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

Table D.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 |
| 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 | 0.1 | 0.11 | 0.11 | 0.12 | 0.11 |
| 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 | 1.0 | 1.00 | 1.00 | 1.00 | 1.00 |

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

Table D.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 |
| 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 |
| 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 | 1.01 | 1.00 | 1.00 | 1.00 | 1.00 |

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

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

| SEA vintage | 2013 | | | | 2016 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Country/region | 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 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.00 | 1.00 | 1.00 | 1.00 | 1.0 | 1.00 | 1.00 | 1.00 | 1.00 |

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

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

| SEA vintage | 2013 | | | | 2016 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Country/region | 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 | 0.08 | 0.07 | 0.07 | 0.07 | 0.07 |
| Construction | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| Nondurables manuf | 0.16 | 0.15 | 0.15 | 0.15 | 0.14 | 0.14 | 0.14 | 0.15 | 0.15 |
| Durables manuf | 0.06 | 0.06 | 0.07 | 0.06 | 0.07 | 0.08 | 0.08 | 0.09 | 0.08 |
| Trade Trans Utilities | 0.18 | 0.19 | 0.19 | 0.19 | 0.19 | 0.20 | 0.19 | 0.18 | 0.19 |
| FIRE | 0.15 | 0.15 | 0.15 | 0.15 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 |
| Business services | 0.08 | 0.09 | 0.09 | 0.08 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 |
| Education Healthcare | 0.08 | 0.08 | 0.08 | 0.08 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| Hospitality | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 |
| Personal services | 0.04 | 0.03 | 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 | 0.07 | 0.07 | 0.07 | 0.07 |
| Households | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total | 1.00 | 1.00 | 1.00 | 1.00 | 1.01 | 1.00 | 1.00 | 1.00 | 1.00 |

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

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

| SEA vintage | 2013 | | | | 2016 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Country/region | 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 | 1.2 | 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 | 0.0 | 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 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 |
| Government | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 | 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 D.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 |
| 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 | -0.18 | 0.10 | 0.02 |
| Euro Area | 0.18 | 0.07 | 0.18 | 0.15 | 0.05 | 0.14 | -0.25 | 0.05 | 0.00 |
| Other advanced | 0.15 | 0.06 | 0.09 | 0.11 | 0.03 | 0.01 | -0.07 | -0.03 | -0.01 |
| Brazil | 0.01 | -0.00 | -0.02 | -0.00 | -0.0 | -0.04 | -0.02 | -0.14 | -0.05 |
| 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 | 0.08 | -0.01 | 0.04 | 0.02 |
| Total | 0.91 | 1.18 | 1.28 | 1.09 | 0.46 | 0.96 | -0.16 | 0.21 | 0.36 |

Note: Reported are contributions by country/region to line 10 in Table 2 in percentage points over various subperiods. Results without markups.

Table D.7: 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 |
| 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 |
| 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 3 in percentage points over various subperiods.

Table D.8: Contribution of markups to world GDP growth, by industry: 1996-2014

| SEA vintage | 2013 | | | | 2016 | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Country/region | 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 | 0.0 | 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 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 |
| Government | 0.00 | 0.00 | 0.00 | 0.00 | 0.0 | 0.00 | 0.00 | 0.00 | 0.00 |
| Households | -0.00 | 0.00 | 0.00 | -0.00 | 0.0 | 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 3 in percentage points over various subperiods.

Table D.9: 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 | 5.37 | 8.05 | 6.06 | 5.11 | 7.94 | 3.29 | 5.57 | 5.46 |
| 2) | World 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) | World 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 | 3.27 | 7.07 | 4.49 | 3.59 | 6.65 | 2.54 | 3.07 | 3.87 |
| 5) | Reallocation of capital | $\sum_i s_i^V s_i^K(\dot{k}_i - \dot{k})$ | 0.32 | 0.17 | 0.26 | 0.25 | 0.38 | 0.61 | 0.80 | 0.68 | 0.61 |
| 6) | ...within countries | | 0.20 | 0.07 | 0.15 | 0.15 | 0.08 | 0.16 | 0.04 | -0.00 | 0.07 |
| 7) | ...across countries | | 0.11 | 0.10 | 0.11 | 0.11 | 0.3 | 0.45 | 0.76 | 0.68 | 0.54 |
| 8) | Reallocation of hours | $\sum_i s_i^V s_i^L(\dot{l}_i - \dot{l})$ | 0.02 | -1.12 | 0.60 | -0.21 | -0.23 | 0.53 | -0.03 | -0.44 | -0.08 |
| 9) | ...within countries | | 0.08 | -0.19 | 0.36 | 0.06 | 0.15 | 0.34 | 0.25 | 0.27 | 0.25 |
| 10) | ...across countries | | -0.06 | -0.93 | 0.23 | -0.28 | -0.38 | 0.19 | -0.28 | -0.70 | -0.33 |
| 11) | Shifts in markups | $\sum_i s_i^D \frac{\mu_i}{1+\mu_i}\dot{y}_i$ | 0.60 | 0.60 | 1.46 | 0.81 | 0.69 | 1.18 | 0.55 | 0.77 | 0.79 |
| 12) | ...Shifts in average markups | $\frac{\bar{\mu}}{1+\bar{\mu}}\dot{\bar{y}}$ | 0.48 | 0.50 | 1.34 | 0.70 | 0.75 | 1.38 | 0.53 | 1.07 | 0.93 |
| 13) | ...Output shifts | $\sum_i s_i^D \frac{\mu_i}{1+\mu_i}(\dot{y}_i - \dot{\bar{y}})$ | 0.12 | 0.11 | 0.12 | 0.11 | -0.05 | -0.20 | 0.02 | -0.30 | -0.14 |
| 14) | Country-industry TFP growth | $\sum_i s_i^D \frac{1}{1+\mu_i}\dot{z}_i$ | 2.98 | 3.62 | 4.75 | 3.64 | 2.75 | 4.32 | 1.21 | 2.05 | 2.56 |

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 D.10: Summary of Euro Area 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) | Euro Area GDP growth | $\dot{v}$ | 2.68 | 1.56 | 2.69 | 2.31 | 1.5 | 2.64 | -0.71 | 0.38 | 0.95 |
| 2) | Euro Area capital growth | $s^K\dot{k}$ | 0.74 | 0.72 | 0.68 | 0.72 | 0.41 | 0.49 | 0.35 | 0.12 | 0.33 |
| 3) | Euro Area hours growth | $s^L\dot{l}$ | 0.74 | 0.33 | 0.86 | 0.63 | 0.38 | 0.99 | -0.60 | -0.29 | 0.11 |
| 4) | Euro Area TFP growth | $\dot{tfp}$ | 1.21 | 0.52 | 1.16 | 0.97 | 0.71 | 1.16 | -0.46 | 0.55 | 0.51 |
| 5) | Reallocation of capital | $\sum_i s_i^V s_i^K(\dot{k}_i - \dot{k})$ | 0.15 | 0.07 | 0.06 | 0.10 | 0.07 | 0.09 | 0.06 | 0.01 | 0.05 |
| 6) | ...within countries | | 0.14 | 0.08 | 0.09 | 0.11 | 0.07 | 0.09 | 0.05 | 0.01 | 0.05 |
| 7) | ...across countries | | 0.01 | -0.02 | -0.03 | -0.01 | -0.0 | 0.00 | 0.01 | 0.00 | 0.00 |
| 8) | Reallocation of hours | $\sum_i s_i^V s_i^L(\dot{l}_i - \dot{l})$ | -0.04 | -0.11 | -0.09 | -0.08 | -0.13 | -0.11 | 0.15 | 0.10 | 0.00 |
| 9) | ...within countries | | 0.03 | 0.00 | 0.01 | 0.01 | -0.0 | -0.01 | 0.03 | -0.00 | 0.00 |
| 10) | ...across countries | | -0.07 | -0.11 | -0.11 | -0.09 | -0.12 | -0.10 | 0.12 | 0.10 | -0.00 |
| 11) | Shifts in markups | $\sum_i s_i^D \frac{\mu_i}{1+\mu_i}\dot{y}_i$ | 0.23 | 0.18 | 0.45 | 0.27 | 0.51 | 0.77 | -0.06 | 0.06 | 0.32 |
| 12) | ...Shifts in average markups | $\frac{\bar{\mu}}{1+\bar{\mu}}\dot{\bar{y}}$ | 0.18 | 0.10 | 0.37 | 0.20 | 0.4 | 0.75 | -0.19 | 0.02 | 0.24 |
| 13) | ...Output shifts | $\sum_i s_i^D \frac{\mu_i}{1+\mu_i}(\dot{y}_i - \dot{\bar{y}})$ | 0.06 | 0.08 | 0.08 | 0.07 | 0.12 | 0.02 | 0.14 | 0.03 | 0.08 |
| 14) | Country-industry TFP growth | $\sum_i s_i^D \frac{1}{1+\mu_i}\dot{z}_i$ | 0.87 | 0.38 | 0.74 | 0.68 | 0.26 | 0.40 | -0.61 | 0.38 | 0.14 |

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.

Table D.11: 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 |
| 4) | Relative hours growth | $\sum_i s_i^V(\dot{l}_i - \dot{l})$ | 0.02 | -2.04 | 1.11 | -0.40 | -0.79 | 0.82 | -0.71 | -1.49 | -0.62 |
| 5) | ...Reallocation of hours | $\sum_i s_i^V s_i^L(\dot{l}_i - \dot{l})$ | -0.01 | -1.34 | 0.50 | -0.33 | -0.56 | 0.35 | -0.36 | -0.97 | -0.44 |
| 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 | -0.6 | 0.27 | -0.44 | -1.07 | -0.51 |
| 8) | Country-industry ALP growth | $\sum_i s_i^V \dot{alp}_i$ | 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 (41). Reported are contributions to average annual growth rates in percentage points over various subperiods.

Table D.12: 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 |
| 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 |
| 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 D.11 in percentage points over various subperiods.

Table D.13: 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 D.14: Country Classification

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

Table D.15: 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).

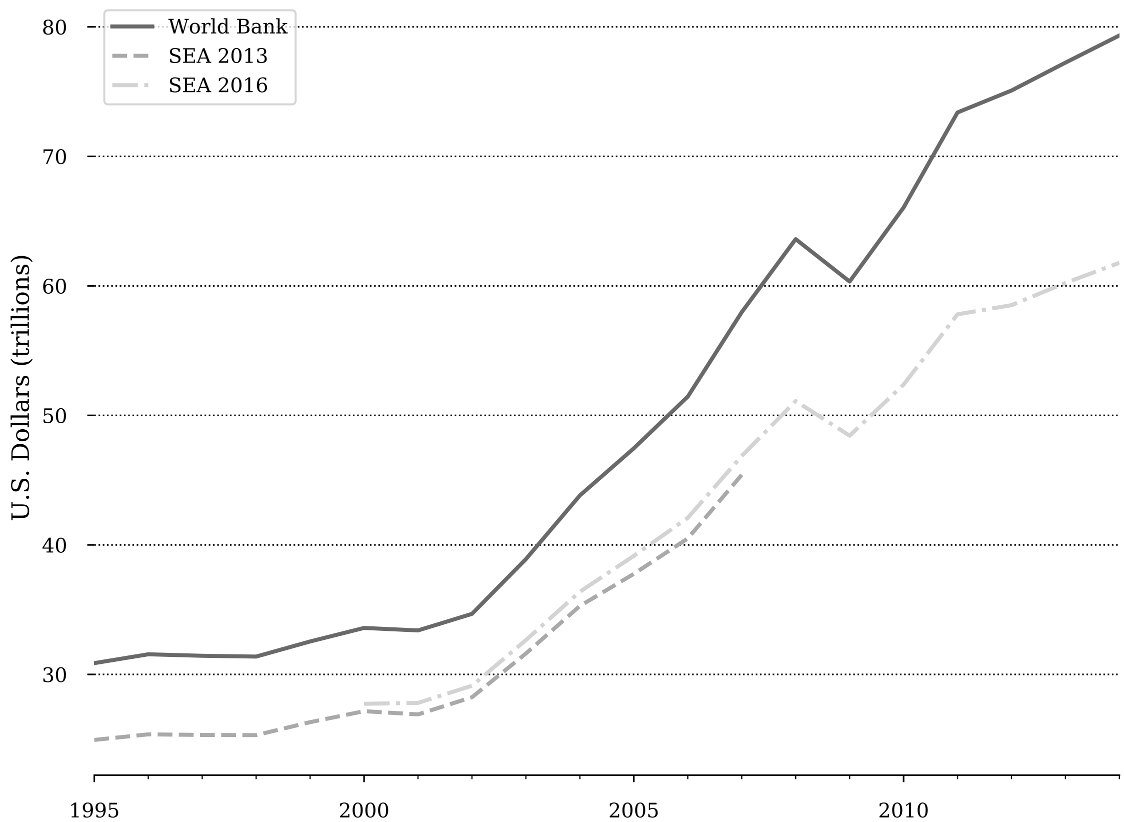


Figure D.1: Nominal world GDP in WIOD-SEA and WDI

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. $.

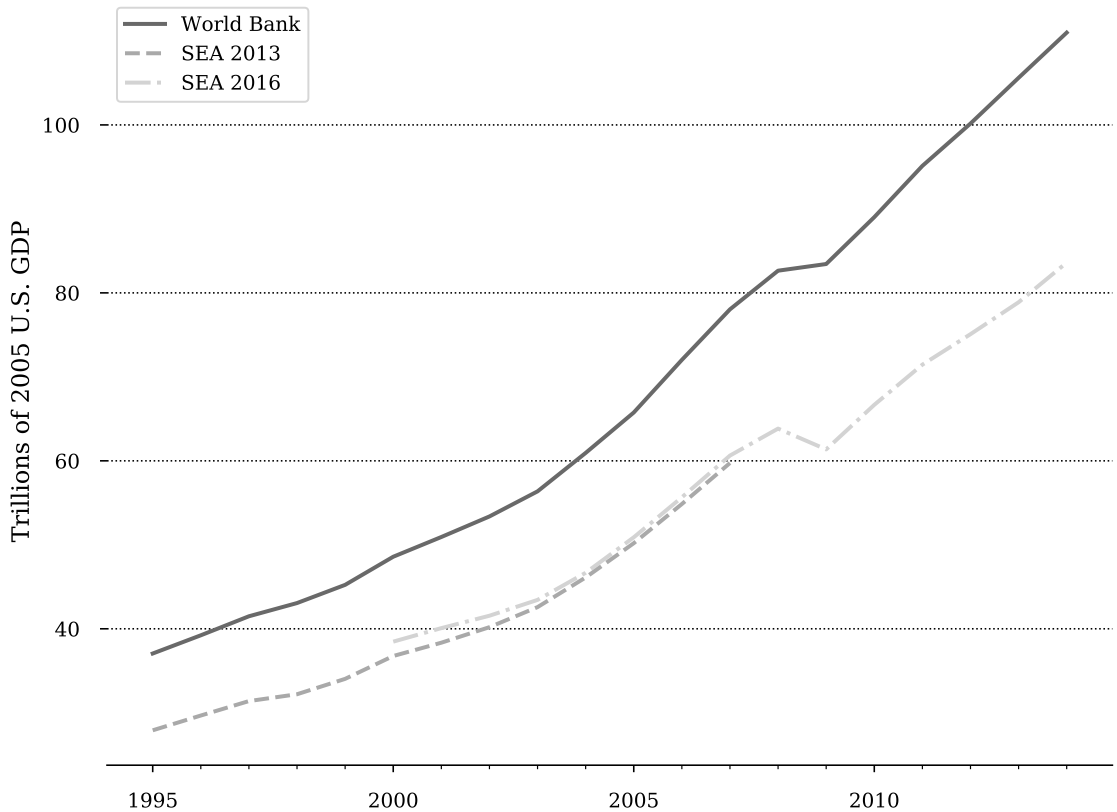


Figure D.2: World GDP PPP in WIOD-SEA and WDI

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.

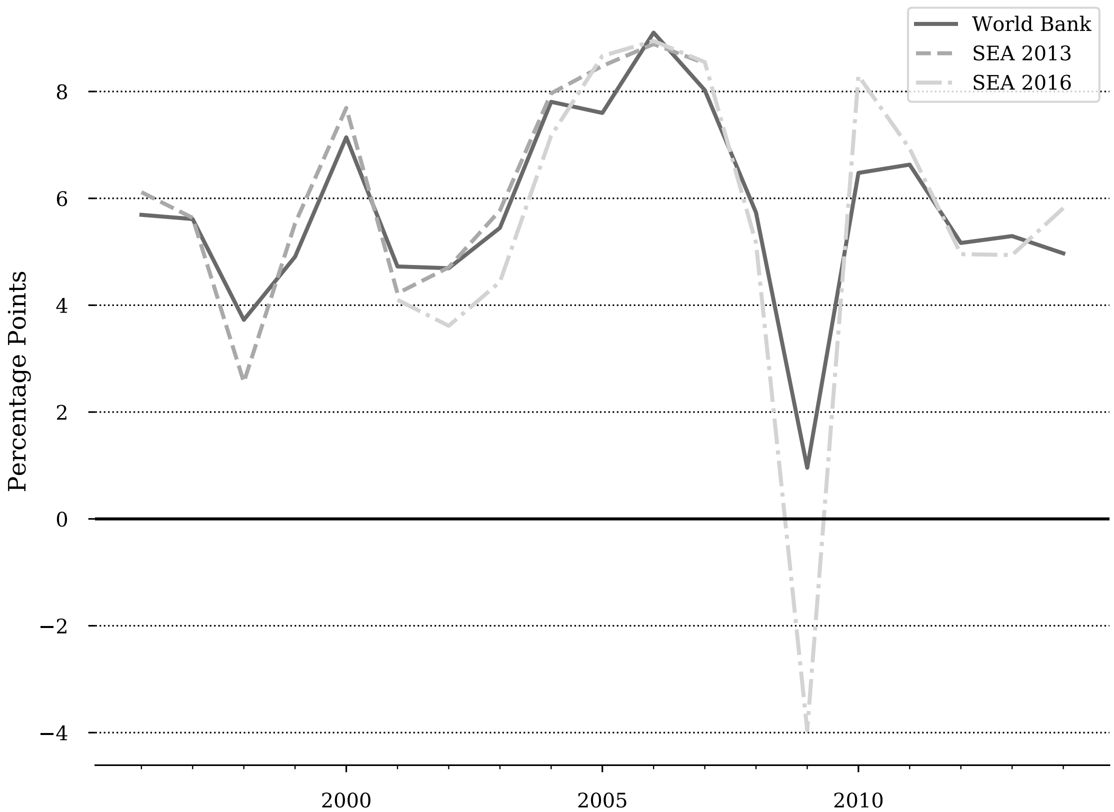


Figure D.3: Growth in world GDP PPP in WIOD-SEA and WDI

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.

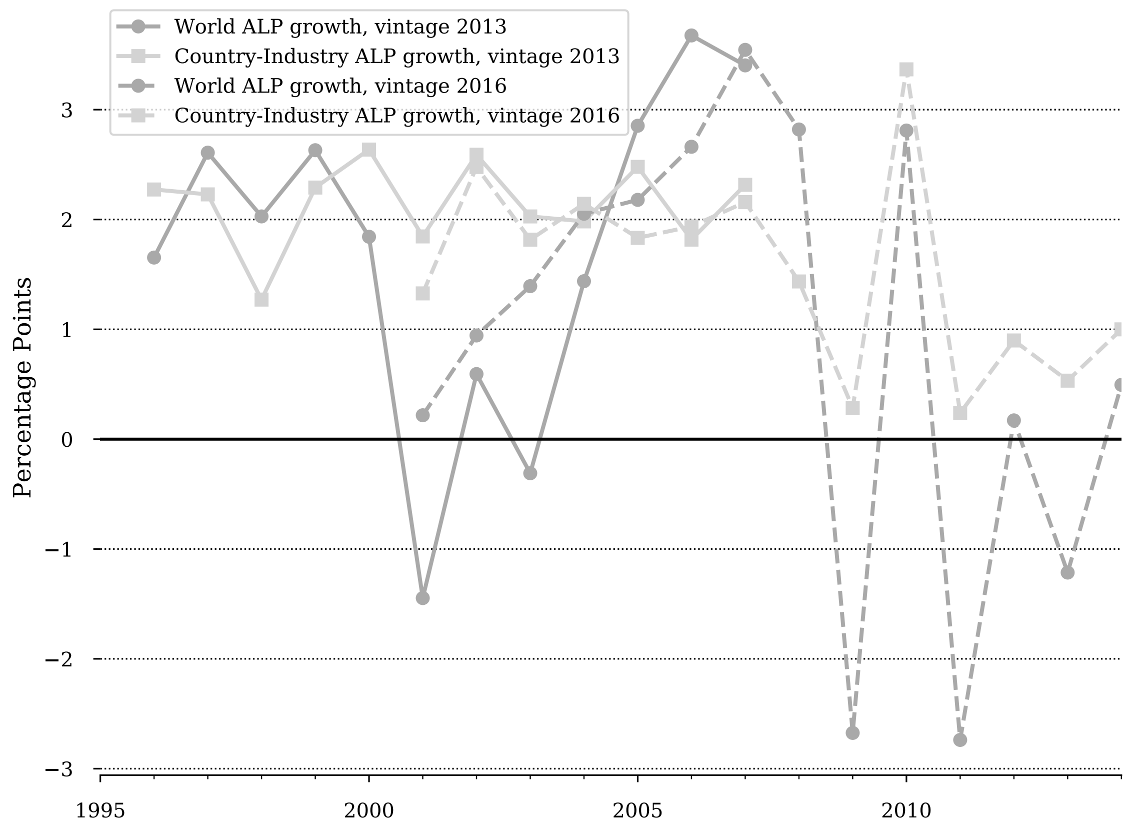


Figure D.4: TFP growth: World vs. country-industry component, vintage 2016.

Note: Solid line is 2013 vintage and dashed line is 2016 vintage.

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