World Productivity: 1996 - 2014*

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Abstract

We use a new normative growth-accounting framework to account for the sources of world GDP growth using data for 40 major economies and 36 industries from the World Input-Output Database from 1996 to 2014. We find that the contribution of productivity growth at the country-industry level to world GDP growth is relatively constant and that the recent productivity slowdown in industrialized countries is largely offset, at the world level, by productivity growth in emerging economies. Most of the fluctuations in world productivity growth are the result of shifts in the misallocation of labor across countries and industries. Using new data on PPP-based value-added measures by country and industry, we show that about a third of this shift in misallocation reflects employment growing in countries, most notably China and India, and industries that benefit from an international cost advantage in terms of deviations from PPP.

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

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1 Introduction

We account for world productivity growth from 1996-2014 by combining data on more than 36 industries and 40 countries. Though world productivity is a concept that is often discussed in models of economic growth and innovation (Caselli & Coleman, 2006) in the context of a world technology frontier, there are very few studies that formally account for world productivity growth. In this paper, we use new global growth accounting techniques to measure growth in the world level of average labor productivity and decompose it into it into technology, labor, capital, as well as changes in distortions in product, labor, and capital markets.

Two main things stand our from our results. First of all, what looks like a productivity slowdown in the 2000's in industrialized countries looks like a shift in the regional composition of productivity growth at a global scale. Secondly, the growth of emerging economies, with more distorted labor markets, decreases world efficiency and causes a drag on global output growth.

The global growth accounting method that we apply 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). Because these studies do not include industry-level data, they do not provide an estimate of the industry-origins of world productivity growth. Moreover, they also do not formally account for reallocation of resources across countries, which turns out to be quantitatively important in the data.

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

The growth accounting methods in the above strand of the literature largely rely on neoclassical assumptions of efficient market allocations. Such assumptions are already at best an approximation at the national level. At the global level, at which we do our accounting here, they are simply not satisfactory. In light of that, we follow Baqaee & Farhi (2017) and consider productivity accounting

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

in an economy with distortions in product, capital, and labor markets.

Our methodological contribution in this paper is that we show that such growth accounting can be done in a normative framework that relies on the application of the envelope theorem to the solution of a distorted planner problem. This approach turns out to yield a decomposition of world GDP growth, measured on the production side, that is similar to that in Jorgenson *et al.* (1987) and the extension with markups in Basu & Fernald (1997). The difference is that each of the terms in our decomposition has a direct normative interpretation in terms of the effect of changes in distortions due to the shift in the use of productive resources within countries and around the world.

The data we use are two vintages of the World Input-Output Database (WIOD), described in Timmer (2012) and Timmer *et al.* (2015). These data cover input-output and productivity data for more than 40 countries and 36 industries from 1996-2014. These countries cover about 80 percent of World GDP measured in dollars over the years in the sample. Unfortunately, not all variables are covered in both vintages of the data. For this reason we calculate results for both Average Labor Productivity (ALP) as well as Total Factor Productivity (TFP) growth.

In spite of the limitations of the data, a clear picture emerges about global productivity patterns over the almost two decades covered in our sample. World productivity growth, both measured in terms of ALP and TFP, is highly volatile across years and even over multi-year periods. The bulk of this volatility reflects shifts in the misallocation of capital and, especially, labor in the world economy.[2] The contribution of the actual underlying country-industry level productivity growth rates to world productivity growth is relatively constant over time.

This relative constancy, however, masks a marked change in the regional composition of this part of world productivity growth. Consistent with other evidence, our results reveal a slowdown in ALP growth for advanced industrialized countries starting in the second half of the 2000s.[3] At a global level, this slowdown is offset, however, by an acceleration of productivity growth in emerging economies, most notably India and China.

The outsized role we find for the misallocation of labor for world productivity growth fluc-

[2]This is similar to country-level and regionalstudies that find a large role for the reallocation of capital (e.g Oliner & Sichel, 2000) and labor, as in Wu (2016) for China and Hofman *et al.* (2016) for Latin America.

[3]See, for example, Byrne *et al.* (2016), ECB (2017) , and OECD (2017a)

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

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

This correction for PPP differentials only accounts for a third of the misallocation effect of labor that we quantify using dollar-based measures of world GDP. Even after this correction, misallocation of labor on net is a substantial drag on world productivity growth and contributes a lot to its volatility. This suggests that it is important to understand barriers to factor movements and distortions in labor markets when analyzing global economic performance.[4]

2 Global growth accounting with distortions

In order to account for the sources of world output growth it is important to use a method that does not only consider technology and production factors, under the assumption of an efficient allocation of resources, but that also allows for distortions to the global allocation of resources. In this section we build on the approach taken by Baqaee & Farhi (2017) and consider an economy with distortions in product, capital, and labor markets. Baqaee & Farhi (2017) consider how to account for the changes in such a distorted market allocation over time.

We show that one can interpret this inefficient market allocation as the solution to a distorted planner problem. This interpretation is useful because it allows us to take the time derivative of the associated Lagrangian, as Hulten (1978) does for the efficient case, which allows us to split the sources of world GDP growth into parts due to technology, capital, labor, and to changes in

[4]Studies of gains from removing the barriers to factor movements across political borders usually find large effects on output and capital accumulation. For example, Klein & Ventura (2009) show that a hypothetical creation of a common labor market within NAFTA results in an increase in output in North America by 10.5%.

distortions in markets.

In the rest of this section we introduce our new growth-accounting result in the following three steps. We first introduce the distorted market allocation, which is similar to that in Baqaee & Farhi (2017). In the second step we show how this allocation coincides with that chosen by a planner that solves a distorted planner's problem. Finally, we then introduce what the solution to this problem implies for the growth rate of output. We limit ourselves to the gist of our results and present the details of our derivations in the appendix.

2.1 Market allocation

The main focus of our analysis is the decisions of producers that produce output and the impact of changes in their inputs choices, technology, and distortions they face on the path of output. We consider the (world) economy to made up of n sectors, indexed by $i = 1 \ldots n$. Each sector reflects a particular industry-country combination. Throughout, we main the assumption of constant returns to scale in each sector.[5]. Producers of product i pay taxes on their capital, K_i, labor, L_i, and intermediate input, M_i, choices. The respective constant tax rates are τ_i^K, τ_i^L, and τ_i^j, where the latter is the tax rate in intermediate inputs bought from sector j. They choose the factor inputs, $\left\{K_i, L_i, \{M_{i,j}\}_{j=1}^n\right\}$, to minimize their cost of production

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

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

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

Similar to Baqaee & Farhi (2017), we assume that producers in sector i charge a price, P_i, that includes a potential net markup, μ_i, over the unit production cost implied by the above cost-minimization problem.

The goods (and services) produced in the n sectors that are not used as intermediate inputs, are

[5] As Baqaee & Farhi (2017) note, this does allow for the case of decreasing returns to scale at the establishment level with fixed operating costs, but it does exclude several cases more explicitly analyzed by Basu & Fernald (1997)

sold to final demand. We denote the final demand for goods produced by sector i by D_i. Like Baqaee & Farhi (2017) we assume that final demand is the result of the following "utility" maximization problem. Namely, final demand and sector-specific factor supplies, $\{K_i, L_i, D_i\}_{i=1}^n$, are chosen to maximize

$$D = \mathcal{G}\left(\{D_i\}_{i=1}^n\right) \tag{3}$$

subject to the budget constraint that after-tax spending on final sales equals the sum of capital and labor income, profits, and a net lump-sum government transfer,

$$\sum_i \left(1+\tau_i^D\right) P_i D_i = \sum_i R_i K_i + \sum_i W_i L_i + \sum_i \frac{\mu_i}{1+\mu_i} P_i Y_i + \tau, \tag{4}$$

and the factor-supply constraints

$$K = \mathcal{K}\left(\{K_i\}_{i=1}^n\right) \tag{5}$$

$$L = \mathcal{L}\left(\{L_i\}_{i=1}^n\right). \tag{6}$$

Here, $\mathcal{K}(.)$ and $\mathcal{L}(.)$ are aggregators of capital and labor and are assumed to be homogenous of degree one. We include them to allow for imperfect substitutibility of capital and labor inputs across sectors. The aggregator $\mathcal{G}$ is assumed to be homogenous of degree one and D is the theoretical equivalent of expenditure-side GDP.

The net lump-sum transfer includes the tax revenue generated by the government from the distortionary taxation of capital inputs, labor inputs, intermediate inputs, and final sales, i.e.

$$\tau = \sum_i \tau_i^K R_i K_i + \sum_i \tau_i^L W_i L_i + \sum_i \sum_j \tau_i^j M_{i,j} + \sum_i \tau_i^D P_i D_i. \tag{7}$$

The decentralized equilibrium allocation of resources in this market economy is characterized by the following distorted first-order conditions

$$
\begin{aligned}
\left(1+\tau_i^K\right)\frac{R_i}{P} &= \frac{1}{(1+\mu_i)}\frac{P_i}{P}Z_iF_i^K, \text{ where } F_i^K = \frac{\partial}{\partial K_i}F_i\left(K_i, L_i, \{M_{i,j}\}_{j=1}^n\right),\\
\left(1+\tau_i^L\right)\frac{W_i}{P} &= \frac{1}{(1+\mu_i)}\frac{P_i}{P}Z_iF_i^L, \text{ where } F_i^L = \frac{\partial}{\partial L_i}F_i\left(K_i, L_i, \{M_{i,j}\}_{j=1}^n\right),\\
\left(1+\tau_i^j\right)\frac{P_j}{P} &= \frac{1}{(1+\mu_i)}\frac{P_i}{P}Z_iF_i^j, \text{ where } F_i^j = \frac{\partial}{\partial M_{i,j}}F_i\left(K_i, L_i, \{M_{i,j}\}_{j=1}^n\right),\\
U_i &= \left(1+\tau_i^D\right)\frac{P_i}{P}, \text{ where } \mathcal{G}_i = \frac{\partial}{\partial D_i}\mathcal{G}\left(\{D_i\}_{i=1}^n\right),\\
\frac{R}{P}\mathcal{K}_i &= \frac{R_i}{P}, \text{ where } \mathcal{K}_i = \frac{\partial}{\partial K_i}\mathcal{K}\left(\{K_i\}_{i=1}^n\right),\\
\frac{W}{P}\mathcal{L}_i &= \frac{W_i}{P}, \text{ where } \mathcal{L}_i = \frac{\partial}{\partial L_i}\mathcal{L}\left(\{L_i\}_{i=1}^n\right),
\end{aligned}
$$

and the, undistorted, technology and resource constraints

$$Y_i = Z_iF_i\left(K_i, L_i, \{M_{i,j}\}\right), \tag{8}$$

$$K = \mathcal{K}\left(\{K_i\}\right), \tag{9}$$

$$L = \mathcal{L}\left(\{L_i\}\right), \tag{10}$$

$$Y_i = D_i + \sum_j M_{j,i}. \tag{11}$$

Here, P is the aggregate price index and R and W are the aggregate rental and wage rates, respectively.

2.2 Distorted planner problem

The above decentralized distorted market allocation coincides with the solution to a planner's problem where the planner chooses $\{Y_i, L_i, K_i, M_{i,j}\}$ to maximize

$$D = \mathcal{G}\left(\{D_i\}\right) \tag{12}$$

subject to the following constraints

$$
\begin{aligned}
Y_i &= Z_i F_i \left(K_i, L_i, \{M_{i,j}\}\right) && (13)\\
\frac{1}{(1+\mu_i)} Y_i &= \left(1+\tau_i^D\right) D_i + \sum_i \left(1+\tau_j^i\right) M_{j,i} + \Theta_i^Y && (14)\\
K &= \sum_i \left(1+\tau_i^K\right) \theta_i^K K_i + \Theta^K && (15)\\
L &= \sum_i \left(1+\tau_i^L\right) \theta_i^L L_i + \Theta^L && (16)
\end{aligned}
$$

What the planner does *not internalize* is that $\left\{\theta_i^K\right\}_{i=1}^n$, $\left\{\theta_i^L\right\}_{i=1}^n$, $\left\{\Theta_i^Y\right\}_{i=1}^n$, Θ^K, and Θ^L themselves depend on the planner's choices. It is this that "distorts" the planner's problem relative to the first-best. In particular, these distortions satisfy

$$
\begin{aligned}
\theta_i^K &= \mathcal{K}_i && (17)\\
\theta_i^L &= \mathcal{L}_i && (18)\\
\Theta_i^Y &= -\frac{\mu_i}{(1+\mu_i)} Y_i - \tau_i^D D_i - \sum_j \tau_j^i M_{j,i} && (19)\\
\Theta^K &= \mathcal{K}\left(\{K_i\}\right) - \sum_i \left(1+\tau_i^K\right) \theta_i^K K_i && (20)\\
\Theta^L &= \mathcal{L}\left(\{L_i\}\right) - \sum_i \left(1+\tau_i^L\right) \theta_i^L L_i && (21)
\end{aligned}
$$

This problem has the following associated Lagrangian

$$
\begin{aligned}
D &= \mathcal{G}\left(\{D_i\}\right) && (22)\\
&- \omega_i \left[Y_i - Z_i F_i \left(K_i, L_i, \{M_{i,j}\}\right)\right] && (23)\\
&+ \psi_i \left[\frac{1}{(1+\mu_i)} Y_i - \left(1+\tau_i^D\right) D_i - \sum_i \left(1+\tau_j^i\right) M_{j,i} - \Theta_i^Y\right] && (24)\\
&+ \kappa \left[K - \sum_i \left(1+\tau_i^K\right) \theta_i^K K_i - \Theta^K\right] && (25)\\
&+ \lambda \left[L - \sum_i \left(1+\tau_i^L\right) \theta_i^L L_i - \Theta^L\right] && (26)
\end{aligned}
$$

In the appendix, we show that the allocation chosen by this planner coincides with the distorted decentralized market equilibrium and that the planner's Lagrange multipliers are related to the market prices in the following manner

$$\omega_i = \frac{1}{(1+\mu_i)} \frac{P_i}{P},\ \psi_i = \frac{P_i}{P},\ \kappa = \frac{R}{P},\ \text{and}\ \lambda = \frac{W}{P}. \tag{27}$$

The advantage of writing the market allocation as resulting from a planner's problem is that, just like in Hulten (1978), we can take the time derivative of the planner's Lagrangian to find the growth rate of the planner's objective, $\dot{d}$, over time. The envelope theorem implies that all terms that involve variables with respect to which the planner optimizes drop out of the resulting time derivative. This means that, in this case, we have to consider the partials of the Lagrangian with respect to technology, $\{Z_i\}_{i=1}^n$, aggregate capital, K, aggregate labor, L, the tax rates, $\left\{\tau_i^K, \tau_i^L, \tau_i^D, \{\tau_i^j\}_{j=1}^n\right\}_{i=1}^n$, and the distortions, $\{\theta_i^K, \theta_i^L, \Theta_i^Y\}_{i=1}^n$, Θ^K, and Θ^L.

As we show in the appendix, the time derivative of the above Lagrangian can be simplified a lot. First of all, it does not depend on the changes in the tax rates, i.e. $\left\{\dot{\tau}_i^K, \dot{\tau}_i^L, \dot{\tau}_i^D, \{\dot{\tau}_i^j\}_{j=1}^n\right\}_{i=1}^n$. Thus, though we allow for these rates to vary over time, their changes are not relevant for our growth accounting. Moreover, we can substitute out the changes in the distortions $\left\{\dot{\theta}_i^K, \dot{\theta}_i^L, \dot{\Theta}_i^Y\right\}_{i=1}^n$, $\dot{\Theta}^K$, and $\dot{\Theta}^L$. The result is that we can write the growth rate of the planner's objective, $\dot{d}$, as

$$\begin{aligned} \dot{d} \;=\;& \sum_i \frac{1}{(1+\mu_i)} \frac{P_i}{PD} Y_i \dot{z}_i + \frac{RK}{PD}\dot{k} + \frac{WL}{PD}\dot{l} \\ +\;& \dot{d} + \sum_i \frac{\mu_i}{(1+\mu_i)} \frac{P_i Y_i}{PD}\dot{y}_i - \sum_i \left[\frac{P_i Y_i}{PD}\dot{y}_i - \sum_j \left(1+\tau_j^i\right) \frac{P_i M_{j,i}}{PD}\dot{m}_{j,i}\right] \\ -\;& \left[\frac{RK}{PD}\dot{k} - \sum_i \frac{R}{PD}\left(1+\tau_i^K\right) \mathcal{K}_i K_i \dot{k}_i\right] \\ -\;& \left[\frac{WL}{PD}\dot{l} - \sum_i \frac{W}{PD}\left(1+\tau_i^L\right) \mathcal{L}_i L_i \dot{l}_i\right] \end{aligned} \tag{28}$$

In terms of normative interpretation, each of the four lines of the above equation have a clear meaning. The first line splits up output growth into the contributions of capital, labor, and technology. The second line reflects the impact of the changes in the product market distortions, $\left\{\dot{\Theta}_i^Y\right\}_{i=1}^n$.

The third line captures the impact of changes in capital market distortions, i.e. $\left\{\dot{\theta}_i^K\right\}_{i=1}^n$ and $\dot{\Theta}^K$. Similarly, the last line quantifies the impact of changes in labor market distortions $\left\{\dot{\theta}_i^L\right\}_{i=1}^n$ and $\dot{\Theta}^L$. As Baqaee & Farhi (2017) emphasize for similar terms in their analysis, the last three lines quantify the impact of *changes* in distortions due to shifts in the allocation of resources. They *do not* measure the *magnitude* of such distortions.

Thus, this decomposition splits up GDP growth, on the expenditure side, into additive parts that each have a clear positive and normative interpretation in terms of shifts in the production possibility frontier and changes in market inefficiencies that result in the market allocation deviating from it.

2.3 Growth accounting equation

The above equation decomposes GDP growth measured in terms of purchaser's prices of final demand. Our focus is on productivity accounting and, in line with the data that we will use in our application, we focus on the sources of growth in GDP measured as the value of production at basic prices. In particular, our concept of nominal GDP is the sum of nominal value added at basic prices, $P^V V$, where

$$P^V V = \sum_i P_i^V V_i, \text{ and } P_i^V V_i \;\; = \;\; P_i Y_i - \sum_j \left(1 + \tau_i^j\right) P_j M_{i,j}. \tag{29}$$

Note that, consistent with the data we use, nominal value added in sector i is defined as the difference between nominal gross output and the value of intermediate inputs at *purchaser's prices*, i.e. including the taxes on intermediate inputs. The associated growth rate of GDP is given by

$$\dot{v} = \sum_i \frac{P_i^V V_i}{PV} \dot{v}_i, \text{ where } \dot{v}_i = \frac{P_i Y_i}{P_i^V V_i} \left[\dot{y}_i - \sum_j \frac{\left(1 + \tau_i^j\right) P_j M_{i,j}}{P_i Y_i} \dot{m}_{i,j}\right] \tag{30}$$

Using this definition, the decomposition of $\dot{d}$ above can be rewritten as a decomposition of $\dot{v}$. This involves subtracting $\dot{d}$ from and adding $\dot{v}$ to both sides of the equation and multiplying it by the ratio of nominal GDP measured as final demand at purchaser's prices and nominal value added at basic prices, i.e. PD/PV. These steps remove the effects of the final demand distortions due to

$\left\{\tau_i^D\right\}_{i=1}^n$ from the equation.

The resulting decomposition, that we use for our analysis of world productivity, is

$$\begin{aligned} \dot{v} &= \sum_i \frac{1}{(1+\mu_i)} s_i^D \dot{z}_i + s^K \dot{k} + s^L \dot{l} \\ &+ \sum_i s_i^D \frac{\mu_i}{(1+\mu_i)} \dot{y}_i + \sum_i s_i^V s_i^K \left(\dot{k}_i - \dot{k}\right) + \sum_i s_i^V s_i^L \left(\dot{l}_i - \dot{l}\right). \end{aligned} \tag{31}$$

Here, the value-added shares and Domar (1962) weights of sector i are given by

$$s_i^V = \frac{P_i^V V_i}{PV}, \text{ and } s_i^D = \frac{P_i Y_i}{PV}, \tag{32}$$

and the aggregate and sector-specific factor shares equal

$$s^K = \sum_i s_i^V s_i^K, \text{ where } s_i^K = \frac{\left(1+\tau_i^K\right) R_i K_i}{P_i V_i} \text{ and } s^L = \sum_i s_i^V s_i^L, \text{ where } s_i^L = \frac{\left(1+\tau_i^L\right) W_i L_i}{P_i V_i}. \tag{33}$$

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

This equation allows us to account for the sources of growth in real value added in basic prices in the world economy. The three terms in the first line are the direct effect of technology and the contributions of growth of aggregate capital and labor. The first term on the second line is the impact of gross-output shifting across sectors with different markups, i.e. is the change in the markup distortion. Note that, because of our definition of value added, markups result in an over estimate of value added by production factors. The final two terms on the second line are the impact of the respective changes in the misallocation of capital and labor on world output.

The last two terms are the same as reallocation terms in common growth-accounting studies based on Jorgenson *et al.* (1987).[6] They are sometimes referred to as misallocation terms because the results in Hulten (1978) show that they are zero in case of the efficient allocation of resources. Our derivations here show that they separate the impact of distortions in capital input markets and

[6] In fact, the above growth-accounting equation is similar to the one derived in Basu & Fernald (1997) for the case of constant returns to scale under markups. What is different here is that we started explicitly with a set of other distortions and relate them to each of the terms in the equation.

in labor markets. Hence, our decomposition adds a normative interpretation to terms already often analyzed in other growth-accounting results.

3 WIOD-data

For the empirical implementation of our global growth accounting method with distortions, we use Socio-Economic Accounts (SEA) data from the WIOD. The reason we use these data is that it is the only productivity dataset that covers a broad set of industries across the major world economies.[7] There are two vintages of the WIOD that have been released, namely one in 2013 and one in 2016. We calculate results using both of them.

These two vintages do not only differ in the industries, countries, and years covered, but also in the productivity variables included. The way we structure our results in the rest of this paper is chosen in order to fully utilize all data available and standardize the results across the two vintages for the overlapping variables for comparison purposes. Thus, to understand our results it is useful to first familiarize oneself with the available data.

3.1 Data vintages and available variables

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

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

The sample of countries in the data is largely comparable across vintages. The 2016 vintage

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

contains three more countries than the 2013, namely Norway, Switzerland, and Croatia. The economies of these countries make up a relatively small fraction of world GDP. This can be seen from the average share of world GDP covered in the data, reported in Table 1. Throughout, we aggregate our results by country into regions. These regions include the individual major world economies as well as groups of countries organized by geographical location.[8]

We present our results for major sectors of the economy, which are listed in Table B.3 in Appendix B. Each of these sectors are made up of ISIC industries for which the WIOD data is reported. Even though the 2016 vintage of the data contains many more industries than the 2013 vintage (see Table 1), the major sectors that we focus on are consistent over time and across vintages.

Both vintages contain data on value added by country and industry and associated deflators. The main difference between the two vintages is the available data on factor inputs. In terms of labor, both vintages contain data on hours worked, which we use as our main measure of the labor input. In addition, the 2013 vintage has more granular data on hours worked by low-, medium-, and high-skilled workers, which form the basis for our measure of labor quality growth.[9]

Throughout the rest of this paper the baseline measure of productivity growth that we focus on is ALP growth, i.e. growth in output per hour. This contrasts with most growth accounting studies that focus on TFP growth. We do this because data on capital inputs is only available for the 2013 and *not* for the 2016 vintage of the WIOD (see Table 1). For the 2013 vintage for which we do have information on capital inputs, we split ALP growth up into capital deepening and TFP components.

3.2 Comparison across vintages and with other data sources

For the overlapping years the two vintages of the data line up very closely in terms of aggregates. Moreover, both vintages closely follow world-level aggregates, published as part of World Bank (2018).[10]

Figure 1 shows how nominal GDP, measured in current US$, in our data lines up with world

[8]The specific regions we use are listed in Table B.2 in Appendix B.

[9]Details on how these variables are defined and measured are in Appendix B.

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

GDP. The short-dashed line is time series for the level of nominal GDP in the sample countries in the 2013 vintage of the data, which the other dashed line is the 2016 vintage of the data. Both of these lines are below the solid line, i.e. world GDP, which reflects 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.

The growth pattern in the WIOD data mimics that of nominal world GDP. There is an acceleration in world GDP after 2000 up until the Great Recession in 2008. Global economic activity shrunk in 2008 causing a dip in world GDP before accelerating again during the recovery phase of 2009-2014. The fact that WIOD data shows the same qualitative patterns makes us confident about capturing the main economic movements at a global level.

Of course, the growth rate of nominal GDP reflects movements in both prices and quantities. Figure 2 solely focuses on the quantities in that it compares the growth rate of real GDP in our data with that of world GDP, from World Bank (2018). It shows that the growth rate of real GDP in our data both is of the same order of magnitude as well as exhibits the same fluctuations as the growth rate of world real GDP. The main difference is that world real GDP growth is a bit higher from 2002 than in our data because our sample of countries does not include many fast-growing emerging economies.

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

3.3 Implementation of world productivity growth measurement

We use the WIOD-SEA data to calculate the terms in (31) in the following way. The data contain direct measures of many variables needed to calculate (31).

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

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

The remaining part of nominal value added, that is not paid to labor, consists of the profits and the payments to capital, i.e.

$$P_i^V V_i - \left(1 + \tau_i^L\right) W_i L_i = \mu_i P_i Y_i + R_i \left(1 + \tau_i^K\right) K_i. \tag{34}$$

The WIOD-SEA data are reported under the assumption that there are no markups, i.e. $\mu_i = 0$, and attribute this whole part of value added to payments to capital. Thus, for the implementation of our growth accounting equation, (31), we need to construct markups for all industries and countries in our data.

We infer the level of markups, μ_i, in a similar manner to Barkai (2016) and Karabarbounis & Neiman (2018), by considering a required return on capital in a user-cost framework as in Hall & Jorgenson (1969).[11]

We assume that the nominal capital service flows equal the nominal replacement value of the capital stock, which is reported in the data, times a real user cost of capital. This real user cost consists of a nominal return on capital corrected for depreciation and capital price inflation. The details are explained in Appendix B. The implicit nominal return we use is from Schmelzing (2017) and based on the 10-year U.S. treasury yield.[12] For the calculated markups, we construct TFP measures, for $\dot{z}_i$, based on cost shares rather than revenue shares of the factor inputs, following Basu & Fernald (1997).

Unfortunately, for the 2016 vintage of the WIOD there is only estimates available for the nominal replacement value of the capital stock. So, for this vintage of the data we are not able to separate the terms related to technology, i.e. $\dot{z}_i$, and growth in the capital stocks, i.e. $\dot{k}_i$. We can, however, construct estimates of the markups, μ_i.

[11] An alternative way, pursued by Baqaee & Farhi (2017), would be to use direct estimates of markups, e.g. those by Loecker & Eeckhout (2017, 2018). As Traina (2018) discusses, these estimates directly pertain to the wedge between price and marginal cost and their magnitude critically hinges on what is assumed to make up variable costs for firms. In our aggregate growth accounting framework such markups would not be the right measure because they would also be non-zero in the case of fixed operating costs or entry costs in which firms' individual technology exhibits decreasing returns to scale (in variable factors) but aggregate technology exhibits constant returns to scale and the market allocation is efficient, e.g. Hopenhayn & Rogerson (1993).

[12] We assume that there are no markups in public administration and education where value added is largely calculated as the cost of inputs. For the other sectors, we use the average depreciation and capital price inflation rates over the years in our sample to smooth out measurement error in these time series.

Because we do not have the necessary data to construct measures of capital growth and TFP growth for the 2016 vintage, we reorganize the terms in (31) to both analyze the growth in world ALP as well as world TFP. The ALP decomposition we consider, and for which we have data in both vintages, is of the form

$$\begin{aligned} \dot{alp} = \dot{v} - \dot{l} &= \sum_i \left[s_i^V \dot{alp}_i - s_i^D \frac{\mu_i}{(1+\mu_i)} \dot{y}_i \right] + \sum_i s_i^D \frac{\mu_i}{(1+\mu_i)} \dot{y}_i \\ &+ \sum_i s_i^V s_i^L \left(\dot{l}_i - \dot{l} \right) + \sum_i s_i^V \left(1 - s_i^L\right) \left(\dot{l}_i - \dot{l} \right). \end{aligned} \tag{35}$$

Here, the first term is the contribution of country-industry specific ALP growth net of the shifts in markups. The second term quantifies the effect of the shifts in markups. The third term is the effect of the change in misallocation of labor on world GDP. In case of an efficient allocation of resources, this term would be zero. The final term is the remaining reallocation that captures the shift in the labor input across sectors with different labor productivity levels.

The decomposition of world TFP growth, based on (31), is

$$\begin{aligned} \dot{tfp} &= \dot{v} - s^K \dot{k} - s^L \dot{l} \\ &= \sum_i \frac{1}{(1+\mu_i)} s_i^D \dot{z}_i + \sum_i s_i^D \frac{\mu_i}{(1+\mu_i)} \dot{y}_i + \sum_i s_i^V s_i^K \left(\dot{k}_i - \dot{k} \right) + \sum_i s_i^V s_i^L \left(\dot{l}_i - \dot{l} \right). \end{aligned} \tag{36}$$

It splits world TFP growth into parts due to technology, shifts in markups, the misallocation of capital, and the misallocation of labor. Because of the data limitations discussed in Table 1, this decomposition is only feasible for the 2013 of the WIOD-SEA data.

4 Results

We use the two WIOD vintages to construct annual estimates of each of the components of equations (35) and (31). We group the results 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. We also report results for all the years in each of the vintages.

The results are listed in Table 2 for ALP growth, i.e. (35), and Table 4 for TFP growth, i.e. (36). The columns are grouped by vintage and contain average annual growth rates of each of the components for over the period. For example, the third number reported in line 1 of the table shows that, according to the 2013 vintage of the WIOD, world GDP growth averaged 3.70 percent a year from 2005-2007. The sixth number in the same row indicates that, according to the 2016 vintage, this was 3.65 percent instead.[13] It is this growth rate of world GDP in line 1 of both tables that we decompose in the lines below.

By comparing the 2001-2004 and 2005-2007 periods across vintages in line 2 of the table, one can see that there is a discrepancy between the two data vintages in terms of hours growth. In particular, hours growth in the 2001-2004 periods is half as much in the 2016 vintage as in the 2013 vintage. This is largely due to the different ways hours growth in China and India are constructed in the two vintages.[14] With this difference in hours growth across data vintages in mind, we mainly focus on the qualitative results that both vintages have in common in the rest of our discussion rather than on the precise numbers.

World ALP growth

Line 3 of the table shows that there are sizable fluctuations in world ALP growth across the five subperiods that we distinguish. During the expansion of the late 1990's, world ALP growth was above 2 percent. It declined substantially in the early 2000's and rebounded during the mid-2000's before declining during the global financial crisis and the Great Recession and its aftermath. Line 8 shows the part of the world ALP growth that can be traced back to country-industry specific ALP growth rates. Lines 4-7 summarize the reallocation terms, split up by within-country and between-country components.

The first thing to note from this table is that the contribution of country-industry specific ALP growth was relatively constant over the first four of the five subperiods we consider and declined in the last subperiod from 2011-2014. Part of this is due to shifts in economic activity across sectors

[13]Note that the difference between these two numbers is due to revisions of the source data as well as due to a slightly different sample of countries across vintages.

[14]We discuss these differences in more detail in Appendix B.

with different markups, i.e. line 12 of the Table.

That line reveals that shifts in markups became increasingly important during the mid 2000's and the recovery from the Great Recession, i.e. 2011-2014. During those periods, these shifts in markups accounted for about a percentage point of world GDP growth. The industries that accounted for the bulk of these shifts were non-durables manufacturing, FIRE, and business services. This has mostly been happening in China and in the United States. In fact, our results indicate that markup shifts in the United States alone account for around 0.2 percentage points of world GDP growth (except for during the Great Recession).

The combination of the fluctuations in world ALP growth and the relatively constant contribution of country-industry specific ALP growth implies that the bulk of the fluctuations in world ALP growth come from the reallocation of labor across industries within countries and across countries. This is borne out by lines 4-7 of Table 2. What turns out to be quantitatively most important is the shifts in the misallocation of hours across countries, reported on line 7 of the Table. These shifts on average are 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, whose share in hours exceeds their share in world-wide compensation, tends to outpace hours growth in developed economies. Our global growth-accounting method interprets these shifts as a reallocation of labor from high to low marginal product of labor countries. The contribution of the cross-country misallocation of labor is more negative in periods when there is a bigger wedge in hours growth between emerging and developed economies, as in 2001-2004, 2008-2010, and 2011-2014. It was slightly positive during the expansion in developed economies from 2005-2007. Note also, from line 6, that shifts in the within-country misallocation of labor contribute little to world GDP growth.

The fairly constant contribution of country-industry ALP growth masks that the *composition* of this component across countries has changed notably over time. This can be seen from Table 3. It splits line 8 of Table 2 up by country/region. Our results are in line with studies that document a broad productivity slowdown in industrialized countries starting in the early 2000's (Byrne *et al.* , 2016; OECD, 2017a). We find that the contribution of country-industry specific ALP growth of these countries (United States, Japan, and the United Kingdom in particlar) 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

World TFP growth

For the 2013 vintage of the data we have information on growth in capital stocks and hours by skill-type that allows us to consider TFP growth, based on (36), in addition to ALP growth. The results obtained for TFP growth are reported in Table 4.

Lines 4 and 12 of Table 4 show that the qualitative picture for world TFP growth is remarkably similar to that for world ALP growth. That is, while there are substantial fluctuations in world TFP growth, line 4, across periods that we consider, the contribution of country-industry specific TFP growth, line 12, does not fluctuate much.

Part of the difference between these two lines are the misallocation of hours and shifts in markups, i.e. lines 8-11, which are identical to those reported in Table 2. The rest are shifts in the misallocation of capital which turns out to contribute little to world TFP growth and also not to fluctuate much over time.

So, adding capital to our analysis does not particularly change the picture. To understand world productivity growth it is most important to understand shifts in the misallocation of hours and trends in ALP over time.

5 Country-industry level PPP data

In the previous section we found that the misallocation of labor across countries acts as a large drag on world productivity growth. This reflects that we observe relatively high hours growth in countries with low labor shares, which is a proxy for the marginal product of labor. Our decomposition shows that this can be interpreted as labor growing in countries with relatively high labor-market distortions.

However, because we use dollar denominated measures of wages and value-added the relatively low labor shares that drive this result might be spurious because of deviations from PPP. A better measure of relative marginal productivity of labor across countries is one based on PPP deflated value added measures. However, such PPP measures are not available at the country-industry level at which we do our analysis. In this section we explain how we combine the results from Timmer *et al.* (2007) and Inklaar & Timmer (2014) with the WIOD to obtain time series of PPP-deflated value added for (most) countries and industries in our sample.

5.1 Construction of data

We construct our country-industry specific value-added deflators in three steps. In the first, we match the country-industry specific *gross output* PPP deflators for 2005 provided by Inklaar & Timmer (2014) to countries and industries in our dataset.[15] In the second step, we extrapolate these 2005-baseyear PPP level estimates using time series for country-industry specific gross output price deflators from WIOD. In the final step, we double deflate value added for each industry. For this double deflation we use the gross output PPP deflators for the deflation of intermediate inputs provided by each of the industries. We assume that the PPP deflator for intermediate inputs bought from countries that are not covered in our dataset is the same as that for the ones bought from the WIOD sample countries. The math involved in these steps is explained in detail in Appendix A. This calculation is possible because WIOD input-output tables provide data on the source of intermediate inputs used by country and industry.

The result of these three steps are estimates of real value added at the country-industry level, measured in units of 2005 U.S. real GDP. To show that this way of constructing these data delivers results that are consistent with more aggregate cross-country estimates of PPP-deflated output from other sources, we compare our data with those sources below.

[15]Some countries in our data are not covered in the PPP data and, thus, the PPP results we present in the rest of this paper are for a narrower sample (see Table B.1). The industry classification for the PPP data is based on the 2013 vintage of the WIOD. For the 2016 vintage we use the industry crosswalk provided in Gouma *et al.* (2018).

5.2 Comparison with other data sources

PPP-based value-added shares tend to put more weight on developing countries than the dollar-denominated weights that we used for our analysis in the previous section. This is largely because the dollar is the world's reserve currency. Since the sample of countries in our dataset is skewed towards the industrialized economies in the world, it covers a smaller share of world GDP measured in PPP-deflated units as in dollar-denominated values. This can be seen from the two lines in Table 1 that list dollar-denominated as well as PPP-deflated average shares of world GDP covered in our data.

Figure 3 compares the time series of PPP-deflated GDP from our two data vintages with that published in World Bank (2018). The first thing to note is that the PPP-deflated WIOD-SEA data exhibit the same main fluctuations as PPP-deflated world GDP growth published by the World Bank. One notable thing is that the Great Recession, which affected advanced industrialized economies more than emerging economies, is more pronounced in our data than in that of the World Bank.

Just like for the dollar-denominated measures, plotted in 2, the data in the overlapping period across the two vintages is very similar with the 2016 vintage capturing a little more economic activity because of the inclusion of a few more countries.

Finally, during the last decade covered by our data, the World Bank measure of world GDP diverges from our measure because growth in countries not included in our data exceeded that in the countries in our dataset. As can be seen from Figure 4, which plots the growth rates of the time series, this is largely due to the effect of the Great Recession. During the other years, the PPP-deflated GDP growth implied by our data closely follows the growth rate of PPP-deflated world GDP, published in World Bank (2018).

6 PPP-based accounting

In terms of notation, we consider the difference between world GDP growth based on dollar-denominated value-added weights, $\dot{v}$, and that based on PPP-based value-added weights, $\dot{v}^*$. This difference is the wedge in growth rates plotted in Figures 2 and 4 respectively. We use the $*$ for all

PPP-based measures. In particular, $\dot{v}_i^*$ is the growth rate of PPP-deflated value added in sector i and s_i^{V*} is the share of the corresponding sector in world GDP measured in PPP, i.e in V^*.

Given this notation, the difference between $\dot{v}$ and $\dot{v}^*$ can be split up into two parts. These two parts reflect that dollar-denominated world GDP grows slower than PPP-deflated world GDP for two reasons. First, because dollar-denominated value added grows slower than PPP-deflated value added on average across industries in the world, i.e. because $\dot{v}_i - \dot{v}_i^*$ tends to be negative. Second, because dollar-denominated value added shares are lower than PPP-based shares for fast-growing industries.

These two reasons are quantified by the respective terms in the following equation

$$\gamma^V = \frac{1}{2}\sum_i \left(s_i^V + s_i^{V*}\right)\left(\dot{v}_i - \dot{v}_i^*\right) \text{ and } \gamma^s = \frac{1}{2}\sum_i \left(\dot{v}_i + \dot{v}_{ic}^*\right)\left(s_i^V - s_i^{V*}\right), \tag{37}$$

which are the result of a standard shift-share decomposition of the wedge $\dot{v} - \dot{v}^*$. Thus, this allows us to write

$$\dot{v} = \gamma^V + \gamma^s + \dot{v}^*. \tag{38}$$

Of course, our interest is not in world GDP but in world productivity growth. For brevity purposes, because our main focus here is the impact of deviations from PPP on our quantification of the importance of the misallocation of labor, we limit ourselves to ALP in this section. In particular, we consider how the dollar-based measure of ALP growth, $\dot{alp}$, relates to the PPP-based measure $\dot{alp}^*$. In turn, similar to $\dot{alp}$, world ALP-PPP growth, $\dot{alp}^*$, can be split up in terms related to the reallocation of labor and country-industry specific ALP-PPP growth. In particular, we rewrite (35) in the following way

$$\begin{aligned} \dot{v} &= \dot{l} + \gamma^V + \gamma^s + \sum_i s_i^{V*}\dot{alp}_i^* \\ &+ \sum_i \left(s_i^{V*} - s_i^V\right) s_i^L \left(\dot{l}_i - \dot{l}\right) + \sum_i \left(s_i^{V*} - s_i^V\right)\left(1 - s_i^L\right)\left(\dot{l}_i - \dot{l}\right) \\ &+ \sum_i s_i^V s_i^L \left(\dot{l}_i - \dot{l}\right) + \sum_i s_i^V \left(1 - s_i^L\right)\left(\dot{l}_i - \dot{l}\right). \end{aligned} \tag{39}$$

The terms in the second line of the equation capture the effect of the reallocation of labor through deviations from PPP. Note that country-industries for which $s_{ic}^{V*} > s_{ic}^{V}$ are ones that have lower than average PPP-prices per dollar. These relatively low PPP prices per dollar can be interpreted as a cost advantage. Thus, these terms capture to what extent the reallocation of labor to country-industries with a cost-advantage contributes to world ALP-PPP growth. The first term in this line is the impact that deviations from PPP have on assessment of the misallocation of labor. The other terms captures the impact of deviations from PPP on the rest of the reallocation of labor. The terms in the last line of the equation are the same as those reported in Table 2.

6.1 Sources of world GDP growth expanded with PPP measures

Table 5 lists the results obtained using (39) for the two data vintages and the same five subperiods we covered before. Its format is similar to Table 2 to accommodate comparisons across tables. In fact, lines 1 through 3 of the tables are the same, up to the effect of the difference in the sample of countries covered.[16] Line 3 lists world ALP growth, i.e. $\dot{alp} = \dot{v} - \dot{l}$.

Line 6 contains PPP-based world ALP growth, i.e. $\dot{alp}^* = \dot{v}^* - \dot{l}$. The difference between lines 3 and 6 is $\dot{v} - \dot{v}^*$. This difference can be gleaned from figures 2 and 4. They show that the growth rate of PPP-deflated world GDP from Figure 4 is almost twice as high as that of dollar-weighted world real GDP growth plotted in Figure 2. Lines 4 and 5 of Table 5 split this difference up into the terms introduced in (37).

Most importantly, line 4 shows that, starting in the early 2000's the fact that growth tends to be higher in countries whose PPP-based value-added shares exceed their dollar-based ones adds about two percentage points a year to world ALP-PPP growth relative to world ALP growth. Figure 5 illustrates the regional sources of the deviation of PPP-based value added shares from dollar-based shares over time.

It shows that the magnitude of γ^s reported in line 4 of Table 4 is largely due to the relatively high wedges in China and India between the two measures as well as in the United States and Japan, but in the opposite direction. The figure shows that $s^{V^*} > s^V$ in China and India and that this wedge has not move much over time. While for the U.S. and Japan $s^{V^*} < s^V$. Though our PPP-deflated value added measures are potentially subject to measurement issues, the order of magnitude of these

[16] The countries covered in the two vintages and the PPP data are listed in Table B.1 in Appendix B.

wedges is so large that they are unlikely to be driven by these measurement issues. Instead, these deviations from PPP are indicative of substantial and persistent cost advantages for India and China in world production. Because these emerging economies, that grow faster than their industrialized counterparts, have higher PPP weights than dollar-weights in terms of value added world GDP-PPP growth, plotted in Figure 4, higher than dollar-weighted world GDP growth, plotted in Figure 2.

Our results for dollar-based value-added share weighted measures of world GDP growth interpret that relatively high growth in hours in these emerging economies with a PPP cost advantage as a deterioriation of the allocation of labor in the world economy. Our PPP-based measures allow us to quantify how much of this inferred misallocation reflects mismeasurement of relative marginal products of labor due to deviations from PPP. This is what we report in line 10 of Table 5. For comparison purposes, we included the dollar-based misallocation term in line 14.

If all of the misallocation of hours was due to deviations from PPP, lines 10 and 14 would sum to zero. But, instead, the deviations from PPP account for only a fraction, approximately a third, of the shifts in misallocation of labor across countries in the world. Even after correcting for deviations from PPP, shifts in the misallocation of labor across economies is a substantial drag on world GDP and the main contributor to world ALP growth fluctuations.

7 Conclusion

World productivity—whether measured by average labor productivity (world GDP per hour) or by the world Solow residual—is highly volatile from year-to-year and even over multiple-year periods. In this paper, we find that shifts in the misallocation of employment across industries and countries with different factor prices explains this volatility. Standard growth-accounting interprets these differences in factor prices as reflecting differences in marginal products. These differences are only partially accounted for by differences in price levels (or cost levels) across countries, as measures by PPPs.

Our conclusions on the role of factor reallocations as a source of world productivity volatility complement a large literature on misallocation within countries. This literature (Hsieh & Klenow, 2009) typically finds that factor misallocation across uses with differing marginal products can explain a considerable share of the productivity differences across countries. Our analysis finds that variations in factor distribution are also important in the time series dimension.

In contrast to the volatility of aggregate world productivity, the contribution of productivity growth at the county-industry level is relatively smooth. This finding mirrors the finding in country studies that "non-technological" terms explain a lot of the variance in aggregate country-level productivity (Basu & Fernald, 2002).

The relative smoothness of productivity growth at a country-industry level masks important differences across regions. In advanced economies, productivity growth slowed down after the mid-2000s. But at a world level, this slowdown has been, largely or completely, offset by faster growth in China, India, and other emerging markets. Using output measured at market exchange rates, productivity slowed down globally after 2007. At PPP, the slowdown returned growth rates to their early 2000s levels.

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Table 1: Comparison of WIOD-SEA vintages

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

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).

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

SEA vintage			Release 2013				Release 2016				
line	description	notation	1996 - 2000	2001 - 2004	2005 - 2007	All	2001 - 2004	2005 - 2007	2008 - 2010	2011 - 2014	All
1.	World GDP growth	$\dot{v}$	3.33	2.51	3.70	3.15	2.31	3.65	0.91	2.56	2.37
2.	World hours growth	$\dot{l}$	1.18	2.44	0.39	1.40	1.16	0.85	-0.07	3.38	1.46
3.	World ALP growth	$\dot{alp}$	2.15	0.07	3.31	1.75	1.15	2.80	0.98	-0.82	0.90
	Reallocation of hours	$\left(1-s_i^L\right)\left(\dot{l}_i-\dot{l}\right)$									
4.	...within countries		0.07	0.13	0.37	0.17	0.17	0.25	-0.06	0.23	0.16
5.	...across countries		-0.05	-0.84	0.24	-0.24	-0.40	0.22	-0.29	-0.74	-0.34
	Misallocation of hours	$s_i^L\left(\dot{l}_i-\dot{l}\right)$									
6.	...within countries		0.07	-0.02	0.15	0.06	0.03	0.08	0.08	0.09	0.07
7.	...across countries		-0.08	-1.32	0.35	-0.39	-0.60	0.27	-0.44	-1.07	-0.51
8.	*Country-industry ALP growth*	$\dot{alp}_i$	2.14	2.11	2.20	2.15	1.94	1.98	1.70	0.67	1.53
9.	...Shifts in markups	$\frac{\mu_i}{1+\mu_i}\dot{y}_i$	-0.55	0.50	0.99	0.19	0.90	1.49	0.38	1.04	0.96
10.	...Net of shifts in markups		2.69	1.61	1.21	1.96	1.04	0.48	1.31	-0.37	0.58

Note: Lines in this table correspond to parts of equation (35). Reported are contributions to average annual growth rates in percentage points over various subperiods.

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

	Release 2013				Release 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
China	0.30	0.28	0.53	0.35	0.23	0.67	0.65	0.59	0.52
Japan	0.31	0.25	0.19	0.26	0.27	0.12	-0.08	0.06	0.11
Germany	0.11	0.08	0.13	0.10	0.11	0.11	0.01	0.03	0.06
France	0.12	0.07	0.05	0.09	0.06	0.05	0.04	0.05	0.05
Great Britain	0.11	0.13	0.10	0.11	0.13	0.05	0.03	0.01	0.06
Brazil	0.04	-0.00	0.02	0.02	-0.02	-0.00	0.27	-0.05	0.04
Italy	0.03	-0.00	0.00	0.01	-0.01	-0.02	-0.03	0.01	-0.01
Russia	-0.02	0.04	0.11	0.03	0.05	0.09	0.09	0.02	0.06
India	0.06	0.02	0.17	0.07	0.05	0.13	0.12	-0.11	0.04
Other America	0.07	-0.02	0.05	0.04	-0.05	0.02	0.01	0.03	-0.00
Other Asia	0.11	0.08	0.27	0.14	0.05	0.26	0.01	-0.10	0.04
Other Euro Area	0.08	0.08	0.11	0.09	0.05	0.09	0.02	0.07	0.06
Other Europe	0.05	0.06	0.05	0.05	0.09	0.04	-0.00	0.03	0.04
Other Oceania	0.03	0.02	-0.00	0.02	0.02	-0.01	0.01	0.03	0.01
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 6 in Table 2 in percentage points over various subperiods.

Table 4: Summary of global TFP growth accounting: 1996-2007

SEA vintage			Release 2013			
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.	Aggregate capital growth	$s^K \dot{k}$	0.67	0.55	0.61	0.62
3.	Aggregate labor growth	$s^L \dot{l}$	0.71	1.44	0.23	0.83
4.	World TFP growth	$\dot{tfp}$	1.96	0.52	2.86	1.70
5.	*Misallocation of capital*	$s_i^K \left(\dot{k}_i - \dot{k} \right)$	0.08	-0.03	-0.04	0.01
6.	... within countries		0.12	0.03	0.05	0.07
7.	... between countries		-0.04	-0.05	-0.09	-0.06
8.	*Misallocation of hours*	$s_i^L \left(\dot{l}_i - \dot{l} \right)$	-0.01	-1.34	0.50	-0.33
9.	... within countries		0.07	-0.02	0.15	0.06
10.	... between countries		-0.08	-1.32	0.35	-0.39
11.	*Shifts in markups*	$\frac{\mu_i}{1+\mu_i} \dot{y}_i$	-0.55	0.50	0.99	0.19
12.	*Country-industry TFP growth*	z_i	2.44	1.38	1.41	1.83

Table 5: Summary of PPP-based global ALP accounting: 1996-2014

SEA vintage			Release 2013				Release 2016				
line	description	notation	1996 - 2000	2001 - 2004	2005 - 2007	All	2001 - 2004	2005 - 2007	2008 - 2010	2011 - 2014	All
1.	World GDP growth	$\dot{v}$	3.27	2.46	3.69	3.10	2.16	3.63	0.90	2.57	2.32
2.	World hours growth	$\dot{l}$	1.25	2.49	0.33	1.43	1.19	0.79	-0.08	3.34	1.45
3.	World ALP growth	$\dot{alp}$	2.02	-0.04	3.36	1.67	0.96	2.85	0.98	-0.77	0.88
	Growth wedge: Dollars vs PPP										
4.	... Value-added shares	γ^s	-0.06	-1.03	-2.02	-0.87	-0.39	-2.10	-2.92	-2.19	-1.81
5.	... Growth rates	γ^V	-2.01	-2.08	-2.83	-2.24	-1.84	-3.11	0.38	-1.17	-1.45
6.	World ALP-PPP growth	$\dot{alp}^*$	4.09	3.08	8.20	4.78	3.19	8.05	3.52	2.60	4.13
	Deviations from PPP	$\left(s_i^{V^*} - s_i^V\right)$									
7.	... within countries		0.14	-0.15	0.63	0.17	0.42	0.51	0.40	0.21	0.38
8.	... across countries		0.11	0.63	-0.18	0.21	0.40	-0.15	0.31	0.59	0.32
	Misallocation										
9.	... within countries		0.09	-0.13	0.22	0.05	0.16	0.25	0.14	0.13	0.17
10.	... across countries		0.06	0.40	-0.13	0.13	0.25	-0.10	0.19	0.36	0.19
	Reallocation of hours	$\left(\dot{l}_i - \dot{l}\right)$									
11.	... within countries		0.15	0.12	0.53	0.23	0.20	0.32	0.02	0.32	0.22
12.	... across countries		-0.14	-2.19	0.65	-0.63	-1.04	0.56	-0.77	-1.76	-0.84
	Misallocation										
13.	... within countries		0.07	-0.02	0.16	0.06	0.03	0.08	0.09	0.09	0.07
14.	... across countries		-0.09	-1.34	0.39	-0.39	-0.62	0.31	-0.46	-1.04	-0.51
15.	Country-industry growth	$\dot{alp}_i^*$	3.84	4.67	6.58	4.80	3.21	6.82	3.56	3.24	4.07

Note: The lines in this table correspond to the terms in (39).

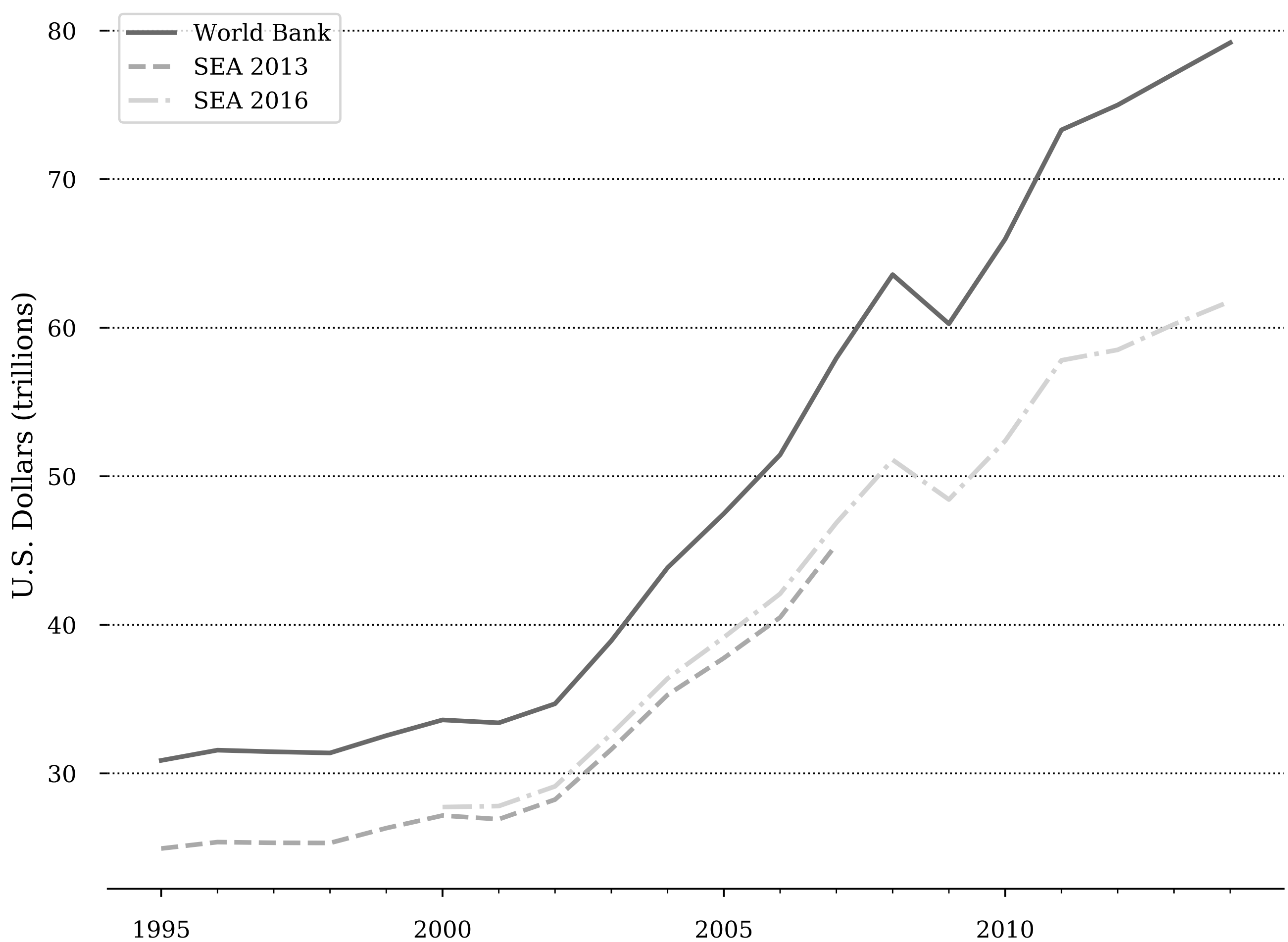


Figure 1: Nominal world GDP in WIOD-SEA and World Development Indicators (WDI)

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. $.

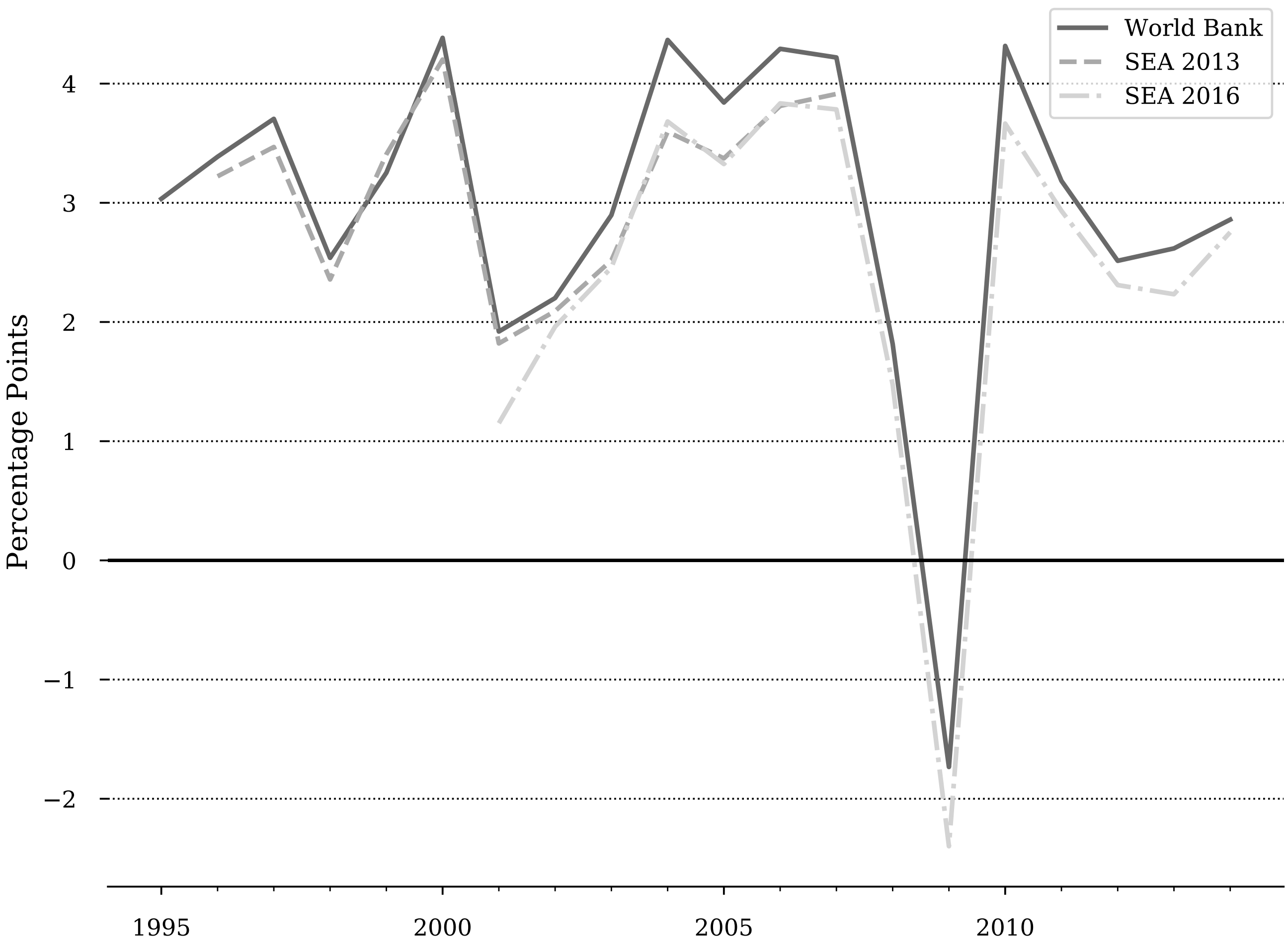


Figure 2: Growth in world real GDP in WIOD-SEA and WDI

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.

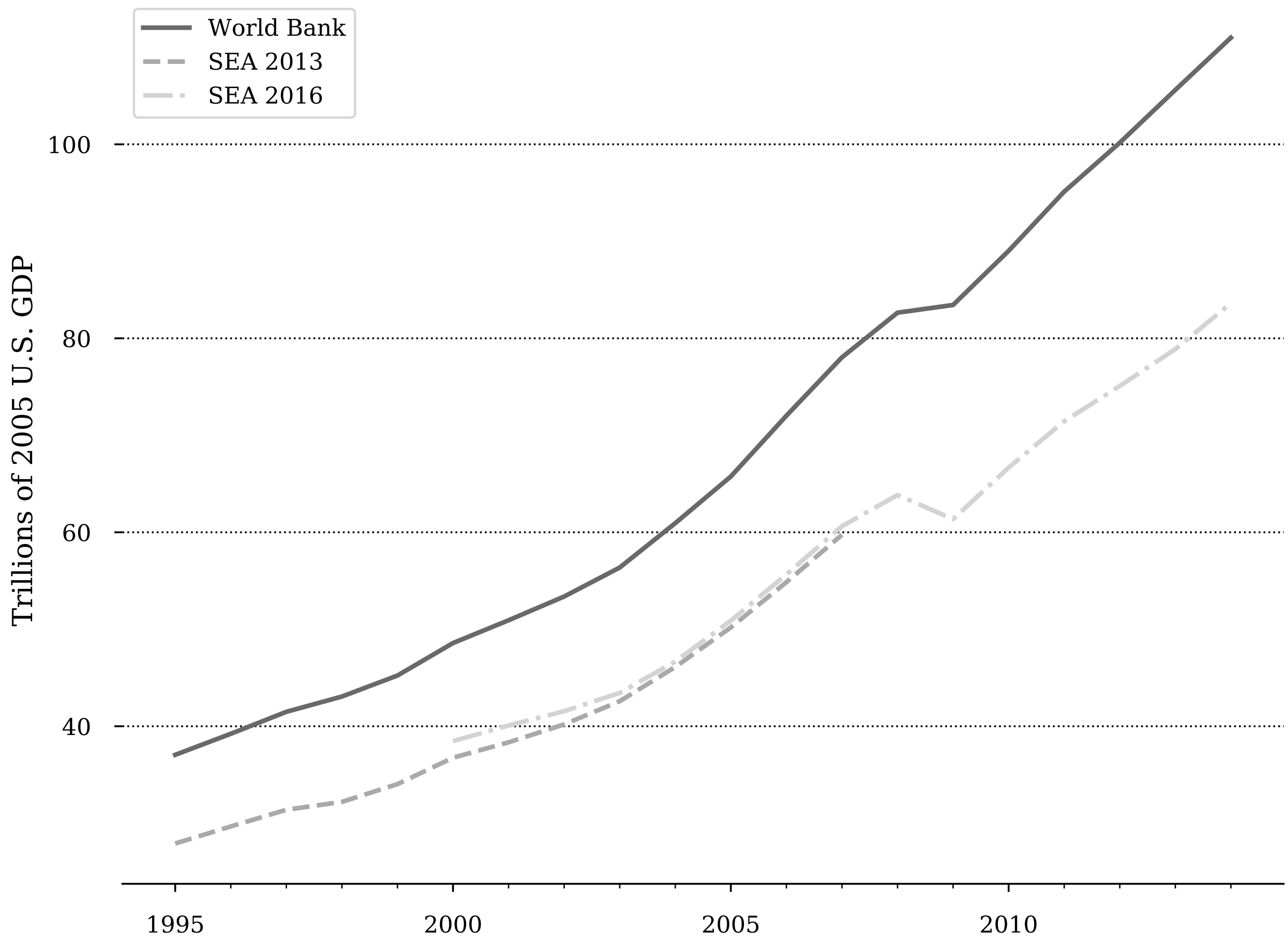


Figure 3: World GDP PPP in WIOD-SEA and WDI

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.

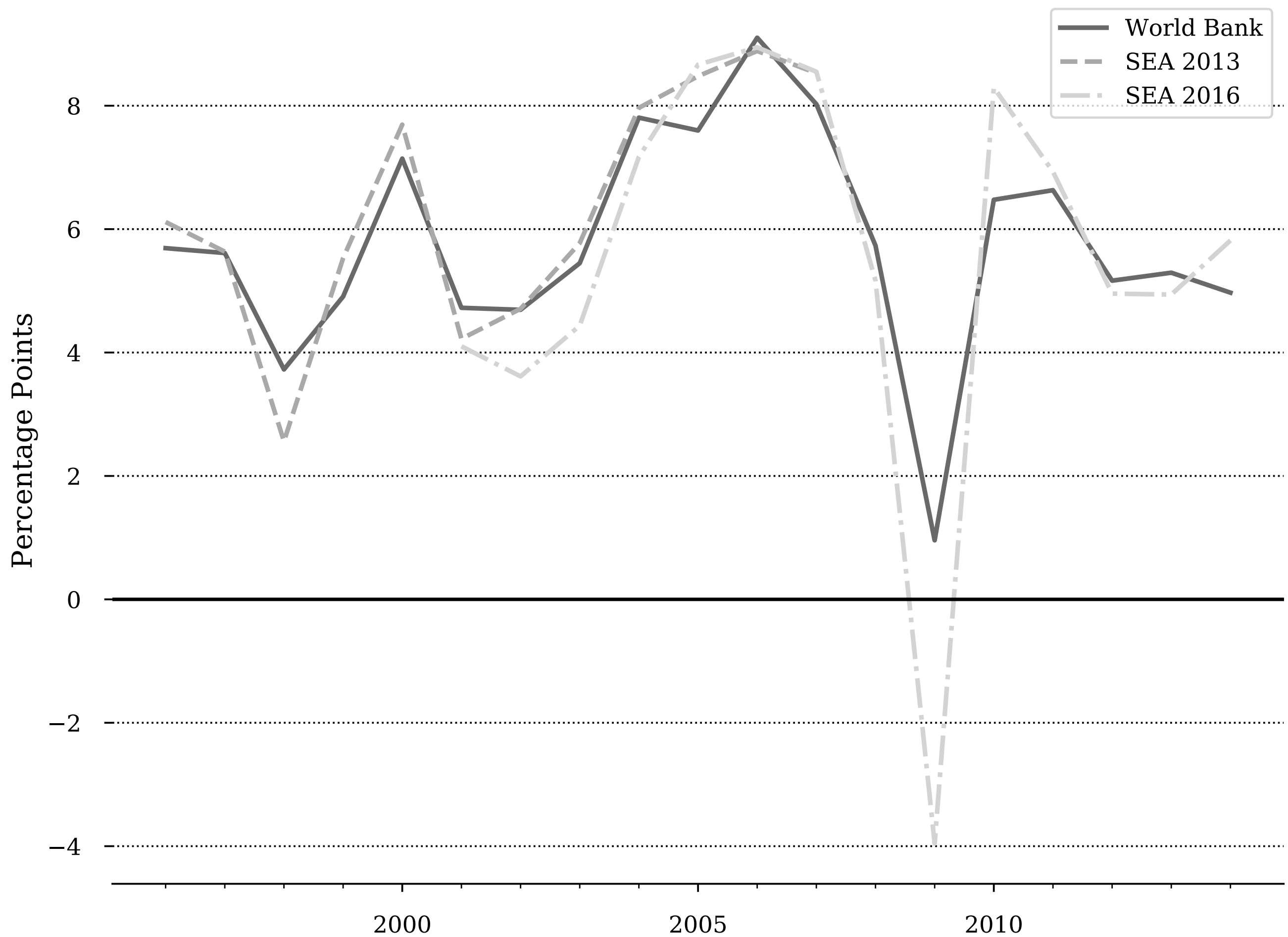
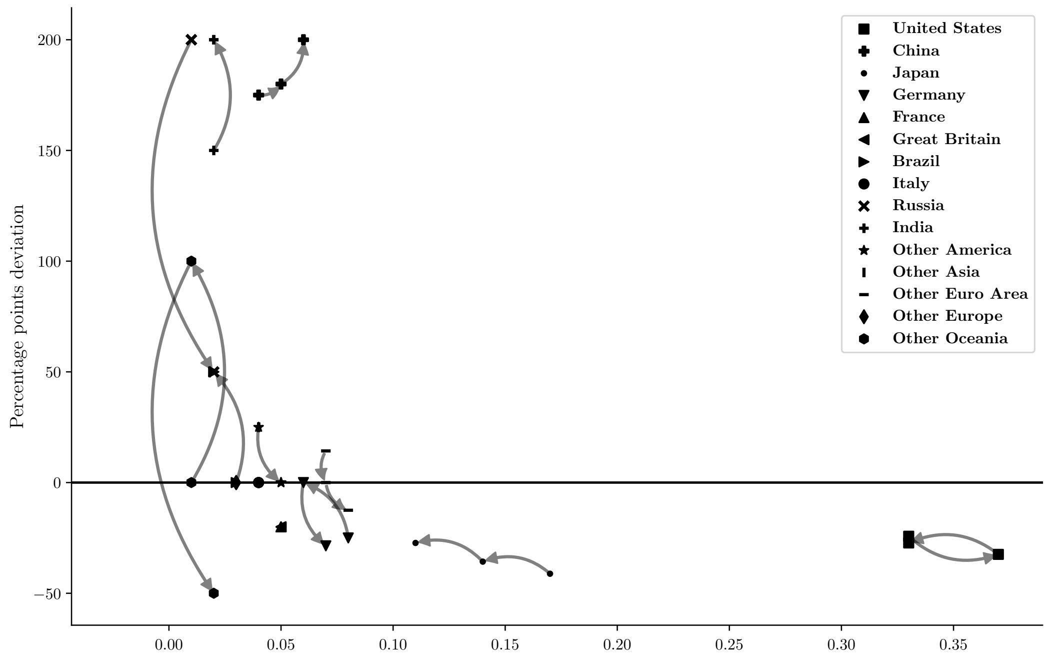


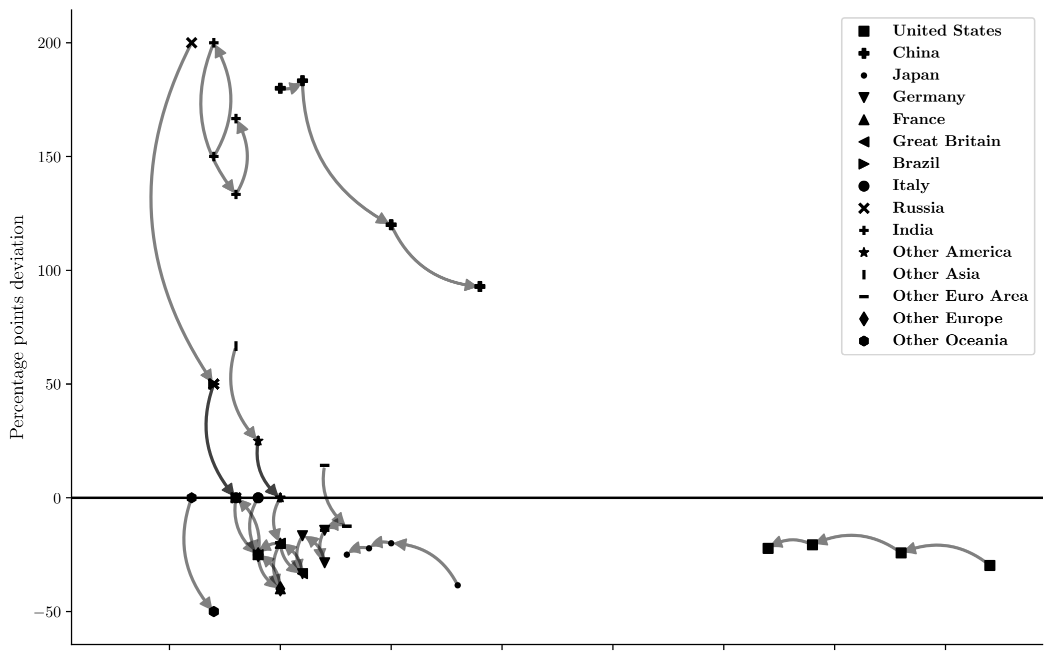
Figure 4: Growth in world GDP PPP in WIOD-SEA and WDI

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.



(a) 2013 vintage



(b) 2016 vintage

Figure 5: Deviation of PPP-deflated from dollar-denominated value added share

Source: Timmer (2012), SEA 2013, and authors' calculations.

Note: The x-axis shows the PPP-deflated average value added share of each country in each of the subperiods. The y-axis is the percentage deviation of dollar-denominated value-added share from the PPP-deflated value added share over the subperiods introduced in the text. The direction of the arrows shows the direction of time (1996-2000, 2001-2004, 2005-2007, 2008-2010, 2011-2014).

A Mathematical derivations

This appendix contains the derivations of the growth accounting equations we use for the calculation of the results in the main text. Most growth accounting methods applied in this paper have been used in other papers and we simply re-derive them here for reference purposes.

Our main derivations are done in continuous time and throughout we drop the time subscript, t. Small letters denote logarithms and changes over time are denoted by a dot.

A.1 Derivation of growth-accounting decomposition with distortions

A.1.1 Distorted equilibrium allocation

Producers Producers in this economy choose their factor inputs to minimize costs of production for a given amount of output. That is, the producers of product i choose $\{K_i, L_i, \{M_{i,j}\}\}$ to minimize

$$\left(1+\tau_i^K\right) R_i K_i + \left(1+\tau_i^L\right) W_i L_i + \sum_j \left(1+\tau_i^j\right) P_j M_{i,j}, \tag{40}$$

subject to the constraint that

$$Y_i = Z_i F_i\left(K_i, L_i, \{M_{i,j}\}\right) \tag{41}$$

The corresponding Lagrangian is

$$\mathcal{C}_i = \left(1+\tau_i^K\right) R_i K_i + \left(1+\tau_i^L\right) W_i L_i + \sum_j \left(1+\tau_i^j\right) P_j M_{i,j} \tag{42}$$

$$+ \lambda_i \left[Y_i - Z_i F_i\left(K_i, L_i, \{M_{i,j}\}\right)\right]. \tag{43}$$

This yields the following optimality conditions

$$\left(1+\tau_i^K\right) R_i = \lambda_i Z_i F_i^K \tag{44}$$

$$\left(1+\tau_i^L\right) W_i = \lambda_i Z_i F_i^L \tag{45}$$

$$\left(1+\tau_i^j\right) P_j = \lambda_i Z_i F_i^j \tag{46}$$

Using the fact that the production function, F_i, is homogenous of degree one, we can write

$$\begin{aligned}\mathcal{C}_i &= \left(1+\tau_i^K\right) R_i K_i + \left(1+\tau_i^L\right) W_i L_i + \sum_j \left(1+\tau_i^j\right) P_j M_{i,j} && (47)\\ &= \lambda_i Z_i \left[F_i^K K_i + Z_i F_i^L L_i + \sum_j Z_i F_i^j M_{i,j}\right] && (48)\\ &= \lambda_i Y_i && (49)\end{aligned}$$

Thus, λ_i is the unit production cost of the producers in sector i.

Similar to BF we will assume that producers in the sector charge a fixed markup, such that the price they charge is equal to

$$P_i = (1+\mu_i)\lambda_i. \quad (50)$$

This assumption allows us to rewrite the above equations as

$$\begin{aligned}\left(1+\tau_i^K\right) R_i &= \frac{1}{(1+\mu_i)} P_i Z_i F_i^K && (51)\\ \left(1+\tau_i^L\right) W_i &= \frac{1}{(1+\mu_i)} P_i Z_i F_i^L && (52)\\ \left(1+\tau_i^j\right) P_j &= \frac{1}{(1+\mu_i)} P_i Z_i F_i^j && (53)\end{aligned}$$

Final demand Final demand is determined by choosing $\{D_i\}$ to max

$$D = G\left(\{D_i\}\right) \quad (54)$$

subject to the constraint that

$$\sum_i \left(1+\tau_i^D\right) P_i D_i = \sum_i R_i K_i + \sum_i W_i L_i + \sum_i \frac{\mu_i}{1+\mu_i} P_i Y_i + \tau. \quad (55)$$

and that

$$\begin{aligned}K &= \mathcal{K}\left(\{K_i\}\right) && (56)\\ L &= \mathcal{L}\left(\{L_i\}\right) && (57)\end{aligned}$$

The associated Lagrangian is

$$\mathcal{D} = G\left(\{D_i\}\right) - \frac{1}{P}\left[\sum_i \left(1+\tau_i^D\right) P_i D_i - \sum_i R_i K_i - \sum_i W_i L_i - \sum_i \frac{\mu_i}{1+\mu_i} P_i Y_i - \tau\right] \quad (58)$$

$$- \frac{R}{P}\left[K - \mathcal{K}\left(\{K_i\}\right)\right] - \frac{W}{P}\left[L - \mathcal{L}\left(\{L_i\}\right)\right] \quad (59)$$

The first-order necessary conditions are

$$G_i = \left(1+\tau_i^D\right)\frac{P_i}{P} \quad (60)$$

$$R\mathcal{K}_i = R_i \quad (61)$$

$$W\mathcal{L}_i = W_i \quad (62)$$

which yields

$$PD = P\sum_i G_i D_i \quad (63)$$

$$= \sum_i \left(1+\tau_i^D\right) P_i D_i \quad (64)$$

$$= \left[\sum_i R_i K_i + \sum_i W_i L_i + \sum_i \frac{\mu_i}{1+\mu_i} P_i Y_i + \tau\right], \quad (65)$$

where

$$\tau = \sum_i \tau_i^K R_i K_i + \sum_i \tau_i^L W_i L_i + \sum_i \sum_j \tau_i^j M_{i,j} + \sum_i \tau_i^D P_i D_i \quad (66)$$

are net transfer payments to the final demand sector.

Note that, there are two ways to define value added in this case. They differ in the way they deal with the taxes paid on intermediate inputs, i.e. $\tau_i^j P_j$. In the data these taxes are measured taxes on production and international transportation margins.

The first, $\tilde{V}$ measures nominal value added as the difference between revenue and the payments to intermediate inputs measured at purchaser's prices (that is, including payments of $\tau_i^j P_j$), i.e.

$$P_i^V V_i = P_i Y_i - \sum_j \left(1+\tau_i^j\right) P_j M_{i,j} \tag{67}$$

$$= \frac{\mu_i}{1+\mu_i} P_i Y_i + \left(1+\tau_i^K\right) R_i K_i + \left(1+\tau_i^L\right) W_i L_i, \tag{68}$$

which equals factor payments to labor and capital as well as profits. Note that this is the way value added is measured, from the use tables, in productivity data, including those that we use from the SEA data from the WIOD.

The WIOD also provides the growth rate of this type of value added for each sector. This growth rate is given by

$$\dot{v}_i = \frac{P_i Y_i}{P_i^V V_i} \left[\dot{y}_i - \sum_j \frac{\left(1+\tau_i^j\right) P_j M_{i,j}}{P_i Y_i} \dot{m}_{i,j} \right] \tag{69}$$

The second, V, measures nominal value added as the difference between as the difference between revenue and the payments to intermediate inputs measured at basic prices (that is, excluding payments of $\tau_i^j P_j$), i.e.

$$P_i^{\tilde{V}} \tilde{V}_i = P_i Y_i - \sum_j P_j M_{i,j} \tag{70}$$

$$= \frac{\mu_i}{1+\mu_i} P_i Y_i + \left(1+\tau_i^K\right) R_i K_i + \left(1+\tau_i^L\right) W_i L_i + \tau_i^j P_j M_{i,j}, \tag{71}$$

This latter concept is the one for value added that is generally used in national accounting. The reason is that it yields that

$$P^{\tilde{V}} \tilde{V} = \sum_i \left(1+\tau_i^K\right) R_i K_i + \sum_i \left(1+\tau_i^L\right) W_i L_i + \sum_i \frac{\mu_i}{1+\mu_i} P_i Y_i + \sum_i \sum_j \tau_i^j P_j M_{i,j} \tag{72}$$

$$= \sum_i R_i K_i + \sum_i W_i L_i + \sum_i \frac{\mu_i}{1+\mu_i} P_i Y_i + \tau \tag{73}$$

$$= \sum_i P_i D_i \tag{74}$$

$$= PD - \sum_i \tau_i^D D_i \tag{75}$$

In the data, we know $\sum_i \tau_i^D D_i$ from the taxes paid on final demand.

We can also write

$$RK = R \sum_i \mathcal{K}_i K_i = \sum_i R_i K_i \tag{76}$$

So, R can be interpreted as the aggregate rental rate. Moreover,

$$WL = W \sum_i \mathcal{L}_i L_i = \sum_i W_i L_i \tag{77}$$

which means that W is the aggregate wage rate.

A.1.2 Equilibrium

Equilibrium is then a set of prices for which all markets clear, such that

$$Y_i \quad = \quad D_i + \sum_j M_{j,i} \tag{78}$$

Consolidated set of equations Thus, the decentralized equilibrium is characterized by the following equations

$$\begin{aligned}
\left(1+\tau_i^K\right)\frac{R_i}{P} &= \frac{1}{(1+\mu_i)}\frac{P_i}{P}Z_iF_i^K && (79)\\
\left(1+\tau_i^L\right)\frac{W_i}{P} &= \frac{1}{(1+\mu_i)}\frac{P_i}{P}Z_iF_i^L && (80)\\
\left(1+\tau_i^j\right)\frac{P_j}{P} &= \frac{1}{(1+\mu_i)}\frac{P_i}{P}Z_iF_i^j && (81)\\
G_i &= \left(1+\tau_i^D\right)\frac{P_i}{P} && (82)\\
\frac{R}{P}\mathcal{K}_i &= \frac{R_i}{P} && (83)\\
\frac{W}{P}\mathcal{L}_i &= \frac{W_i}{P} && (84)\\
Y_i &= Z_iF_i\left(K_i, L_i, \{M_{i,j}\}\right) && (85)\\
K &= \mathcal{K}\left(\{K_i\}\right) && (86)\\
L &= \mathcal{L}\left(\{L_i\}\right) && (87)\\
Y_i &= D_i + \sum_j M_{j,i} && (88)
\end{aligned}$$

A.1.3 Distorted planner problem

The next question we ask is whether this distorted competitive allocation can be interpreted as the result of a particular type of planner problem in which the planner solves it in a distorted way.

Consider a planner that chooses $\{Y_i, L_i, K_i, M_{i,j}\}$ to maximize

$$D = G\left(\{D_i\}\right) \tag{89}$$

subject to the following constraints

$$\begin{aligned}
Y_i &= Z_iF_i\left(K_i, L_i, \{M_{i,j}\}\right) && (90)\\
\frac{1}{(1+\mu_i)}Y_i &= \left(1+\tau_i^D\right)D_i + \sum_i \left(1+\tau_j^i\right)M_{j,i} + \Theta_i^Y && (91)\\
K &= \sum_i \left(1+\tau_i^K\right)\theta_i^K K_i + \Theta^K && (92)\\
L &= \sum_i \left(1+\tau_i^L\right)\theta_i^L L_i + \Theta^L && (93)
\end{aligned}$$

What the planner does *not internalize* is that $\left\{\theta_i^K\right\}$, $\left\{\theta_i^L\right\}$, $\left\{\Theta_i^Y\right\}$, Θ^K, and Θ^L themselves depend on the planner's choices. It is this that "distorts" the planner's problem relative to the first-best. In particular, we impose that

$$\theta_i^K = \mathcal{K}_i \tag{94}$$

$$\theta_i^L = \mathcal{L}_i \tag{95}$$

$$\Theta_i^Y = -\frac{\mu_i}{(1+\mu_i)} Y_i - \tau_i^D D_i - \sum_j \tau_j^i M_{j,i} \tag{96}$$

$$\Theta^K = \mathcal{K}\left(\{K_i\}\right) - \sum_i \left(1+\tau_i^K\right) \theta_i^K K_i \tag{97}$$

$$\Theta^L = \mathcal{L}\left(\{L_i\}\right) - \sum_i \left(1+\tau_i^L\right) \theta_i^L L_i \tag{98}$$

This problem has the following associated Lagrangian

$$D = G\left(\{D_i\}\right) \tag{99}$$

$$- \quad \omega_i \left[Y_i - Z_i F_i \left(K_i, L_i, \{M_{i,j}\}\right)\right] \tag{100}$$

$$+ \quad \psi_i \left[\frac{1}{(1+\mu_i)} Y_i - \left(1+\tau_i^D\right) D_i - \sum_i \left(1+\tau_j^i\right) M_{j,i} - \Theta_i^Y\right] \tag{101}$$

$$+ \quad \kappa \left[K - \sum_i \left(1+\tau_i^K\right) \theta_i^K K_i - \Theta^K\right] \tag{102}$$

$$+ \quad \lambda \left[L - \sum_i \left(1+\tau_i^L\right) \theta_i^L L_i - \Theta^L\right] \tag{103}$$

It yields the following first-order conditions

$$D_i: \quad 0 = G_i - \psi_i(1+\tau_i^D) \tag{104}$$

$$Y_i: \quad 0 = \omega_i - \frac{1}{(1+\mu_i)} \psi_i \tag{105}$$

$$M_{i,j}: \quad 0 = \omega_i Z_i F_i^j - \psi_j (1+\tau_i^j) \tag{106}$$

$$K_i: \quad 0 = \omega_i Z_i F_i^K - \kappa \left(1+\tau_i^K\right) \theta_i^K \tag{107}$$

$$L_i: \quad 0 = \omega_i Z_i F_i^L - \lambda \left(1+\tau_i^L\right) \theta_i^L \tag{108}$$

and has the associated aggregate resource constraints

$$Y_i = Z_i F_i \left(K_i, L_i, \{M_{i,j}\} \right) \tag{109}$$

$$K = \mathcal{K} \left(\{K_i\} \right) \tag{110}$$

$$L = \mathcal{L} \left(\{L_i\} \right) \tag{111}$$

$$Y_i = D_i + \sum_j M_{j,i} \tag{112}$$

This is the same set of equations as the decentralized equilibrium and results in the same allocation with the following mapping between the planner's multipliers and the prices in the decentralized allocation

$$\omega_i = \frac{1}{(1+\mu_i)} \frac{P_i}{P} \tag{113}$$

$$\psi_i = \frac{P_i}{P} \tag{114}$$

$$\kappa = \frac{R}{P} \tag{115}$$

$$\lambda = \frac{W}{P} \tag{116}$$

Note that this mapping between the planner's multipliers and the observed prices depends on the way the distortions are included in the decentralized equilibrium.

Time derivative of the planner's Lagrangian Because we have represented the inefficient allocation as a distorted social planner problem, we can apply the same method Hulten did to the social planner problem and take the time derivative of the planner's Lagrangian to obtain the change in output.

$$
\begin{aligned}
\dot{D} &= \sum_i \omega_i Y_i \dot{z}_i + \kappa \dot{K} + \lambda \dot{L} && (117)\\
&- \sum_i \psi_i \left[\dot{\Theta}_i^Y + \frac{1}{(1+\mu_i)^2} \dot{\mu}_i Y_i + \dot{\tau}_i^D D_i + \sum_j \dot{\tau}_j^i M_{j,i} \right] && (118)\\
&- \kappa \left[\dot{\Theta}_i^K + \sum_i \theta_i^K K_i \dot{\tau}_i^K + \sum_i \left(1+\tau_i^K\right) \dot{\theta}_i^K K_i \right] && (119)\\
&- \lambda \left[\dot{\Theta}_i^L + \sum_i \theta_i^L L_i \dot{\tau}_i^L + \sum_i \left(1+\tau_i^L\right) \dot{\theta}_i^L L_i \right] && (120)
\end{aligned}
$$

But, the time derivative of the distortions is given by

$$
\begin{aligned}
\dot{\Theta}_i^Y &= -\frac{1}{(1+\mu_i)^2} \dot{\mu}_i Y_i - \dot{\tau}_i^D D_i - \sum_j \dot{\tau}_j^i M_{j,i} - \frac{\mu_i}{(1+\mu_i)} \dot{Y}_i - \tau_i^D \dot{D}_i - \sum_j \tau_j^i \dot{M}_{j,i} && (121)\\
\dot{\Theta}_i^K &= \dot{K} - \sum_i \left(1+\tau_i^K\right) \theta_i^K \dot{K}_i - \sum_i \theta_i^K K_i \dot{\tau}_i^K - \sum_i \left(1+\tau_i^K\right) \dot{\theta}_i^K K_i && (122)\\
\dot{\Theta}_i^L &= \dot{L} - \sum_i \left(1+\tau_i^L\right) \theta_i^L \dot{L}_i - \sum_i \theta_i^L L_i \dot{\tau}_i^L - \sum_i \left(1+\tau_i^L\right) \dot{\theta}_i^L L_i && (123)
\end{aligned}
$$

This yields that[17]

$$
\begin{aligned}
\dot{D} &= \sum_i \omega_i Y_i \dot{z}_i + \kappa \dot{K} + \lambda \dot{L} && (124)\\
&- \sum_i \psi_i \left[-\frac{\mu_i}{(1+\mu_i)} \dot{Y}_i - \tau_i^D \dot{D}_i - \sum_j \tau_j^i \dot{M}_{j,i} \right] && (125)\\
&- \kappa \left[\dot{K} - \sum_i \left(1+\tau_i^K\right) \mathcal{K}_i \dot{K}_i \right] && (126)\\
&- \lambda \left[\dot{L} - \sum_i \left(1+\tau_i^L\right) \mathcal{L}_i \dot{L}_i \right] && (127)
\end{aligned}
$$

What is nice about this setup is that it is additive in the product, capital, and labor market distortions. So, we could do some accounting for each of them separately. Also, the time derivatives of all the distortions drop out. So, even though they might vary over time, their change is not part

[17] Note that $\theta_i^K = \mathcal{K}_i$ and $\theta_i^L = \mathcal{L}_i$.

of our decomposition.

By substituting back in the resource constraint for each of the sectors, we can write

$$\begin{aligned}
\dot{D} &= \sum_i \omega_i Y_i \dot{z}_i + \kappa \dot{K} + \lambda \dot{L} && (128)\\
&- \sum_i \psi_i \left[\frac{1}{(1+\mu_i)} \dot{Y}_i - \left(1+\tau_i^D\right) \dot{D}_i - \sum_j \left(1+\tau_j^i\right) \dot{M}_{j,i} \right] && (129)\\
&- \kappa \left[\dot{K} - \sum_i \left(1+\tau_i^K\right) \mathcal{K}_i \dot{K}_i \right] && (130)\\
&- \lambda \left[\dot{L} - \sum_i \left(1+\tau_i^L\right) \mathcal{L}_i \dot{L}_i \right] && (131)
\end{aligned}$$

Substituting in market prices In terms of market prices, this is equal to

$$\begin{aligned}
\dot{D} &= \sum_i \frac{1}{(1+\mu_i)} \frac{P_i}{P} Y_i \dot{z}_i + \frac{R}{P} \dot{K} + \frac{W}{P} \dot{L} && (132)\\
&- \sum_i \frac{P_i}{P} \left[\frac{1}{(1+\mu_i)} \dot{Y}_i - \left(1+\tau_i^D\right) \dot{D}_i - \sum_j \left(1+\tau_j^i\right) \dot{M}_{j,i} \right] && (133)\\
&- \frac{R}{P} \left[\dot{K} - \sum_i \left(1+\tau_i^K\right) \mathcal{K}_i \dot{K}_i \right] && (134)\\
&- \frac{W}{P} \left[\dot{L} - \sum_i \left(1+\tau_i^L\right) \mathcal{L}_i \dot{L}_i \right] && (135)
\end{aligned}$$

Writing it in terms of the growth rate of final demand $\frac{\dot{D}}{D}$, we obtain that

$$\begin{aligned}
\dot{d} &= \sum_i \frac{1}{(1+\mu_i)} \frac{P_i}{PD} Y_i \dot{z}_i + \frac{RK}{PD} \dot{k} + \frac{WL}{PD} \dot{l} && (136)\\
&- \sum_i \left[\frac{1}{(1+\mu_i)} \frac{P_i Y_i}{PD} \dot{y}_i - \left(1+\tau_i^D\right) \frac{P_i D_i}{PD} \dot{d}_i - \sum_j \left(1+\tau_j^i\right) \frac{P_i M_{j,i}}{PD} \dot{m}_{j,i} \right] && (137)\\
&- \left[\frac{RK}{PD} \dot{k} - \sum_i \frac{R}{PD} \left(1+\tau_i^K\right) \mathcal{K}_i K_i \dot{k}_i \right] && (138)\\
&- \left[\frac{WL}{PD} \dot{l} - \sum_i \frac{W}{PD} \left(1+\tau_i^L\right) \mathcal{L}_i L_i \dot{l}_i \right] && (139)
\end{aligned}$$

We are not interested in the demand side of the economy, but instead, would like to focus on growth in terms of the production side. This is possible by realizing that the above equation can be rewritten as

$$\begin{aligned}
\dot{d} &= \frac{P^V V}{PD}\left[\sum_i \frac{1}{(1+\mu_i)}\frac{P_i Y_i}{P^V V} Y_i \dot{z}_i + \frac{RK}{P^V V}\dot{k} + \frac{WL}{P^V V}\dot{l}\right] && (140)\\
&+ \dot{d} + \frac{P^V V}{PD}\sum_i \frac{\mu_i}{1+\mu_i}\frac{P_i^V V_i}{P^V V}\frac{P_i Y_i}{P_i^V V_i}\dot{y}_i && (141)\\
&- \frac{P^V V}{PD}\sum_i \frac{P_i^V V_i}{P^V V}\frac{P_i Y_i}{P_i^V V_i}\left[\dot{y}_i - \sum_j \left(1+\tau_j^i\right)\frac{P_i M_{j,i}}{P_i Y_i}\dot{m}_{j,i}\right] && (142)\\
&- \frac{P^V V}{PD}\left[\frac{RK}{P^V V}\dot{k} - \sum_i \frac{R}{P^V V}\left(1+\tau_i^K\right)\mathcal{K}_i K_i \dot{k}_i\right] && (143)\\
&- \frac{P^V V}{PD}\left[\frac{WL}{P^V V}\dot{l} - \sum_i \frac{W}{P^V V}\left(1+\tau_i^L\right)\mathcal{L}_i L_i \dot{l}_i\right] && (144)\\
&= \frac{P^V V}{PD}\left[\sum_i \frac{1}{(1+\mu_i)}\frac{P_i Y_i}{P^V V} Y_i \dot{z}_i + \frac{RK}{P^V V}\dot{k} + \frac{WL}{P^V V}\dot{l}\right] && (145)\\
&+ \dot{d} + \frac{P^V V}{PD}\sum_i \frac{\mu_i}{1+\mu_i}\frac{P_i^V V_i}{P^V V}\frac{P_i Y_i}{P_i^V V_i}\dot{y}_i && (146)\\
&- \frac{P^V V}{PD}\sum_i \frac{P_i^V V_i}{P^V V}\dot{v}_i && (147)\\
&- \frac{P^V V}{PD}\left[\frac{RK}{P^V V}\dot{k} - \sum_i \frac{R}{P^V V}\left(1+\tau_i^K\right)\mathcal{K}_i K_i \dot{k}_i\right] && (148)\\
&- \frac{P^V V}{PD}\left[\frac{WL}{P^V V}\dot{l} - \sum_i \frac{W}{P^V V}\left(1+\tau_i^L\right)\mathcal{L}_i L_i \dot{l}_i\right] && (149)
\end{aligned}$$

Part of this equation reflect distortions in the market for final sales. Most notably, $\frac{P^V V}{PD}$, reflects the difference in the nominal value added at basic prices used to calculate the productivity statistics and the nominal final sales measured at purchaser's prices. But we can simplify these out to obtain an equation for the growth rate of aggregate real value added, i.e. of

$$\dot{v} = \sum_i \frac{P_i^V V_i}{P^V V}\dot{v}_i \qquad (150)$$

Namely, we obtain that

$$\begin{aligned}
\dot{v} &= \sum_i \frac{P_i^V V_i}{P^V V} \dot{v}_i && (151)\\
&= \left[\sum_i \frac{1}{(1+\mu_i)} \frac{P_i Y_i}{P^V V} Y_i \dot{z}_i + \frac{RK}{P^V V} \dot{k} + \frac{WL}{P^V V} \dot{l} \right] && (152)\\
&+ \sum_i \frac{\mu_i}{1+\mu_i} \frac{P_i^V V_i}{P^V V} \frac{P_i Y_i}{P_i^V V_i} \dot{y}_i && (153)\\
&- \left[\frac{RK}{P^V V} \dot{k} - \sum_i \frac{R}{P^V V} \left(1+\tau_i^K\right) \mathcal{K}_i K_i \dot{k}_i \right] && (154)\\
&- \left[\frac{WL}{P^V V} \dot{l} - \sum_i \frac{W}{P^V V} \left(1+\tau_i^L\right) \mathcal{L}_i L_i \dot{l}_i \right] && (155)
\end{aligned}$$

The next step is to insert the decentralized optimality conditions into these equations to relate these terms to observables. We know that

$$\begin{aligned}
\frac{W}{P^V V} \left(1+\tau_i^L\right) \mathcal{L}_i L_i &= \frac{P_i V_i}{P^V V} \frac{P_i Y_i}{P_i V_i} \frac{\left(1+\tau_i^L\right) W_i L_i}{P_i Y_i} && (156)\\
\frac{R}{P^V V} \left(1+\tau_i^K\right) \mathcal{K}_i K_i &= \frac{P_i V_i}{P^V V} \frac{P_i Y_i}{P_i V_i} \frac{\left(1+\tau_i^K\right) R_i K_i}{P_i Y_i} && (157)
\end{aligned}$$

Using the above definition, let's consider the term that has to do with the labor distortion. First, note that

$$\begin{aligned}
\Omega_L &= \left[\frac{WL}{P^V V} \dot{l} - \sum_i \frac{W}{P^V V} \left(1+\tau_i^L\right) \mathcal{L}_i L_i \dot{l}_i \right] && (158)\\
&= \left[\frac{WL}{P^V V} \dot{l} - \sum_i \frac{P_i V_i}{P^V V} \frac{P_i Y_i}{P_i V_i} \frac{\left(1+\tau_i^L\right) W_i L_i}{P_i Y_i} \dot{l}_i \right] && (159)\\
&= \left[\frac{WL}{P^V V} \dot{l} - \sum_i \frac{P_i V_i}{P^V V} \frac{\left(1+\tau_i^L\right) W_i L_i}{P_i V_i} \dot{l}_i \right] && (160)\\
&= -\left[\sum_i \frac{P_i V_i}{P^V V} \frac{\tau_i^L W_i L_i}{P_i V_i} \right] \dot{l} && (161)\\
&- \left[\sum_i \frac{P_i V_i}{P^V V} \frac{\left(1+\tau_i^L\right) W_i L_i}{P_i V_i} \right] \sum_i \frac{\frac{P_i V_i}{P^V V} \frac{\left(1+\tau_i^L\right) W_i L_i}{P_i V_i}}{\sum_j \frac{P_j V_j}{P^V V} \frac{\left(1+\tau_j^L\right) W_j L_j}{P_j V_j}} \left(\dot{l}_i - \dot{l}\right) && (162)
\end{aligned}$$

The next to last term is the distortion due to the different between wages and salaries, W_i, paid to workers as a fraction of value added and the total compensation of employees $\left(1+\tau_i^L\right)$ assuming there is no reallocation of labor. This is something that is, in principle, reported by the OECD for the countries in our sample.

The second term, which can be calculated directly from the SEA data from WIOT, is the change in the distortion due to the reallocation of labor across sectors with different levels of distortions.

Similarly, we can write

$$\begin{aligned}
\Omega_K &= \left[\frac{RK}{P^V V}\dot{k} - \sum_i \left(1+\tau_i^K\right)\mathcal{K}_i K_i \dot{k}_i\right] && (163)\\
&= \left[\frac{RK}{P^V V}\dot{k} - \sum_i \frac{P_i V_i}{P^V V}\frac{\left(1+\tau_i^L\right)R_i K_i}{P_i V_i}\dot{k}_i\right] && (164)\\
&= -\left[\sum_i \frac{P_i V_i}{P^V V}\frac{\tau_i^K R_i K_i}{P_i V_i}\right]\dot{k} && (165)\\
&- \left[\sum_i \frac{P_i V_i}{P^V V}\frac{\left(1+\tau_i^K\right)R_i K_i}{P_i V_i}\right]\sum_i \frac{\frac{P_i V_i}{P^V V}\frac{\left(1+\tau_i^K\right)R_i K_i}{P_i V_i}}{\sum_j \frac{P_j V_j}{P^V V}\frac{\left(1+\tau_j^K\right)R_j K_j}{P_j V_j}}\left(\dot{k}_i - \dot{k}\right) && (166)
\end{aligned}$$

Substituting this into our growth-accounting equation, we obtain the equation we introduced in the main text.

$$\dot{v} = \sum_i \frac{P_i^V V_i}{PV} \dot{v}_i \tag{167}$$

$$= \sum_i \frac{1}{(1+\mu_i)} \frac{P_i^V V_i}{PV} \frac{P_i Y_i}{P_i^V V_i} \dot{z}_i \tag{168}$$

$$+ \left[\sum_i \frac{P_i^V V_i}{PV} \frac{\left(1+\tau_i^K\right) R_i K_i}{P_i V_i} \right] \dot{k} \tag{169}$$

$$+ \left[\sum_i \frac{P_i^V V_i}{PV} \frac{\left(1+\tau_i^L\right) W_i L_i}{P_i V_i} \right] \dot{l} \tag{170}$$

$$+ \sum_i \frac{P_i^V V_i}{PV} \frac{P_i Y_i}{P_i^V V_i} \frac{\mu_i}{(1+\mu_i)} \dot{y}_i \tag{171}$$

$$+ \left[\sum_i \frac{P_i V_i}{PV} \frac{\left(1+\tau_i^K\right) R_i K_i}{P_i V_i} \right] \sum_i \frac{\frac{P_i V_i}{PV} \frac{\left(1+\tau_i^K\right) R_i K_i}{P_i V_i}}{\sum_j \frac{P_j V_j}{PV} \frac{\left(1+\tau_j^K\right) R_j K_j}{P_j V_j}} \left(\dot{k}_i - \dot{k} \right) \tag{172}$$

$$+ \left[\sum_i \frac{P_i V_i}{PV} \frac{\left(1+\tau_i^L\right) W_i L_i}{P_i V_i} \right] \sum_i \frac{\frac{P_i V_i}{PV} \frac{\left(1+\tau_i^L\right) W_i L_i}{P_i V_i}}{\sum_j \frac{P_j V_j}{PV} \frac{\left(1+\tau_j^L\right) W_j L_j}{P_j V_j}} \left(\dot{l}_i - \dot{l} \right) \tag{173}$$

A.2 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, $\mathcal{P}_{i,j,t}$, is the number of U.S. dollars in 2005 per unit of output in industry i in country c 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

$$\mathcal{P}_{i,j,t} = \frac{\$/GO_{i,t}}{\$/USGDP_t} = \frac{USGDP_t}{GO_{i,t}} \text{ for } t = 2005. \tag{174}$$

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 industry i in country c 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

$$\mathcal{P}_{i,t} = \mathcal{P}_{i,2005} \frac{P_{i,t}/P_{i,2005}}{\mathcal{P}_t/\mathcal{P}_{2005}}. \tag{175}$$

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 industry i in country c in year t, i.e. $P_{i,t}Y_{i,t}$, into units of U.S. GDP. Let $Y^*_{i,j,t}$ be output in industry i in country c in year t measured in PPP units of U.S. GDP in the same period, then we can calculate it through

$$Y^*_{i,t} = \frac{P_{i,t}Y_{i,t}}{\mathcal{P}_{i,t}} \frac{1}{\mathcal{P}_t} = \frac{P_{i,t}Y_{i,t}}{P^*_{i,t}}, \text{ where } P^*_{i,t} = \mathcal{P}_{i,t}\mathcal{P}_t. \tag{176}$$

This equation means the following. The inverse of $\mathcal{P}_{i,j,t}$ converts dollars of nominal gross output of industry i in country c 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 industry i in country c in year t is the difference between nominal gross output and the nominal value of intermediate inputs.

$$P^V_{i,t}V_{i,t} = P_{i,t}Y_{i,t} - \sum_{i'} P_{i',t}M_{i',t}. \tag{177}$$

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,

$$V_{i,t}^{*} = \frac{P_{i,t}Y_{i,t}}{P_{i,t}^{*}} - \sum_{i'} \frac{P_{i',t}M_{i',j',t}}{P_{i',t}^{*}}. \tag{178}$$

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

$$P_{i,t}^{V*} = \frac{P_{i,t}^{V}V_{i,t}}{V_{i,t}^{*}}. \tag{179}$$

The calculation of (178) 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

$$P_{i,t}^{M*} = \sum_{i'} \frac{P_{i',t}M_{i',t}}{\sum_{i''} P_{i'',t}M_{i'',t}} P_{i',t}^{*}. \tag{180}$$

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, (179).

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

A.3 Accounting for the importance of deviations from PPP

The derivation of our quantification of the importance of deviations from PPP for our measure of the misallocation of labor is as follows. We denote PPP-deflated value added by v^{*}. Our calculations include both the growth rate of world GDP calculated using dollar-denominated value-added share weights, i.e.

$$\dot{v} = \sum_i s_i^V \dot{v}_i, \tag{181}$$

and the growth rate of PPP-deflated world GDP, calculated using PPP-based value-added share weights, i.e.

$$\dot{v}^* = \sum_i s_i^{V^*} \dot{v}_i^*. \tag{182}$$

Using a shift-share analysis, we can split up the difference between dollar-weighted and PPP-weighted world GDP growth as follows

$$\begin{aligned} \dot{v} &= (\dot{v} - \dot{v}^*) + \dot{v}^* & (183) \\ &= \frac{1}{2} \sum_i \sum_c \left(s_{ic}^V + s_{ic}^{V^*} \right) (\dot{v}_{ic} - \dot{v}_{ic}^*) + \frac{1}{2} \sum_i \sum_c (\dot{v}_{ic} + \dot{v}_{ic}^*) \left(s_{ic}^V - s_{ic}^{V^*} \right) + \dot{v}^* & (184) \\ &= \gamma^V + \gamma^s + \dot{v}^*. & (185) \end{aligned}$$

The first term on the right-hand side of this equation captures the part of the difference between the two world GDP growth measures that is due to countries-industries with high value-added shares growing faster in dollar-denominated value added than in PPP-deflated value added. The second term is the part of the difference due to the differences in the dollar- and PPP-denominated value-added shares.

In terms of ALP growth, we can write the above equation as

$$\begin{aligned} \dot{v} &= \dot{l} + \dot{alp} & (186) \\ &= \dot{l} + (\dot{v} - \dot{v}^*) + \dot{alp}^* & (187) \\ &= \dot{l} + (\dot{v} - \dot{v}^*) + \sum_i s_i^{V^*} \left(\dot{v}_i^* - \dot{l} \right) & (188) \\ &= \dot{l} + (\dot{v} - \dot{v}^*) + \sum_i s_i^{V^*} \left(\dot{v}_i^* - \dot{l}_i \right) + \sum_i s_i^{V^*} \left(\dot{l}_i - \dot{l} \right) & (189) \\ &= \dot{l} + \gamma^V + \gamma^s + \sum_i s_i^{V^*} \dot{alp}_i^* + \sum_i s_i^{V^*} \left(\dot{l}_i - \dot{l} \right) & (190) \end{aligned}$$

The last term in this equation is the reallocation of labor term. We split it up into four parts. We split it up into the term due to the misallocation of labor and the rest of the reallocation of labor.

$$\dot{v} = \dot{l} + \gamma^V + \gamma^s + \sum_i s_i^{V^*} \dot{alp}_i^* + \sum_i s_i^{V^*} s_i^L \left(\dot{l}_i - \dot{l} \right) + \sum_i s_i^{V^*} \left(1 - s_i^L\right) \left(\dot{l}_i - \dot{l} \right). \quad (191)$$

Our aim is to measure the effect of deviations from PPP on the assessment of the misallocation of labor. To do so, we rewrite the last two terms above into parts due to deviations from PPP and the dollar-based terms that we reported in our benchmark results.

$$\begin{aligned} \dot{v} &= \dot{l} + \gamma^V + \gamma^s + \sum_i s_i^{V^*} \dot{alp}_i^* \\ &+ \sum_i \left(s_i^{V^*} - s_i^V\right) s_i^L \left(\dot{l}_i - \dot{l} \right) + \sum_i \left(s_i^{V^*} - s_i^V\right) \left(1 - s_i^L\right) \left(\dot{l}_i - \dot{l} \right) \\ &+ \sum_i s_i^V s_i^L \left(\dot{l}_i - \dot{l} \right) + \sum_i s_i^V \left(1 - s_i^L\right) \left(\dot{l}_i - \dot{l} \right). \end{aligned} \quad (192)$$

B Data details

Table B.1: List of countries in each vintage of SEA and the ones that have PPP data

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

Table B.2: Country Classification

Classification	Country
United States	
China	
Japan	
Germany	
France	
Great Britain	
Brazil	
Italy	
Russia	
India	
Other America	Canada and Mexico
Other Asia	Indonesia, Republic of Korea, Turkey and Taiwan
Other Euro Area	Austria, Belgium, Cyprus, Spain, Estonia, Finland, Greece, Ireland, Lithuania, Luxemberg, Latvia, Malta, Netherlands, Norway, Portugal, Slovakia, Slovenia
Other Europe	Bulgaria, Croatia, Czech Republic, Denmark, Hungary, Poland, Romania, Sweden, Switzerland
Other Oceania	Australia

The industries were classified into major categories in table (B.3) in order to be consistent with the North American Industry Classification System (NAICS):

Table B.3: 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).

- **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.

- **Capital**: Data on capital compensation (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 reallocation of capital across countries and industries.

- **Labor**: Number of employees (thousands) and total hours worked by persons engaged (millions) provide information on the growth in hours along with reallocation 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). 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 forms the basis of our labor quality growth measurement.