Which Sectors Make the Poor Countries so Unproductive?*

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Abstract

We ask which sectors are mainly responsible for the low aggregate TFPs of poor countries. We argue that existing two–sector studies have not settled this issue because they are not disaggregated enough. Instead of two, we consider four sectors: services, consumption goods, construction, and equipment. Using the Penn World Tables, we find that the TFP differences between rich and poor countries are very large in equipment, large in consumption goods, and small in services. Moreover, we find that the TFP differences in construction tend to be smaller than in equipment, but that there is not enough information to make more precise statements. We show the usefulness of our findings with two applications. First, we use them to evaluate whether bad institutions, bad policies, and low human capital endowments cause the low aggregate TFPs of poor countries. Second, we use them to account for the results of the existing two–sector studies.

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Contents

1 Introduction **1**

2 Model **5**

2.1 Example 5

2.2 Environment 7

2.3 Competitive equilibrium 9

3 Data and Measurement **11**

3.1 Definitions 11

3.2 Measurement 15

3.2.1 General procedure 15

3.2.2 Measurement with U.S. data 16

3.2.3 Measurement with PWT96 data 17

4 Findings **19**

4.1 Cross–country sector TFP differences 19

4.2 The findings of the literature 22

4.3 Relative prices and relative TFPs 26

5 Towards a Theory of International TFP Disparity **30**

5.1 Institutions 31

5.2 Human Capital 32

5.3 Policies 33

6 Conclusion **34**

1 Introduction

A major challenge in economics is to understand the causes of the large international disparity in GDP per capita, which is more than thirty times higher in the richest countries than in the poorest countries. Growth–accounting studies find that cross–country differences in aggregate total factor productivity (TFP henceforth) account for a large part of the income disparity.[1] This suggests that we need to understand where the international disparity in aggregate TFP comes from. In this paper, we ask which sectors are mainly responsible for the low aggregate TFPs of poor countries. We argue that the answer to this question is not only interesting in its own right, but that it also helps us to distinguish between different possible causes of the aggregate TFP differences.

There is no agreement in existing literature as to which the problem sectors are. This is probably due to the fact that different areas of the literature disaggregate in different ways. For example, international trade theorists typically consider tradables and nontradables, and so Balassa (1964) and Samuelson (1964) conjectured many years ago that the cross–country differences in labor productivity are much larger in the tradable sectors than in the nontradable sectors.[2] In contrast, development economists tend to split the aggregate into agriculture and non–agriculture and find that that cross–country differences in agricultural labor productivity are much larger in than in the aggregate of the other goods.[3] Finally, growth theorists find it natural to think about capital accumulation, and so they disaggregate into consumption and investment. In this tradition, Hsieh and Klenow (2003) found that cross–country differences in investment TFP are much larger in consumption TFP.[4] To make the confusion complete recent firm–level evidence collected by the McKinsey Global Institute paints yet a different picture. In his summary, Lewis (2004) concludes that low labor productivity in key nontradable sectors (specially

[1]See, for example, Klenow and Rodriguez-Clare (1997), Prescott (1998), Hall and Jones (1999), Hendricks (2002), and Caselli (2005).

[2]Rogoff (1996) offers a review of the literature on the Balassa–Samuelson hypothesis. He concludes that the supporting evidence is surprisingly scant and mostly indirect.

[3]One of the classic references is Kuznets (1971). More recent examples include Restuccia et al. (2006), Córdoba and Ripoll (2004), Gollin et al. (2004), and Caselli (2005).

[4]Previous authors noted that the relative price of capital is negatively correlated with income growth rates [Jones (1994)] and with income levels [Chari et al. (1996) and Restuccia and Urrutia (2001)].

retailing and construction) are the problem.[5]

We argue that existing two–sector studies have not reached consensus on the sectoral TFP patterns across countries because they are not disaggregated enough. Instead of two, we consider four sectors: services (nontradable consumption), consumption goods (tradable consumption), construction (nontradable investment), and equipment investment (tradable investment). One advantage of considering these four sectors is that that we can aggregate them to the three different two–sector splits considered in the literature. First, the aggregate tradables is composed of consumption goods and equipment while the aggregate nontradables is composed of services and construction. Second, the aggregate consumption is composed of services and consumption goods while the aggregate investment is composed of construction and equipment. Third, agricultural goods are a large part of consumption goods in poor countries, so distinguishing between consumption goods and the aggregate of nontradables and equipment ("the rest") will allow us to speak also to the development literature.

A key challenge for measuring sector TFPs comes from the limited available data. Unfortunately, disaggregate and comparable data on sector inputs and outputs does not exist for a wide range of rich and poor countries.[6] The only broad source of such data is the Penn World Tables provided by Heston et al. (2002). We will work with the largest and most recent benchmark study from 1996 (PWT96 henceforth), which provides information about expenditures, purchase prices, and quantities. We will interact this information with economic theory so as to infer the unobserved sector inputs and outputs needed to calculate sector TFPs. Our approach uses the basic fact that differences in unobservable sector TFPs lead to observable differences in statistics such as relative prices and investment shares. Given a model, we can then go the other way and infer the differences in unobservable sector TFPs from the observable statistics. Our approach is related to that of Hsieh and Klenow (2003), who used information about relative

[5]See also Bailey and Solow (2001).

[6]The McKinsey Global Institute collected firm level data for a small number of countries, but that data is not publicly available. There is data for many OECD members, but it is typically not in comparable units. Moreover, the poorest countries are not OECD members.

purchase prices and investment shares to account for the international correlation between investment quantities and income. Our approach is also related to that of Caselli and Coleman (2005), who used information about relative wages to obtain the elasticities of substitution between skilled and unskilled labor in a large number of countries.

To make our approach operational, we build a growth model with several new features. First, our model has the four sectors services, consumption goods, construction, and equipment investment. Since we consider construction and equipment investment separately, our model distinguishes between the stocks of buildings and equipment. Second, our model pays close attention to the three main wedges between a country's observed relative purchase prices and its unobserved relative sector TFPs: taxes, distribution services, and different capital intensities. We define taxes broadly to include all distortions that lead to rents and drive wedges between purchase prices and competitive producer prices. Examples are value–added taxes, tariffs, bribes, and monopoly power. We define distribution services in the standard way as retail, wholesale, and transport services. Taking both taxes and distribution services into account allows us to infer the unobserved competitive producer prices from the observed purchase prices. To infer the unobserved relative sector TFPs from these competitive producer prices, we take into account that the capital intensities may differ across sectors. The reason why this is relevant here is that the relative producer prices of capital–intensive goods tend to be higher in capital scarce countries, which tend to be the poor countries. Below, we will show that these three wedges between the relative purchase prices and relative sector TFPs are quantitatively important.

We find that the cross-country differences in the relative TFPs are very large in some sectors and small in others. Specifically, they are very large in equipment, closely followed by consumption goods, but they are much small in services. It turns out that the PWT96 do not contain sufficient information to pin down the tax on services. While this indeterminacy does not affect the previously mentioned findings much, it makes it impossible to obtain robust statements about the cross–country TFP differences in construction other than that they tend to be smaller than the differences in equipment. Fortunately, this has hardly any implications when we aggregate services and construction to the nontradables. We then find that the cross–country TFP differences in the tradables are much larger than in the nontradables. Since poor countries have less capital than the US, this finding gets amplified when we consider sector labor productivities instead of sector TFPs. So, we confirms the conjecture of Balassa (1964) and Samuelson (1964) and suggest that the findings of the McKinsey Studies for selected industries of 10 countries do not generalize to a broad cross section of countries.[7]

Our findings also shed light on the other two–sector studies. On the one hand, if we compute the labor productivities of consumption goods and "the rest", we find that consumption goods are the problem sector in which the labor productivity differences across countries are much larger. This finding again is fairly robust to the choice of the service tax, because "the rest" contains the aggregate nontradables. On the other hand, if compute the sector TFPs of aggregate consumption and investment, we find that investment tends to be the problem sector in which the sector TFP differences across countries are much larger than in consumption. We use the term "tends" because this finding is not robust to the choice of the service tax. The reason is that the service part of the robust aggregate nontradables is in consumption whereas the construction part is in investment. In sum, we find that the very different results from two–sector studies come from the fact that at our four–sector level of disaggregation the TFPs differences across countries behave very differently.

We take the view that a successful theory of aggregate TFP ought to be consistent with the international sector TFP patterns. Most existing theories attribute the cross–country differences in TFP to exogenous cross–country differences in institutions, human capital endowment, or policies. This raises the question why these exogenous differences should do so much more damage in some sectors than in others. We argue below that this constitutes a challenge for theories that emphasize the damaging effects of bad insti-

[7]We should mention that the indeterminacy of the service tax implies that we cannot rule out that there are very large cross–country TFP differences in some nontradables. We can rule out though that if they exist, these differences do not show up at the level of the aggregate nontradables.

tutions or low endowments of human capital, while it points to theories that emphasize bad policies. Examples for such bad policies that deserve further attention are trade restrictions, financial frictions, and barriers. We discuss them below, paying particular attention to their damaging effects in agriculture.

The next section lays out the model. Section 3 describes our measurement and the calibration of our model. Section 4 reports our findings and accounts for the findings of existing two–sector studies. Section 5 discusses the implications of our findings for existing theories of international TFP disparity. Section 6 concludes. An appendix contains all proofs and a detailed description of our data work.

2 Model

Our model is a growth model with several new features: there are four final goods sectors with different TFPs and capital shares; there are taxes on all four final goods; there is a distribution sector that delivers tradable goods to consumers. Before we develop the model, it may be useful to motivate these features by means of a benchmark example that does not have any of them.

2.1 Example

Let there be two countries $i \in \{1, 2\}$ and two final goods $j \in \{T, NT\}$. The good indexed by T is tradable between the two countries whereas the good indexed by NT is not. Each country is populated by a measure one of people, each of which is endowed with one unit of labor. People allocate their labor between producing the tradable and the nontradable good. The technologies are linear in labor:

$$y^i_T = A^i_T l^i_T,$$

$$y^i_{NT} = A^i_{NT} l^i_{NT}.$$

Here we are interested in the sector TFP differences between the two countries, that is, A_j^1/A_j^2 for $j \in \{T, NT\}$. They would be trivial to obtain if we observed the outputs y_j^i and the inputs l_j^i of both sectors in units that are comparable between the two countries. For example, it would suffice to observe output in international prices and labor in hours. Unfortunately, such data does not exist even for all OECD countries.

Fortunately, we do not need to observe sector outputs if instead we observe the relative producer prices in each country. To see this, note that if markets are competitive, then the marginal value products of both sectors are equalized in each country. Letting the price of tradables be the same in both countries and normalizing it to one, we have

$$A_T^i = p_{NT}^i A_{NT}^i \quad \Longrightarrow \quad \frac{A_T^i}{A_{NT}^i} = p_{NT}^i.$$

So, if we observe p_{NT}^i, then we know A_T^i/A_{NT}^i. Now, letting all international prices equal one the GDPs in international prices are:

$$y^i \equiv A_T^i l_T^i + A_{NT}^i l_{NT}^i.$$

Combining the previous two expression, we get expressions for A_j^1/A_j^2:

$$\begin{aligned} \frac{A_T^1}{A_T^2} &= \frac{y^1}{y^2} \frac{l_T^2 + l_{NT}^2/p_{NT}^2}{l_T^1 + l_{NT}^1/p_{NT}^1}, \\ \frac{A_{NT}^1}{A_{NT}^2} &= \frac{A_T^1}{A_T^2} \frac{p_{NT}^2}{p_{NT}^1}. \end{aligned}$$

In sum, if we observed the two GDPs in international prices, the relative producer prices, and the inputs in both sectors, then we could calculate both cross–country relative sector TFPs. Unfortunately, even these data are not available.

What is available comes from the benchmark years of the Penn World Tables, which offer comparable data on GDPs in domestic and international prices, relative purchase prices, investments in domestic and international prices, and purchased quantities. The challenge is to obtain the missing information about the relative producer prices and the inputs in both sectors. More precisely, from the observed purchase prices we will need to infer what the producer prices must have been. The two main candidates that drive a wedge between the two prices are distribution margins and taxes. Moreover, we will need to infer what the sector inputs must have been. This is more complicated than in our simple example, as capital is an additional production input and the capital shares may differ across sectors.

We will proceed in two steps to solve these problems. First, we will obtain the depreciation rates of capital, the distribution margins, and sector capital shares from US data. We will then impose the restriction that these parameters do not vary across countries. Second, we will obtain the remaining unobservable parameters by restricting our model to match as closely as possible the standard observations from the PWTs, namely the relative incomes in international prices, the relative purchase prices, the investment shares for buildings and equipment in domestic and international prices, and the consumption shares of services and consumption goods in domestic prices.

We now turn to the details of the model that we will use to achieve this.

2.2 Environment

There is a finite set $\mathcal{J}$ of small open economies. Time is discrete and runs forever. All final goods are tradable within each country, but they may or may not be tradable across countries. We call a final good tradable if it is tradable across countries and nontradable if it is not. In each period, there are four final goods: services x_s and construction of building x_b are nontradable while consumption goods x_g and equipment investment x_e are tradable. We denote the set of goods indices by $\mathcal{I} \equiv \{s, b, g, e\}$. Construction and equipment investment augment the stocks of buildings k_b and equipment k_e, which depreciate at the rates $\delta_b, \delta_e \in (0, 1)$.[8]

Each economy $j \in \mathcal{J}$ is populated by a representative household, whose preferences

[8]Note that some authors use the terms "structures and residential housing" and "machinery/equipment" instead.

are described by the utility function:[9]

$$\sum_{t=0}^{\infty} \beta^t u\left(x_{st}^j, x_{gt}^j\right). \tag{1}$$

$\beta \in (0,1)$ is the discount factor and u has the standard regularity properties. The representative household is endowed with one unit of labor in each period and with positive stocks of buildings k_{b0}^j and equipment k_{e0}^j in the initial period.

All technologies have constant returns to scale. There is no technological progress. This is without loss of generality here, as we are interested in ratios that along balanced growth paths are constant and independent of growth rates. Country $j \in \mathcal{J}$ produces final good $i \in \mathcal{I}$ according to

$$y_i^j = F_i^j(k_{bi}^j, k_{ei}^j, l_i^j). \tag{2}$$

k_{bi} and k_{ei} are the stocks of buildings and equipment and l_i is the labor allocated to the production of y_i. F_i^j has the usual regularity properties. Note that F_i^j differs across goods and countries. We will be more specific on the nature of these differences in Subsection 3.1 below when we specify functional forms.

Tradable output is sold in the world market. Delivering it from there to household requires distribution services. Burstein et al. (2003, 2004) document that the share of distribution services in the purchase price of tradable goods (the so called distribution margin) can be large quantitatively.[10] To capture this, we assume that the production function for delivering x_i units of tradable good $i \in \{g, e\}$ to the representative household in country j is given by

$$x_i^j = G_i(y_i^{*j}, y_{si}^j), \tag{3}$$

where y_i^{*j} is the quantity of good i that is purchased in the world market and y_{si}^j are the distribution services. G_i has the standard regularity properties of a production function.

[9] We will specify functional forms below when we do our quantitative exercise.

[10] We do not consider a distribution margin for construction because the IO tables do not report it. We do not consider a distribution margin for services because distribution services are services.

Again we will be more specific in Subsection 3.1 below.

2.3 Competitive equilibrium

We abstract from the possibility that assets are traded across countries. This is without loss of generality because we will restrict our attention to balanced–growth–path comparisons.

In each period there are markets for each final good and each factor of production. The market clearing conditions are:

$$p_g^*(y_g^{*j} - y_g^j) + (y_e^{*j} - y_e^j) = 0 \tag{4a}$$

$$x_s^j + y_{sg}^j + y_{se}^j = y_s^j, \qquad x_b^j = y_b^j, \tag{4b}$$

$$k_b^j = \sum_{i \in \mathcal{I}} k_{bi}^j, \qquad k_e^j = \sum_{i \in \mathcal{I}} k_{ei}^j, \qquad 1 = \sum_{i \in \mathcal{I}} l_i^j, \qquad j \in \mathcal{J}. \tag{4c}$$

The first condition says that trade must be balanced in each country.[11] The second condition says that the purchases of services by the household and the distribution sector must equal the production of services. Note that this implicitly assumes that consumed services and distribution services are perfect substitutes. The reason for this assumption is that we do not have information about the relative prices of the two in our data set. The third condition says that the purchases of new buildings must equal the construction of buildings. The last three conditions say that the three factors owned by the household must equal the sums of the quantities rented by the four sectors.

We take into account that taxes can be a source of cross-country differences in observable relative prices, as suggested by Chari et al. (1996) and Restuccia and Urrutia (2001). We define taxes broadly as any distortion that increases the purchase price and gets rebated to the households. Examples include value–added taxes, tariffs, bribes, and monopoly rents. The tax rates are denoted by τ_{it}^j where $i \in \mathcal{I}$ and $j \in \mathcal{J}$. The tax revenues are rebated to the households through lump-sum transfers Λ_t^j. The fact that

[11] Recall that we don't have borrowing and lending across countries. Recall too that we consider small open economies, so we do not need to impose world market clearing for the tradable goods.

they are rebated distinguish taxes from sector TFPs: a decrease in a sector's TFP has the same effect on the relative price as an increase in the "tax", but only the tax revenue gets rebated to the representative household.

We choose equipment in the world market as the numeraire: $p_e^* = 1$. We denote the relative world–market price of consumption goods before delivery by p_g^*, the relative producer prices by p_i^j, the relative purchase prices after delivery and taxes by P_i^j, and the rental rates by r_b^j, r_e^j, and w^j where $(i, j) \in \mathcal{I} \times \mathcal{J}$.

For convenience, we define the following column vectors:

$$\boldsymbol{\tau} \equiv (\tau_s, \tau_b, \tau_g, \tau_e)', \qquad \boldsymbol{r} \equiv (r_b, r_e)', \qquad \boldsymbol{x} \equiv (x_s, x_b, x_g, x_e)', \tag{5a}$$

$$\boldsymbol{P} \equiv (P_s, P_b, P_g, P_e)', \qquad \boldsymbol{p} \equiv (p_s, p_b, p_g, p_e)', \tag{5b}$$

$$\boldsymbol{k} \equiv (k_b, k_e)', \qquad \boldsymbol{k_i} \equiv (k_{bi}, k_{ei})', \tag{5c}$$

$$\boldsymbol{k_b} \equiv (k_{bs}, k_{bb}, k_{bg}, k_{be})', \qquad \boldsymbol{k_e} \equiv (k_{es}, k_{eb}, k_{eg}, k_{ee})', \tag{5d}$$

$$\boldsymbol{y} \equiv (y_s, y_b, y_g, y_e)', \qquad \boldsymbol{l} \equiv (l_s, l_b, l_g, l_e)'. \tag{5e}$$

Definition 1 (Competitive Equilibrium)

Given sequences of taxes and rebates $\{\boldsymbol{\tau}_t^j, \Lambda_t^j\}_{t=0}^{\infty}$ where $j \in \mathcal{J}$, a competitive equilibrium consists of sequences of relative prices $\{\boldsymbol{P}_t^j, p_g^*, \boldsymbol{p}_t^j, \boldsymbol{r}_t^j, w_t^j\}_{t=0}^{\infty}$, household allocations $\{\boldsymbol{x}_t^j, \boldsymbol{k}_{t+1}^j\}_{t=0}^{\infty}$, firm allocations $\{\boldsymbol{y}_t^j, \boldsymbol{k}_t^j, \boldsymbol{l}_t^j\}_{t=0}^{\infty}$, $\{x_{it}^j, y_{it}^{*j}, y_{sit}^j\}_{t=0}^{\infty}$ for $i \in \{g, e\}$ such that:

1. *$p_g^j = p_g^*$ and $p_e^j = 1$;*

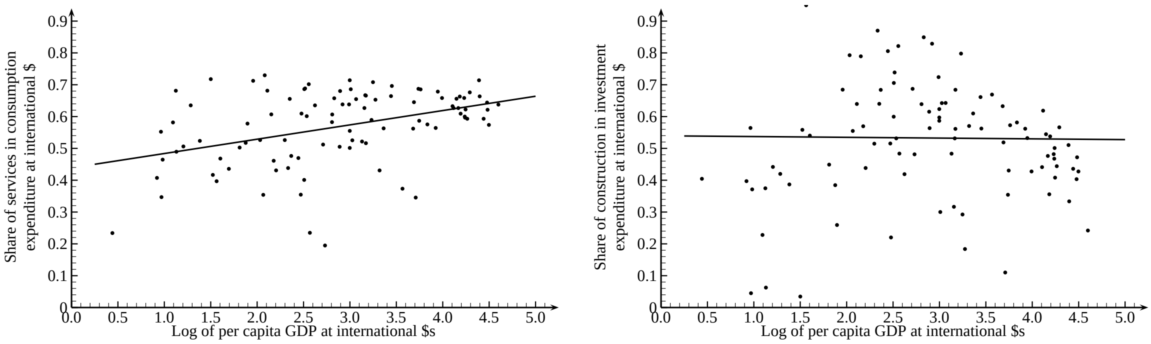
2. *given prices, $\{\boldsymbol{x}_t^j, \boldsymbol{k}_{t+1}^j\}_{t=0}^{\infty}$ solve the problem of the household in country j:*[12]

$$\max_{\{\boldsymbol{x}_t^j, \boldsymbol{k}_{t+1}^j\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t u(x_{st}^j, x_{gt}^j) \tag{6a}$$

$$\begin{aligned} s.t. \quad & (\boldsymbol{P}_t^j)' \cdot \boldsymbol{x}_t^j = (\boldsymbol{r}_t^j)' \cdot \boldsymbol{k}_t^j + w_t^j + \Lambda_t^j, \\ & k_{it+1}^j = (1 - \delta_i) k_{it}^j + x_{it}^j \quad i \in \{b, e\}, \\ & \boldsymbol{x}_t^j, \boldsymbol{k}_{t+1}^j \geq 0, \qquad \boldsymbol{k}_0^j > 0 \textit{ given}; \end{aligned}$$

[12]Note that profits are zero in competitive equilibrium, so we suppress them.

Figure 1: The composition of consumption and investment



3. *given prices,* $\{y^j_{it}, \boldsymbol{k}^j_{it}, l^j_{it}\}_{t=0}^{\infty}$ *solve the problem of the firm in sector* $i \in \mathcal{I}$*:*

$$\max_{\{y^j_{it}, \boldsymbol{k}^j_{it}, l^j_{it}\}} p^j_{it} y^j_{it} - (\boldsymbol{r}^j_t)' \cdot \boldsymbol{k}^j_{it} - w^j_t l^j_{it} \quad s.t. \quad (2); \tag{6b}$$

4. *given prices,* $\{x^j_{it}, y^{*j}_{it}, y^j_{sit}\}_{t=0}^{\infty}$ *for* $i \in \{g, e\}$ *solve the problems of the firms in the distribution sector:*

$$\max_{\{x^j_{gt}, y^{*j}_{gt}, y^j_{sgt}\}} \frac{P^j_{gt}}{1+\tau^j_{gt}} x^j_{gt} - (p^*_{gt} y^{*j}_{gt} + p^j_{st} y^j_{sgt}) \;\; s.t. \;\; (3), \tag{6c}$$

$$\max_{\{x^j_{et}, y^{*j}_{et}, y^j_{set}\}} \frac{P^j_{et}}{1+\tau^j_{et}} x^j_{et} - (y^{*j}_{et} + p^j_{st} y^j_{set}) \;\; s.t. \;\; (3); \tag{6d}$$

5. *markets clear, that is,* (4) *hold.*

3 Data and Measurement

3.1 Definitions

As mentioned before, we work with the Penn World Tables. We restrict our attention to benchmark years and countries, because only for those the International Comparisons Program actually collects the data. We work with the 1996 Benchmark Study of the Penn World Tables, or PWT96 for short. The PWT96 is a disaggregate cross section for 1996, which is collected within the International Comparisons Program. It contains internationally comparable information about expenditures, purchased quantities, and purchase prices for 30 categories in 98 countries with more than 1 million inhabitants.

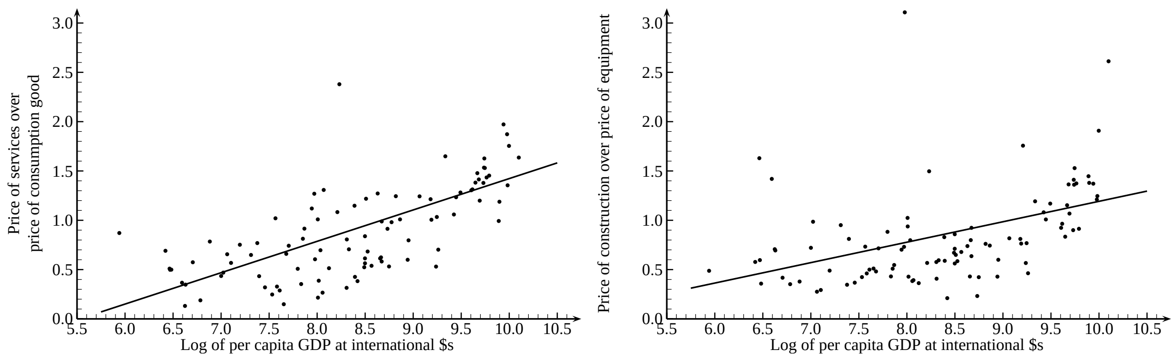
The question may arise why we did not use another existing data sources, such as OECD STAN database, the ICOP Industrial Database, or the data of the United Nations Statistical Office. These data sources are not sufficiently informative so as to construct cross–country relative sector TFP estimates. First, they are restricted to the OECD countries at best, whereas here we are interested in the whole range of international disparity between the leading countries and the developing countries. Second, they do not contain economy–wide information that is comparable across countries.[13]

We are going to apply our model to three "economies": the U.S., Latin America, and the 20 poorest countries in our sample.[14] We represent them by the superscripts US, LA, and PC, so $j \in \mathcal{J} \equiv \{US, LA, PC\}$. Two remarks about our choice of countries are at order. First, our small–economy assumption is somewhat questionable for the U.S. We make it nonetheless because the alternative would be to assume that the world market clears among our three economies. This is more questionable, as most of U.S. trade is with countries outside of the set considered here. Second, we calculate the relevant statistics for Latin America and the Poorest Countries as the averages of the member countries' statistics. Since we have data only for 1996, our hope is that by taking averages across broad sets of countries we eliminate most of individual countries' deviations from their balanced growth paths. Note that because of this concern, we do not consider countries such as India and China, who are typically viewed as being in a transition, so they are

[13]Specifically, the OECD STAN database is based on the OECD input–output tables. It contains information about input and output variables, hours worked, and the depreciation of capital for the whole economy. Unfortunately, all numbers are in *domestic* prices (current and constant). The Groningen Growth and Development Center offers the ICOP Industrial Database, which stands for International Comparisons of Output and Productivity by Industry. This data set contains relative labor productivities and unit labor costs for 20 manufacturing industries in the US and 13 European Union countries during the period 1979–2001. Unfortunately, it does not contain information about industries other than manufacturing and about inputs and outputs. The United Nations Statistical Office reports GDP by sectors for a large number of countries. However, these numbers are in current and constant domestic prices.

[14]The identity of the Latin American countries and the twenty poorest countries of our sample can be found in Appendix B.1.

Figure 2: Prices of nontradables relative to tradables



not close to their balanced growth path. Note also that the gap between the US and Latin America or the Poorest Countries have received most of the attention of previous studies.[15]

We aggregate the 30 expenditure categories of the PWT96 to our four sectors. To do this, we judge each categories as to whether it is nontradable or tradable and investment or consumption. The details are described in Appendix B.1.1. The resulting assignment is very similar to that typically used in other studies; see for example de Gregorio et al. (1994). Having formed our four sectors, we provide descriptive statistics suggesting that disaggregating to our four, instead of two, sectors was a good idea.[16] Figure 1 shows that both consumption and investment have large nontradable and tradable parts. Figure 2 shows that for both consumption and investment the prices of the nontradable relative to the tradable component increase systematically with income. To the extent that relative prices reflect relative sector TFPs, important information should be obtained from disaggregating consumption and investment into their nontradable and tradable components. For completeness, Figure 14 in Appendix C also shows the usual way of reporting relative price variations across countries, namely by looking at the price of nontradables relative to tradables or by looking at the price of consumption relative to investment. Both increase systematically with income too.

[15]See for example Cole et al. (2005) on the gap between the US and Latin America and Prescott (1998) on the gap between the US and the Poorest Countries.

[16]Appendix B.1 explains in detail how to compute the prices and quantities of our four categories.

Next, we need to discuss what happens when countries specialize. A country that specializes produces only one of the two tradable goods and replaces the domestic technology for the other tradable good by the world–market technology, so it can obtain the other tradable good at the world market price. We can avoid dealing with the different possible specialization patterns if we endow each country with the world–market technology of exchanging the two tradable goods. This implies that we must restrict the domestic technologies such that the marginal rate of transformation between the two tradables equals p_g^* in all countries. Given this restriction, it is without loss of generality that we consider only the equilibrium in which all countries produce everything themselves, so exports and imports are zero. While this may seem restrictive, it is easy to show that in any equilibrium (with or without specialization) the marginal rates of transformation for the operated technologies equal p_g^* anyways, and that the following variables are the same: the relative prices, the consumed and produced quantities of nontradables, the consumed quantities of tradables and the world productions of tradables, and welfare. In other words, equilibria with different specialization patterns differ at most in the quantities of tradables that the different countries produce. Since the PWT96 has no information about the quantities produced, we do not have anything to say here about these quantities anyways.

To compute our model, we work with the following functional forms:

$$u(x_s^j, x_g^j) \equiv \log\left((x_s^j)^{\alpha}(x_g^j - \bar{x}_g)^{1-\alpha}\right) \qquad j \in \mathcal{J},\ i \in \mathcal{I}, \tag{7a}$$

$$F_i^j(k_{bi}^j, k_{ei}^j, l_i^j) \equiv A_i^j (k_i^j)^{\theta_i} (l_i^j)^{1-\theta_i}, \tag{7b}$$

$$k_i^j \equiv \left[\mu^{\frac{1}{\sigma}}(k_{bi}^j)^{\frac{\sigma-1}{\sigma}} + (1-\mu)^{\frac{1}{\sigma}}(k_{ei}^j)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \qquad j \in \mathcal{J},\ i \in \mathcal{I}, \tag{7c}$$

$$G_i(y_i^{*j}, y_{si}^j) \equiv \min\left\{y_i^{*j}, \psi_i y_{si}^j\right\} \qquad j \in \mathcal{J},\ i \in \{g, e\}. \tag{7d}$$

$\alpha \in (0,1)$ and $\bar{x}_g \in (0,\infty)$ are constants that determine the expenditure share of services. Since our category consumption goods include food and beverages, we interpret $\bar{x}_g$ as the subsistence level of consumption goods. Having $\bar{x}_g > 0$ allows us to match the well known fact that both the relative price of services and the expenditure share of services are much lower in the poorer countries than in the U.S.[17] Our production function has the standard Cobb–Douglas form in capital and labor, but here capital is a CES aggregator of the stocks of buildings and equipment. In particular, A_i^j is the TFP of producing y_i in country j, $\theta_i \in (0,1)$ is the capital share (which possibly differs across sectors but is restricted to be the same across countries), $\sigma \in [0,\infty)$ is the elasticity of substitution between buildings and equipment, $\mu \in (0,1)$ determines the share of buildings in output. Our production function of the distribution sector is Leontief where $\psi_i \in (0,\infty)$ determines the distribution services required to deliver one unit of x_i, $i \in \{g,e\}$.

3.2 Measurement

3.2.1 General procedure

We now choose the model parameters and measure the taxes and the sector TFPs. To this end, we normalize $A_e^{US} = 1$. We assume that all taxes are zero in the U.S.: $\tau_i^{US} = 0$ for $i \in \mathcal{I}$. This leaves us with 32 parameters. Specifically, there are 21 technology parameters: the 11 remaining sectoral TFPs; the 4 capital shares; the 2 parameters in the CES–aggregator of buildings and equipment; the 2 parameters of the distribution technologies; the 2 depreciation rates. Moreover, we have the 3 preference parameters (namely β, α, and $\bar{x}_g$) and 8 taxes for Latin America and the Poorest Countries.

We will calibrate to the U.S. economy 8 of these parameter values, namely the four sector capital shares, the two depreciation rates, and the two parameters of the distribution technology. Given these 8 values, we will choose the remaining 24 parameter values so as to match as closely as possible 28 different statistics from the PWT96. Among these 24 parameters are the 11 sectoral TFPs that we aim to measure.

We start by explaining how we measure the capital shares, the depreciation rates, and the distribution parameters for the U.S. economy.

[17] For the same reason, several recent studies, including Kongsamut et al. (2001) and Gollin et al. (2004), assumed subsistence terms.

3.2.2 Measurement with U.S. data

We calculate the sector capital shares from the U.S. input–output tables of 1997 as reported by the Bureau of Economic Analysis (4 statistics).[18] Computing the capital shares is less straightforward than it might seem at first sight. To begin with, proprietor's income contains a labor component which needs to be included in the labor share. Moreover, since our data has no information about intermediate inputs, we have not modeled them here. This implies that the capital shares in the model contain the payments to capital that accrue when intermediate inputs are produced whereas the capital shares in the data do not contain these. Appendix B.1 reports the detailed steps required to take care of this. Table 1 summarizes the resulting findings. Note that the tradables are more capital intensive than nontradables. While Bhagwati (1982) and Kravis and Lispsey (1988) suggested that this is the case, there has been quite some confusion in the literature. For example, Stockman and Tesar (1995) claimed that the capital share is higher in non–tradables than in tradables.

Table 1: Capital shares in the US economy

whole economy	services	construction	consumption goods	equipment
0.31	0.32	0.20	0.39	0.31

tradables	nontradables	consumption	investment
0.35	0.30	0.33	0.27

[18]The data of BEA do not allow us to compute the capital shares for 1996, the year of our cross section in the PWTs. 1997 is the closest year for which data is available. Note that for each sector in the PWT96 we needed to make a call as to which of our four model sectors it corresponds. In contrast, we do not need to make that call in the input–output tables, as they provide more detailed information. In particular, the counterparts of our four sectors in the input–output tables are as follows: services equal the sale to final expenditure by all sectors except agriculture, mining, manufacturing, personal transportation equipment, and construction; construction equals the construction commodities delivered to final expenditure fixed investment; consumption goods equal the agriculture, mining, and manufacturing commodities not delivered to final expenditure fixed investment; equipment investment equals the agriculture, mining, and manufacturing commodities delivered to final expenditure fixed investment plus the final expenditure on personal transportation equipment.

We calculate the depreciation rates from the fixed asset and investment data of the Bureau of Economic Analysis by setting the depreciation rate equal to the average of $[x_{it}+k_{it}-k_{it+1}]/k_{it}$ between 1987-2003 (2 statistics). We find that the average depreciation rates were $\delta_b = 0.02$ and $\delta_e = 0.14$. These numbers are somewhat different from those of Greenwood et al. (1997), who had $\delta_b = 0.06$ and $\delta_e = 0.12$. The likely reasons for the differences are that these authors considered structures but not buildings and that during the 1990s the BEA changed its way of calculating capital stocks.

We calculate the two distribution margins using the 1997 benchmark IO–tables at producer and purchase prices. One difference between these two tables is that at producer prices the output of the distribution industries (retail and wholesale trade and transportation) is reported separately whereas at purchase prices it is included in the output of the industries that use them. Using this, the distribution margins equal the difference between the shares of final expenditures at purchase and producer prices divided by final expenditure at purchase prices. We find that the distribution margins for consumption goods and equipment equal equals 0.46 and 0.18.[19] In equilibrium the two distribution margins equal $P_s^{US}/(P_g^{US}\psi_g)$ and $P_s^{US}/(P_e^{US}\psi_g)$. Using the observed values for P_s^{US}/P_g^{US} and P_s^{US}/P_e^{US} in addition, we can solve for ψ_g, ψ_e.

3.2.3 Measurement with PWT96 data

Given these eight parameter values, we choose the remaining 24 parameter values so as to match as closely as possible 28 statistics from the PWT96.[20] These are: the ratios of U.S. per–capita GDP in international prices over Latin American and the Poorest Countries per–capita GDP in international prices (2 statistics); the three relative prices in each country (9 statistics); the expenditure shares of services in domestic currency in each country, which we have plotted against income in Figure 17 in Appendix C (3 statistics); the investment shares of buildings and equipment in domestic and international prices in each country, which we have plotted against income in Figures 15–16 in Appendix C

[19]To put these numbers into perspective, Burstein et al. (2003) calculated 0.42 and 0.17.

[20]Appendix B.1.2 explains how we compute these statistics. Appendix B.3 explains our minimization procedure.

(12 statistics). We also use the fact that when multiplied with the \$–market exchange rate as reported by the IMF, the prices of equipment across countries are unrelated to income. This has been noted by Eaton and Kortum (2001) and used by Hsieh and Klenow (2003). It can be seen in Figure 18 in Appendix C. Given $P_e^{US} = 1$ we therefore impose $P_e^{LA} = P_e^{PC} = 1$ (2 statistics).

Table 2: Statistics in the data and the model

	US		LA		PC	
	Data	Model	Data	Model	Data	Model
Income relative to the US	1.00	1.00	3.77	3.80	19.76	19.64
Equip invest share (dom prices)	0.11	0.11	0.09	0.09	0.10	0.09
Constr invest share (dom prices)	0.09	0.09	0.12	0.09	0.10	0.11
Equip invest share (int \$s)	0.15	0.14	0.12	0.08	0.06	0.05
Constr invest share (int \$s)	0.10	0.10	0.12	0.10	0.07	0.08
Services expenditure share	0.77	0.59	0.51	0.56	0.34	0.31
Relative price services	1.92	1.92	0.90	0.90	0.36	0.36
Relative price construction	1.21	1.21	0.90	0.90	0.70	0.70
Relative price consumption goods	1.03	1.03	0.82	0.82	0.64	0.64
Aggregate capital share	0.31	0.33	–	0.34	–	0.33
Distribution margin cons goods	0.46	0.46	–	–	–	–
Distribution margin equipment	0.18	0.18	–	–	–	–

Table 2 summarizes our target statistics in the data and the model. We match all relative prices by construction. We come reasonably close for the other target statistics. The exceptions are the shares of services in total consumption. The reason is that as countries develop the share of manufacturing consumption goods remains roughly constant while the shares of services increase and of agricultural goods decrease. Our model with two consumption goods only is not disaggregate enough to capture this. To be sure that this does not critically affect our measurement of sector TFPs, we have experimented with more complicated utility functions that allow us to match the three service shares more closely. This did not importantly change our measurement of the sector TFPs. Since our current utility function is simpler, we decided to stick with it.

Table 3 summarizes our parameter values. Somewhat reassuringly those of our pa-

Table 3: Parameter values

$\theta_s = 0.32$	$\theta_b = 0.20$	$\theta_g = 0.39$	$\theta_e = 0.31$	$\delta_b = 0.02$	$\delta_e = 0.14$
$\psi_g = 4.07$	$\psi_e = 10.65$	$\sigma = 1.58$	$\mu = 0.45$		
$\beta = 0.98$	$\alpha = 0.60$	$\bar{x}_g = 0.01$			

rameters that would feature also in standard growth models take standard values. Note that $\bar{x}_g = 0.01$ implies that in the U.S. 3% the consumed quantities of goods are for subsistence, while in Latin America and the Poorest Countries these numbers are 14% and 63%, respectively.

4 Findings

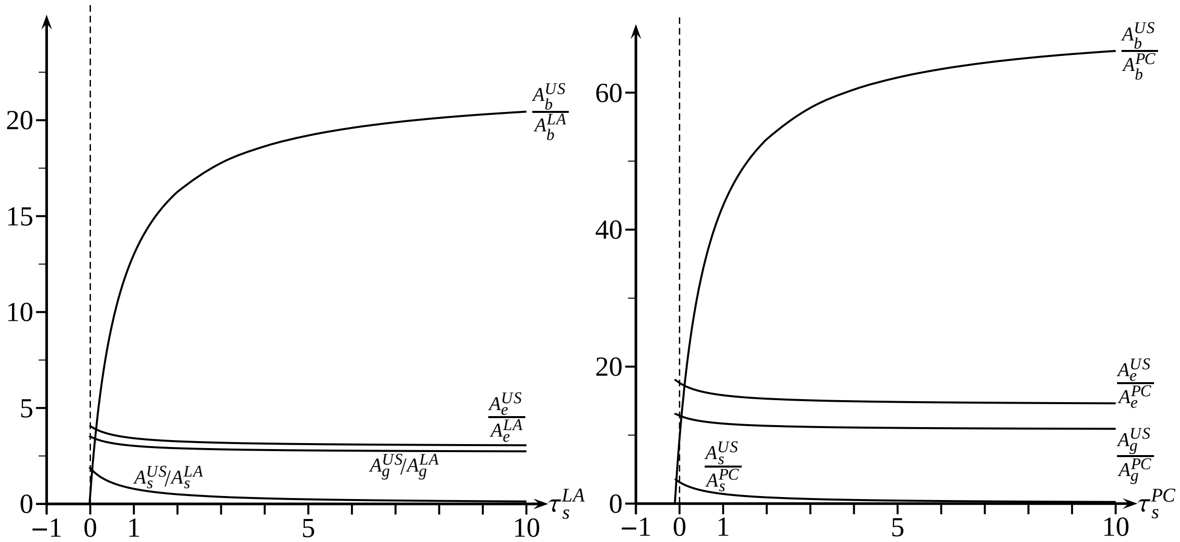
4.1 Cross–country sector TFP differences

We find that the PWTs do not contain enough information to pin down the services taxes. Instead, there are small negative lower bounds for LA and PC such that for all larger service taxes we match all targets equally well. Given a choice of the service tax, however, all other parameter values are uniquely determined. We will therefore report our findings as functions of the services taxes $\tau_s^j \in [0, 10]$, where the upper bound corresponds to an implausibly large service tax of 1000%. We experimented with even larger service taxes but found that nothing changes anymore.[21]

Figure 3 reports our findings. Within the tradables, the cross–country TFP differences in equipment are larger than in consumption goods. We also find that the TFP differences in both tradables are much larger than in services. Note that our findings that the cross–country relative sector TFP differences are larger in equipment than in consumption goods

[21]Note that irrespective of service taxes, the taxes on the two tradable goods are uniquely determinate. The reason is that their producer prices are equalized across countries. Thus, there is an additional constraint that pins down the taxes as the differences between the purchases prices after taking out the distribution margins and the producer prices in the world market.

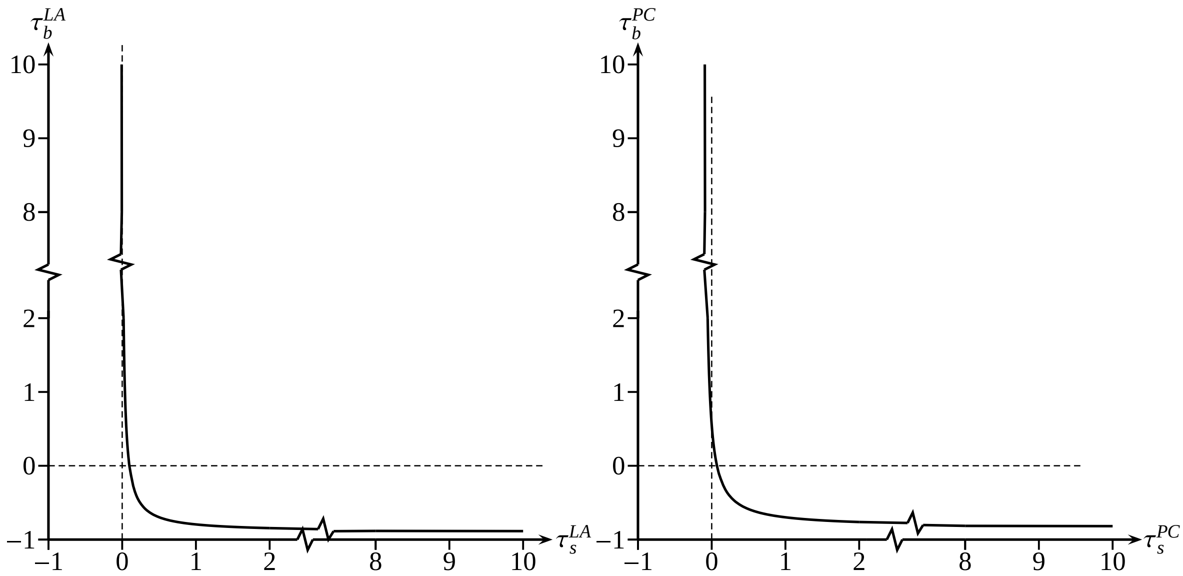
Figure 3: International sector TFP disparity



suggests that the poor countries have a comparative advantage in consumption goods. They may therefore specialize in consumption goods and import their equipment. In this case, our measured sector TFP in equipment is not the TFP which the poor countries produce equipment, but the TFP with which they obtain equipment in the world market. This is the product of their low TFP in consumption goods and the world market price of equipment relative to consumption goods. While the poor countries could not possibly have a higher TFP if they produced equipment themselves (otherwise they would not specialize in consumption goods), they could well have a lower one. Given the limitations of our data, we cannot say anything other that our measure is a lower bound for how bad the poor countries are at producing equipment.

Our findings for construction are too sensitive to the choice of τ_s for making robust statements. For example, the construction TFP differences between the US and the Poorest Countries lie anywhere between zero and sixty. To understand intuitively why we cannot pin down the service taxes, Figure 4 plots the construction tax as a function of the service tax. We can see that τ_b^j is a decreasing function of τ_s^j. Moreover, recall from Figure 3 that A_s^{US}/A_s^j is a decreasing function and A_b^{US}/A_b^j is an increasing function

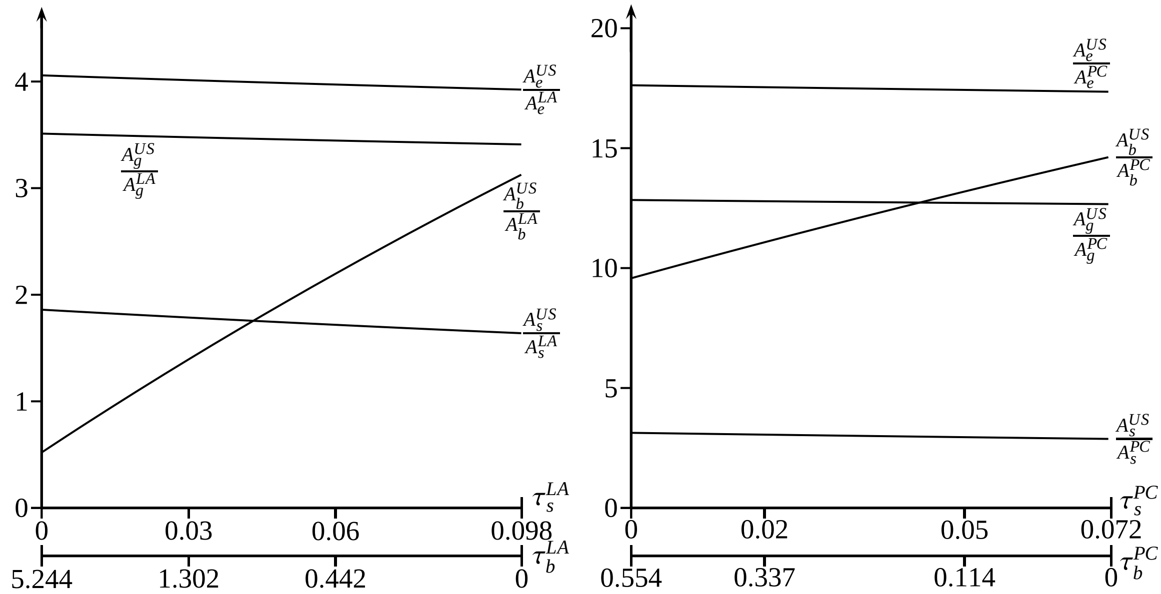
Figure 4: Nontradable taxes



of τ_b^j. These reactions to changes in the services tax occur because the loss function is to remain the same, so purchase prices and produced quantities cannot change much. For the relative price of service not to change much, the price effect of the increase in τ_s^j must be neutralized by a decrease in A_s^j. For the service production not to change much, the output effect of the decrease in A_s^j must be neutralized by a reallocation of capital and labor from the construction sector to the service sector. For the output of the construction sector not to change much, the output effect of this reallocation must be neutralized by an increase in A_b^j. For the relative price of construction not to change much, the price effect of the increase in A_b^j must be neutralized by an increase τ_b^j.

Related studies deal with the tax indeterminacy by imposing an arbitrary additional restriction. For example, Hsieh and Klenow (2003) set the tax on the aggregate consumption to zero. Since we have no evidence to justify such a restriction, we do not want to impose it here. However, we feel comfortable to consider the weaker restriction that both nontradable taxes be nonnegative. To understand what that means, recall that we set all taxes in the US to zero, so a positive tax in one of the two countries means that taxes there are larger than in the US and a negative tax means that taxes there are smaller

Figure 5: International Sector TFP disparity with nonnegative taxes in nontradables



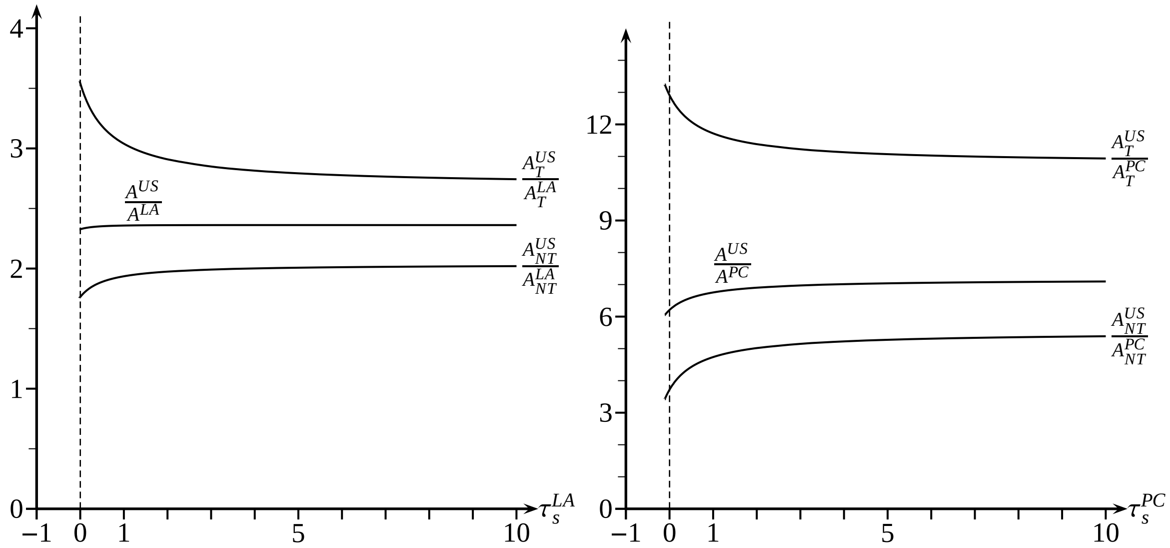
than in the US. To us this sounds like a reasonable prior. Amplifying the part of figure 3 for which both nontradable taxes are nonnegative leads to Figure 5. We can see that while the cross–country TFP differences in construction still move a bit, they now are always smaller than in equipment.

4.2 The findings of the literature

Employing two–sector studies, the existing literature has identified many problem sectors, but it has not reached a consensus as to which are they. We argue that the literature has not disaggregated sufficiently to get to the bottom of this. We show this by aggregating the findings of four–sector analysis to the different two–sector splits considered in the literature. As is standard, we use international prices to aggregate. For example, given that $\boldsymbol{\pi} = (1, 1, 1, 1)$ in the PWTs, we calculate the TFP of tradables as:

$$A_T^j \equiv \frac{A_g^j (k_g^j)^{\theta_g} (l_g^j)^{1-\theta_g} + A_e^j (k_e^j)^{\theta_e} (l_e^j)^{1-\theta_e}}{(k_g^j)^{\theta_g} (l_g^j)^{1-\theta_g} + (k_e^j)^{\theta_e} (l_e^j)^{1-\theta_e}}. \tag{8}$$

Figure 6: International TFP disparity in the aggregate, tradables, and nontradables



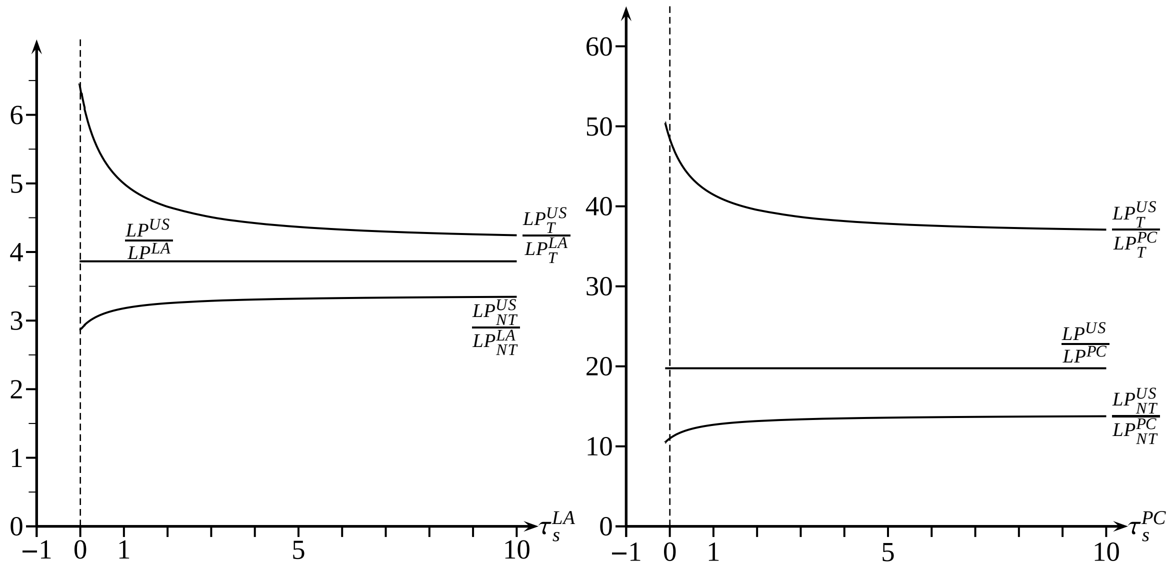
We start with Balassa (1964) and Samuelson (1964), who conjectured many years ago that the international disparities in labor productivity are much larger in the tradable sectors than in the nontradable sectors. They were motivated by the systematic variations of relative prices and real exchange rates with income.[22] Figure 6 shows our findings when we aggregate to tradables and nontradables. Both in Latin America and in the Poorest Countries, we find much larger differences in the TFPs of the tradables than in those of the nontradables, with aggregate TFP differences lying between the two. These findings turn out to be relatively robust to the range of services taxes that allow us to match our targets equally well. Note that our findings are about cross–country relative sector TFPs whereas Balassa and Samuelson talked about cross–country relative labor productivities. Since poorer countries tend to have lower capital stocks, international disparities in sector TFPs get amplified to even larger disparities in labor productivities, our findings confirm the Balassa–Samuelson hypothesis. Figure 7 shows the exact magnitudes.[23]

This suggests that the findings of the McKinsey Studies for selected industries of 10

[22] Rogoff (1996) offers a review of the more recent (indirect) evidence on the Balassa–Samuelson hypothesis.

[23] Again Appendix B.1 explains the details of how to compute aggregate labor productivities.

Figure 7: International disparity of labor productivities in aggregate, tradables and nontradables

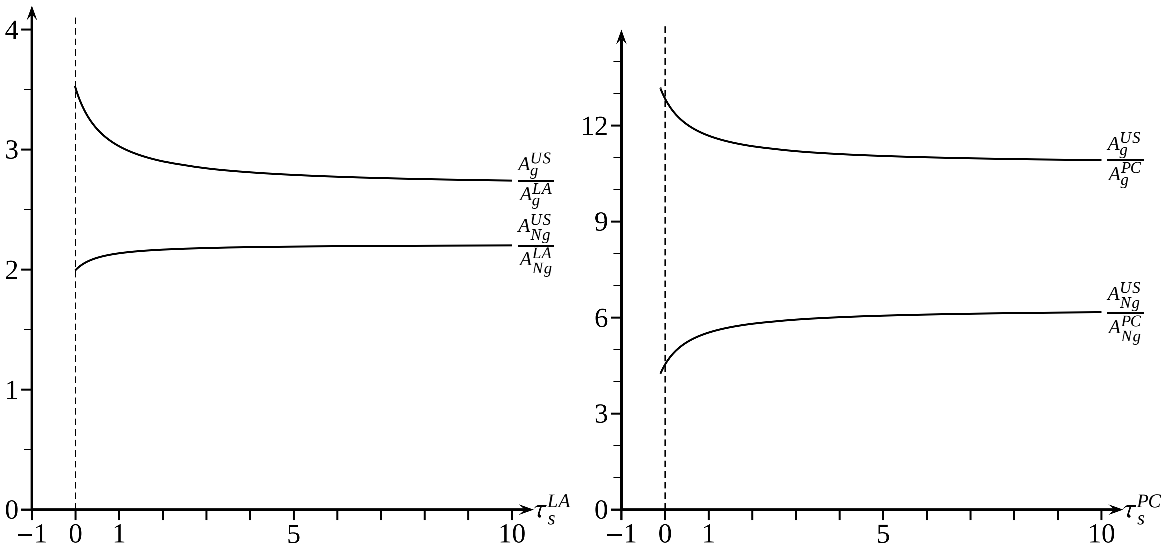


countries do not generalize to a broad cross section of industries and countries. To be precise, McKinsey have firm–level data for two developing countries only, namely Brazil and India. In contrast, the PWTs allow us to consider the whole of Latin America and twenty very poor countries. We should also point out that since we cannot separately identify the taxes on services and construction, our findings do not rule out the possibility that some nontradable sectors have very large cross–country TFP differences. All we can say is that if such differences exist, then they do not show up at the level of the aggregate nontradables.

We now turn to two other groups of two–sector studies that have identified yet different problem sectors. First, Kuznets (1971), and a large subsequent literature, found that cross–country differences in labor productivity are much larger in agriculture than in the aggregate of the other goods.[24] Since agricultural goods are a large part of consumption goods in poor countries, distinguishing between consumption goods and the aggregate of nontradables and equipment ("the rest" or "Not consumption goods") allows us to relate our results to those of this literature. Figure 8 reports that our analysis implies a much

[24]see also Restuccia et al. (2006), Córdoba and Ripoll (2004), Gollin et al. (2004), and Caselli (2005).

Figure 8: International TFP disparity in consumption goods and the rest



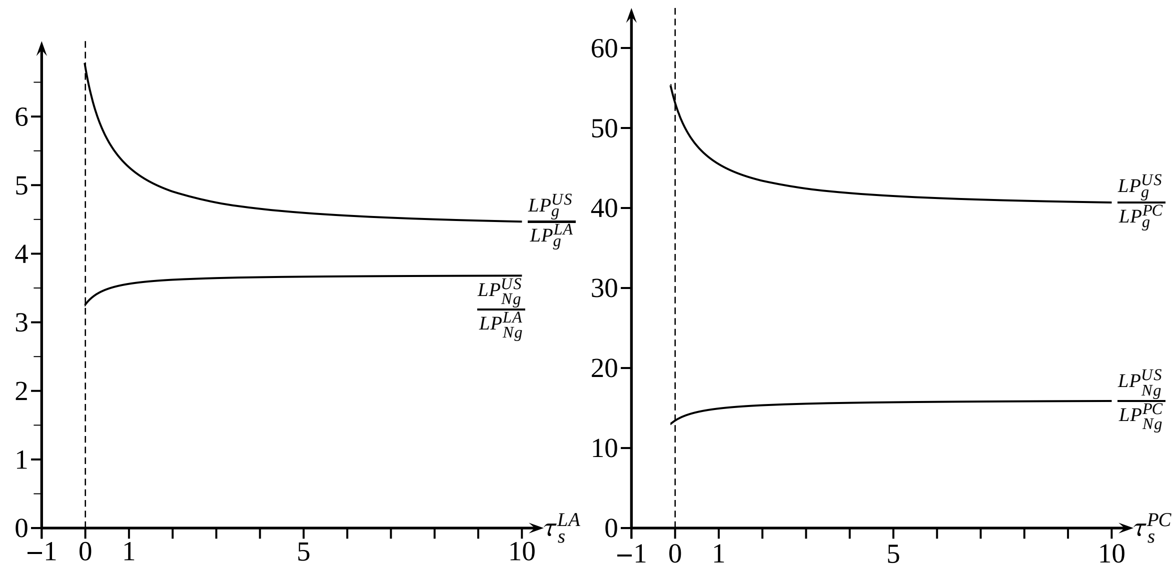
larger international disparity in the TFPs of consumption goods than in "the rest". The reason is twofold. First, as can be seen in Figures 3 and 6, the TFP differences in equipment are largest, followed by consumption, and the aggregate nontradables. Second, the nontradables constitute by far the largest share of "the rest".[25] Consequently, the smaller TFP differences in the nontradables dominate the larger TFP differences in equipment, so the TFP differences of "the rest" are smaller than those of consumption goods. Note that, again, larger TFP differences between consumption goods than between "the rest" imply even larger differences in the labor productivities of these two aggregates. Figure 9 shows the exact magnitudes.

On other hand, Hsieh and Klenow (2003) found that cross–country differences in sector TFP are much larger in investment than in consumption.[26] Their evidence also comes from the benchmark studies of Penn World Tables. Our disaggregate findings are that the TFP differences in buildings tend to be larger than in services and the TFP differences in equipment are larger than in consumption goods, so we too find that the TFP differences

[25]Specifically, in international prices, the shares of the nontradables in "the rest" are 78% for the US, 86% for Latin America, and 90% for the Poorest Countries).

[26]Previous authors observed that the relative price of capital is negatively correlated with income growth rates [Jones (1994)] and with income levels [Chari et al. (1996) and Restuccia and Urrutia (2001)].

Figure 9: International disparity of labor productivities in consumption goods and "the rest"



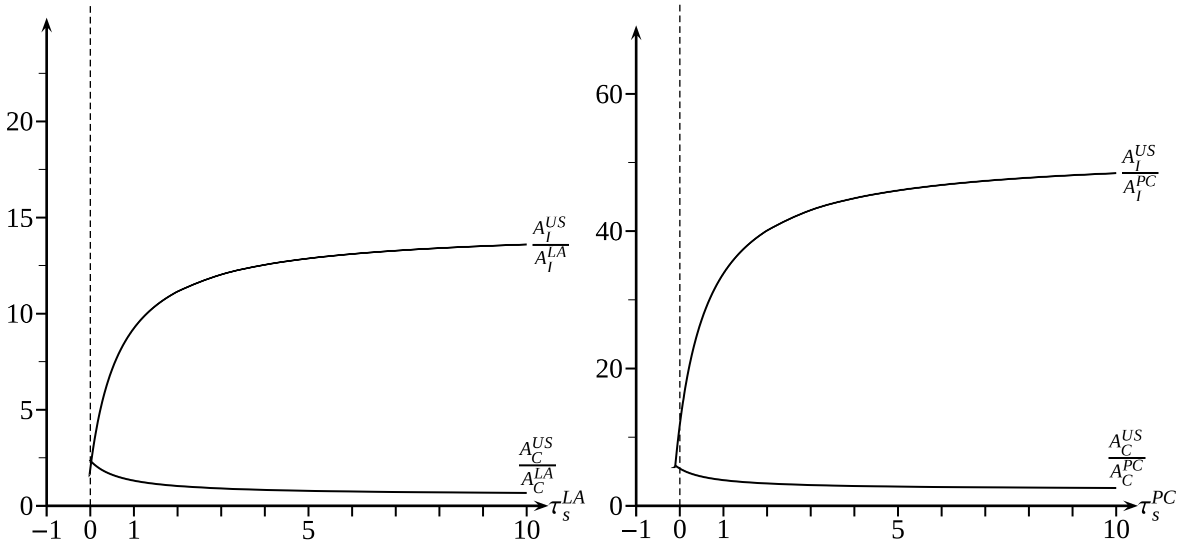
in the aggregate investment tend to be larger than in the aggregate consumption. Figure 10 reports the details. Note that we use "tend" here to indicate that for the consumption–investment split the relative TFP differences are sensitive to the value of the service tax. In fact, for very small values of service taxes, the difference between the investment and consumption TFPs disappears altogether.

In sum, we find that the explanation for the conflicting results from two–sector studies is that the relative TFPs at our four–sector level of disaggregation differ widely.

4.3 Relative prices and relative TFPs

In Subsection 2.1 above, we observed that it is not straightforward to infer relative sector TFPs within a country from the observed relative purchase prices. Having obtained our findings, we come back to this issue now and ask how large are the differences between the relative purchase prices we observe and the relative sector TFPs we find. The answers are in Figure 11, which compares the sector TFPs of tradables relative to nontradables with the inverse of their relative purchase price, and Figures 12 and 13, which do the same for consumption goods relative to "the rest" and for consumption relative to investment. For

Figure 10: International disparity in TFPs of consumption and investment



tradables relative to nontradables and for consumption goods relative to "the rest", the relative TFPs can be as much as twice as larger as the inverse of the relative prices. While this suggests that the inverse of the relative prices is a lower bound, this lower bound is too far away from the actual relative TFPs to be of practical use. For consumption relative to investment, the inverse of the relative price tends to be an upper for the relative TFPs. However, the distance between the two is very sensitive to the choice of service taxes, which can become so large that the upper bound again is of little practical use.

To understand why there are such big differences between the inverse of relative prices and relative TFPs, consider tradables and nontradables as an example and ask how taxes, distribution margins, and different sector capital shares drive wedges between relative prices and relative TFPs. To fix ideas, we restrict our example further and set the service tax to zero everywhere. Table 4.3 summarizes the relevant statistics for this case, suggesting that we need to understand why the relative TFP differences are larger than the relative purchase price differences and why the gap between the two shrinks the poorer the country is.[27] We start with the US, where the distribution margin in tradables

[27]Note that the tradable taxes in LA and PC are independent of the value of τ_s^j.

Figure 11: Relative TFPs and relative prices of tradables and nontradables

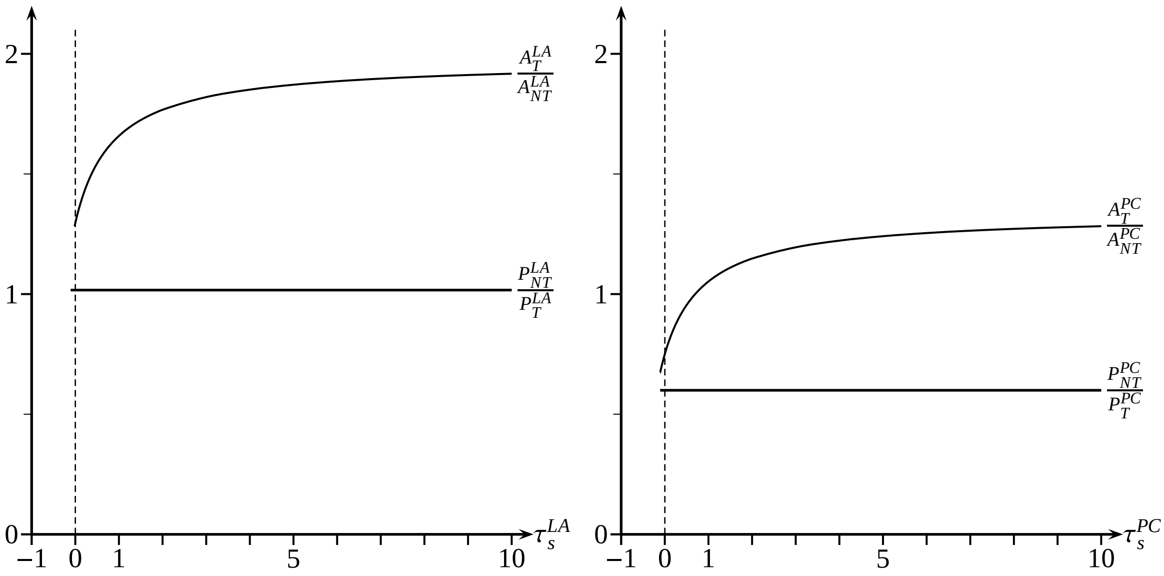
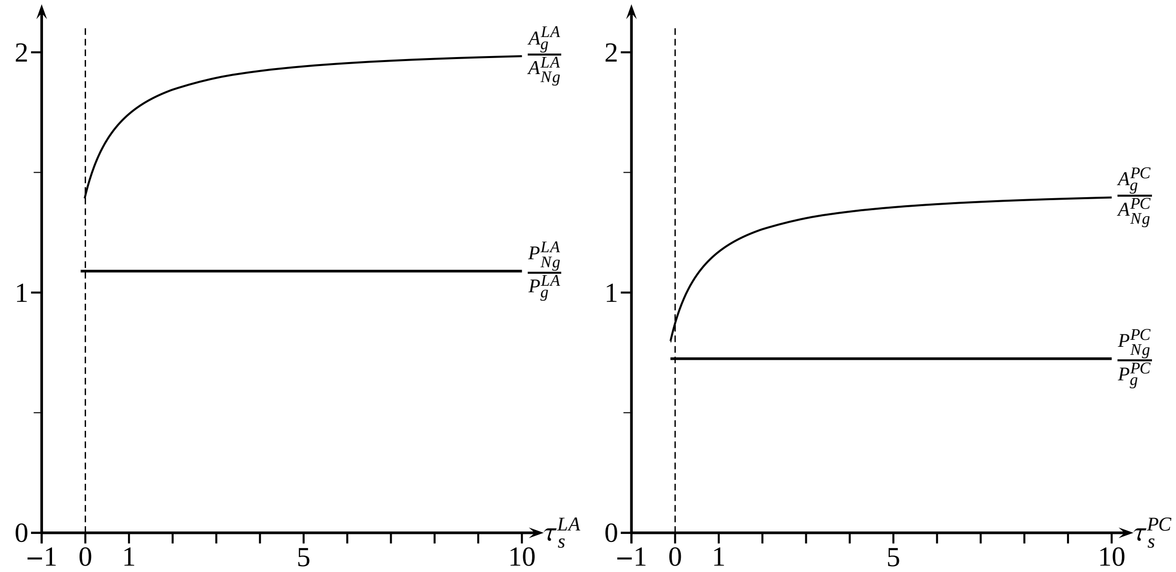


Table 4: Relative taxes, distribution margins, relative TFPs, relative prices,

	τ_s^j	τ_b^j	τ_g^j	τ_e^j	D_g^j	D_e^j	$\frac{P_{NT}^j}{P_T^j}$	$\frac{A_T^j}{A_{NT}^j}$
US	0	0	0	0	0.46	0.18	1.7	2.6
LA	0	5.24	0.06	0.11	0.27	0.08	1	1.3
PC	0	0.55	0.00	0.17	0.14	0.03	0.6	0.8

is large. Taking this distribution margin out of the purchase price of tradables reduces this price. In other words, the relative producer price of nontradables to tradables is much larger than the relative purchase price. This means that the TFP of tradables relative to nontradables is much larger than the relative purchase price. We now turn to LA and PC. Since services are cheaper in poorer countries, the distribution margins fall a lot, and more so in PC than in LA. This implies that the gap between relative purchase prices and relative TFPs falls a lot too, and more so in PC than in LA. This is what we observe. We continue with taxes. We can see that both LA and PC have higher taxes on nontradables than on tradables. Taking the taxes into account therefore reduces the gap between the relative TFPs and the relative purchase prices. Since the nontradable relative to tradable

Figure 12: Relative TFPs and relative prices of consumption goods and the rest



taxes tend to be larger in LA than in PC, this effect tends to be stronger in LA than PC. This is not what we observe. We conclude with the role of the different sector capital shares. Recall that according to our measurement above the tradables are less capital intensive than the nontradables. This implies that the producer price of nontradables relative to tradables tends to be higher in capital–scarce countries, which tend to be the poorer countries. Taking this into account reduces the gap between relative purchase prices and relative TFPs, and more so in PC than in LA. Again this is what we observe. In sum, two of the three effects go in the right direction whereas one goes in the wrong direction. It seems that quantitatively the two effects dominate the third.

We should point out that for LA and PC the distribution margins in Table 4.3 do not come from the data, but from our model given the assumption that the distribution technology (7d) is the same for all countries. To get a sense of how much of a stretch this assumption is, we would need independent information about inputs and outputs of the distribution sector in poor countries. To our knowledge, such information is not available. However, there is some indirect evidence on the distribution margins of food by Adamopoulos (2006), who estimates it in large sample of countries as the differences between the food prices in the 1985 benchmark study of the Penn World Tables (which include distribution services) and the producer prices in the data of the Food and Agricultural Organization (which do not include distribution services).[28] He finds that the distribution margins of food in the richest countries are by more than a factor two higher than the poorest countries of his sample. Our findings suggest from the PWT96 suggest that the distribution margin in consumption goods is about three times higher in the US than the Poorest Countries. So our findings suggest that the distribution margin of consumption goods (which include food) raises somewhat faster with income than what Adamopoulos (2006) finds. The likely reason for the difference is that poor countries have lower TFPs in transportation than richer countries. Given our assumption of the same distribution technology, we will erroneously attribute this to lower TFP in the production of consumption goods, and so we will overestimate the relative TFP differences in tradables. The gap between our and Adamopoulos' findings is not large enough, though, to be the main reason for why we find that the relative TFP differences in tradables are larger than in nontradables.

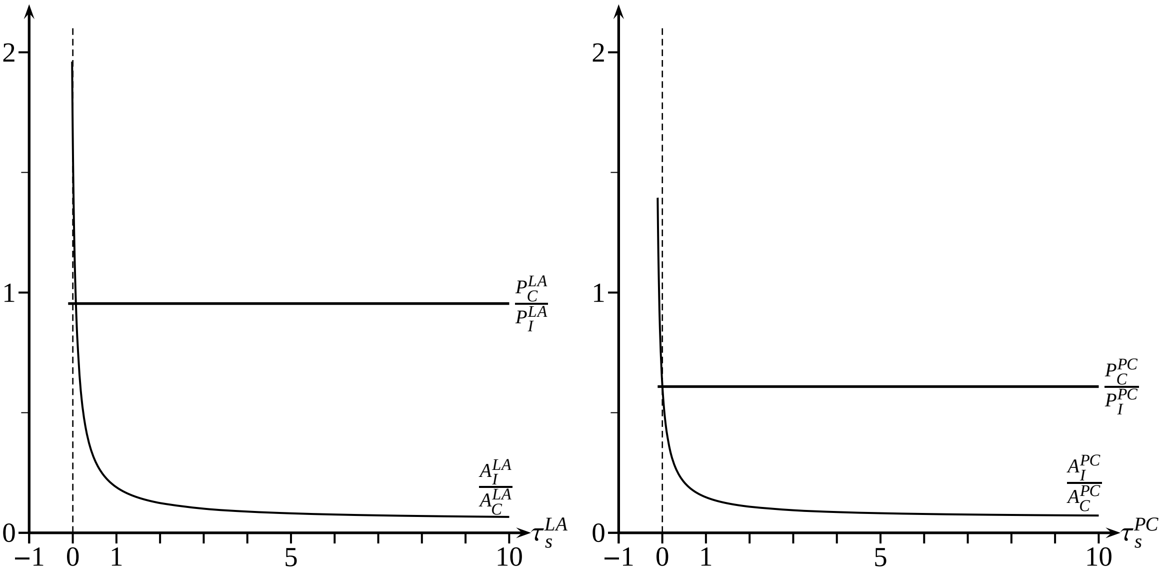
5 Towards a Theory of International TFP Disparity

The development literature argues that cross–country differences in the quality of institutions, the choice of policies, or the stock of human capital endowments cause the differences in economic performance. This raises the question why these cross-country difference should do so much more damage in some sectors than in others.[29] In this section, we argue that this question poses a challenge for theories that attribute the problem of poor countries to bad institutions or low endowments of human capital. In contrast, this question points to theories that attribute the problem of poor countries to bad policies, such as barriers to entry or financial frictions.

[28]The Penn World Tables do not contain direct information on distribution services. All they report is "purchased transportation services" and "operation of transportation equipments". Their prices relative to other services do not vary with income at all.

[29]In this section, we will not use our findings on construction TFP differences, because they are not robust to the choice of service taxes.

Figure 13: Relative TFPs and relative prices of consumption and investment



5.1 Institutions

We start by discussing whether differences in the quality of institutions can explain the differences in economic performance.[30] Our problem with this view is that it does not answer the question why bad institutions should reduce TFP by much more in the tradable sectors than in services.

Acemoglu et al. (2001), for example, distinguish between settler and nonsettler colonies. In the settler colonies the European colonizers settled because they did not face high mortality risks whereas in the nonsettler colonies the colonizers did not settle because they faced high mortality risks. Acemoglu et al. (2001) argue that only when they settled did the colonizers transfer the comparatively good European institutions to the colonies, that the resulting initial differences in institutional quality persist today, and that they account for the observed differences in economic performance. Our findings raise the question why the lack of good institutions in the non–settler colonies should do so much more damage in the tradable sectors than in services. One possibility is that in addition

[30]Recent examples of this view include Knack and Keefer (1995), Mauro (1995), Hall and Jones (1999), Acemoglu et al. (2001, 2002), Dollar and Kray (2003), and Easterly and Levine (2003).

to not setting up good European institutions, the colonizers of the non–settler colonies set up particularly bad institutions in the tradable sectors so as to export rents back to Europe. Acemoglu et al. (2001) mention that trade monopolies and restrictions were common in the non–settler colonies but they do not provide systematic evidence. We leave exploring this possibility to future research.

5.2 Human Capital

While it is widely agreed that unmeasured cross–country differences in human capital show up as cross–country differences in TFP, it is still hotly debated for how much human capital can account.[31] Be that as it may, our disaggregate four–sector analysis has the testable implication that unmeasured differences in human capital should cause the largest TFP differences in the sectors that have the largest labor shares. Here, we focus on the robust finding that, irrespective of the service tax, the sectors TFP differences are largest in equipment, followed by consumption goods, followed by services. In contrast, Table 1 above implies that in the US these labor shares equal 0.69, 0.61, and 0.68. In other words, services have a much larger share than consumption goods but services show much smaller sector TFP differences across countries. A similar picture emerges when we aggregate to nontradable versus tradables: the labor shares are 0.7 and 0.65, whereas the TFP differences are smaller in the nontradables than in the tradables.

While this speaks against simple theories of human capital, it still leaves room for more sophisticated ones. For example, Acemoglu and Zilibotti (2001) argued that poorer countries often do not adopt new technologies because they have too few skilled workers that can operate them.[32] If somehow this matters more in the tradable than in the nontradable sectors (for example because the technologies there are more skill intensive), then unmeasured differences in human capital can cause sector TFP differences that line up with our findings. Another possibility is that bad institutions in poorer countries

[31] See for example Barro (1991, 1997), Barro and Lee (1994), Mankiw et al. (1992), Blis and Klenow (2000), Hendricks (2002), Glaeser et al. (2004), Erosa et al. (2005), and Manuelli and Seshadri (2005).

[32] This is a version of the appropriate–technology hypothesis; see also Basu and Weil (1998).

allow rent extraction mainly in the nontradable sectors, as international competition puts a limit to it in the tradable ones. This could distort the allocation of skilled workers towards the nontradable sectors, so unmeasured differences in human capital would lead to larger sector TFP differences in the tradables. We leave exploring these possibilities to future research.

5.3 Policies

We think that our findings point to bad policies as a cause of low aggregate TFP. The simple reason is that bad policies are likely to affect different sectors in different ways. We give three examples. First, distortions of international trade affect the tradable sectors differently from the nontradable sectors; see for example Holmes and Schmitz (1995) and Herrendorf and Teixeira (2005a). Second, barriers to entry, monopoly rights, and rent extraction are less likely in services and agriculture, as home–production and black markets limit the possible monopoly power; see, for example, Parente and Prescott (1999) and Herrendorf and Teixeira (2005b). Third, financial frictions, such as a lack of enforcement of contracts, are likely to affect the sectors more that have a large need for external financing; see for example Amaral and Quintin (2004) and Erosa and Hidalgo (2004).

How does this view square with the finding that agriculture is one of the problem sectors of poor countries? It is important to realize that for agriculture to be unproductive, it is not necessary that bad policies directly affect it. Instead, bad policies are likely to affect measured agricultural TFP in various *indirect* ways. First, bad policies can increase the relative price of manufacturing goods, which include intermediate agricultural inputs such as fertilizer and pesticides [Restuccia et al. (2006)] and capital goods such as tractors and harvesting machines. The higher relative price implies that it is more costly for farmers to adopt science–based, modern farming technology. Many authors view the resulting lack of adoption as a major problem of agriculture in poor countries; see for example Schultz (1964), Ruttan and Hayami (1970), or Johnson (1997). This will reduce the measured TFP of capital and labor in agriculture. Second, inefficient distribution systems (including bad roads) have very much the same effect, as they tend to reduce the prices of agricultural outputs and increase the prices of intermediate inputs and capital, both at the farm gate [Herrendorf et al. (2006)]. Third, bad policies often reduce the relative employment in other sectors such as manufacturing [Parente and Prescott (1999)]. Since poor countries consume relatively few services and relative many agricultural goods, this tends to imply relatively large agricultural employment. Given the fixed factor land, this will reduce labor productivity in agriculture. Moreover, it will reduce the measured TFP of capital and labor in agriculture.[33]

6 Conclusion

In this paper, we have asked which sectors drive the aggregate TFP differences across countries. We have observed that the existing two–sector studies do not provide a conclusive answer and we have argued that we need to disaggregate further than is usually done. We have considered four sectors instead of two: services, consumption goods, construction, and equipment. Interacting the Penn World Tables with a four sector growth model, we have found that the cross–country TFP differences are very large in equipment, large in consumption goods, and fairly small in services. Moreover, we have found that the Penn World Tables do not contain enough information to make robust statements about TFP differences in construction. We have illustrated the usefulness of our findings by accounting for the conflicting findings of more aggregate two–sector studies and by evaluating the main theories of aggregate TFP disparity. We have concluded that bad policies, not bad institutions or low human capital endowments, are the main problem of poor countries. We are hopeful that this work will help future research to reach a consensus about what causes the international TFP disparity.

[33] Schultz (1953) called this the "food problem" of poor countries; see Gollin et al. (2006) for a recent restatement.

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Appendix A. Proofs

A.1 Household first–order conditions

Given there are no government expenditure, rebating taxes implies that lump–sum transfers are:

$$\Lambda_t = \frac{\tau_{st}}{1+\tau_{st}} P_{st} \left(x_{st} + \frac{x_{gt}}{\psi_g} + \frac{x_{et}}{\psi_e} \right) + \frac{\tau_{gt}}{1+\tau_{gt}} P_{gt} x_{gt} + \frac{\tau_{bt}}{1+\tau_{bt}} P_{bt} x_{bt} + \frac{\tau_{et}}{1+\tau_{et}} P_{et} x_{et}. \quad (9)$$

The total expenditure on consumption net of taxes are therefore equal to total income minus the expenditures on the investment goods:

$$\Omega_t \equiv \frac{1}{1+\tau_{st}} P_{st} x_{st} + \left(\frac{1}{1+\tau_{gt}} - \frac{\tau_s}{1+\tau_{st}} \frac{P_{st}}{P_{gt}\psi_g} \right) P_{gt} x_{gt} \quad (10a)$$

$$= r_{bt} k_{bt} + r_{et} k_{et} + w_t - \frac{1}{1+\tau_{bt}} P_{bt} x_{bt} - \left(\frac{1}{1+\tau_{et}} - \frac{\tau_s}{1+\tau_{st}} \frac{P_{st}}{P_{et}\psi_e} \right) P_{et} x_{et}. \quad (10b)$$

The first–order conditions to problem (6a) imply:

$$\frac{P_{st}}{P_{gt}} = \frac{\alpha}{1-\alpha} \frac{x_{gt} - \bar{x}_g}{x_{st}}, \quad (11a)$$

$$\frac{1}{P_{st}} \left(\frac{x_{gt} - \bar{x}_g}{x_{st}} \right)^{1-\alpha} = \beta \frac{1}{P_{st+1}} \left(\frac{x_{gt+1} - \bar{x}_g}{x_{st+1}} \right)^{1-\alpha} \frac{(1-\delta_e) P_{et+1} + r_{et+1}}{P_{et}}, \quad (11b)$$

$$\frac{(1-\delta_e) P_{et+1} + r_{et+1}}{P_{et}} = \frac{(1-\delta_b) P_{bt+1} + r_{bt+1}}{P_{bt}}. \quad (11c)$$

Solving (11a) for $P_{st} s_t$ yields

$$P_{st} x_{st} = \frac{\alpha}{1-\alpha} [P_{gt} x_{gt} - P_{gt} \bar{x}_g]$$

Substituting this into (10a) and rearranging, we get expressions that will prove useful when we compute the model:

$$P_{gt}x_{gt} = \frac{1-\alpha}{\frac{1-\alpha}{1+\tau_{gt}} + \frac{1}{1+\tau_{st}}\left(\alpha - (1-\alpha)\frac{P_{st}\tau_{st}}{P_{gt}\psi_g}\right)}\left(\Omega_t + P_{gt}\bar{x}_g \frac{\alpha}{1-\alpha}\frac{1}{1+\tau_{st}}\right), \tag{12a}$$

$$P_{st}x_{st} = \frac{\alpha}{\frac{1-\alpha}{1+\tau_{gt}} + \frac{1}{1+\tau_{st}}\left(\alpha - (1-\alpha)\frac{P_{st}\tau_{st}}{P_{gt}\psi_g}\right)}\left(\Omega_t + P_{gt}\bar{x}_g\left(\frac{1}{1+\tau_{st}}\frac{P_{st}\tau_{st}}{P_{gt}\psi_g} - \frac{1}{1+\tau_{gt}}\right)\right). \tag{12b}$$

A.2 Steady state prices and quantities

Step 1. Firms take *producer prices* p_i as given. Solving their maximization problems with respect to labor, buildings and equipment gives:

$$w = (1-\theta_i)p_iA_i\left(\frac{k_i}{l_i}\right)^{\theta_i}, \tag{13a}$$

$$r_b = \theta_i p_i A_i \left(\frac{k_i}{l_i}\right)^{\theta_i - 1}\mu^{\frac{1}{\sigma}}\left(\frac{k_i}{k_{bi}}\right)^{\frac{1}{\sigma}}, \tag{13b}$$

$$r_e = \theta_i p_i A_i \left(\frac{k_i}{l_i}\right)^{\theta_i - 1}(1-\mu)^{\frac{1}{\sigma}}\left(\frac{k_i}{k_{ei}}\right)^{\frac{1}{\sigma}}. \tag{13c}$$

Step 2. We express the two capital–labor ratios and the composite–capital–labor ratio as functions of the interest rates, which in steady state are readily computed from the Euler equations. (13b) and (13c) imply

$$\frac{k_{ei}}{k_{bi}} = \left(\frac{r_b}{r_e}\right)^{\sigma}\frac{1-\mu}{\mu}.$$

Substituting this into (7c) and rearranging leads to

$$\frac{r_b}{r} = \left(\mu\frac{k_i}{k_{bi}}\right)^{\frac{1}{\sigma}}, \tag{14a}$$

$$\frac{r_e}{r} = \left((1-\mu)\frac{k_i}{k_{ei}}\right)^{\frac{1}{\sigma}}, \tag{14b}$$

where

$$r \equiv \left[\mu r_b^{1-\sigma} + (1-\mu) r_e^{1-\sigma}\right]^{\frac{1}{1-\sigma}} . \tag{15}$$

Plugging (14a) into (13b), we obtain:

$$\frac{k_i}{l_i} = \left(\frac{\theta_i p_i A_i}{r}\right)^{\frac{1}{1-\theta_i}} . \tag{16a}$$

Substituting (16a) into (14a) and (14b) and rearranging leads to:

$$\frac{k_{bi}}{l_i} = \mu \left(\frac{r}{r_b}\right)^{\sigma} \left(\frac{\theta_i p_i A_i}{r}\right)^{\frac{1}{1-\theta_i}} , \tag{16b}$$

$$\frac{k_{ei}}{l_i} = (1-\mu) \left(\frac{r}{r_e}\right)^{\sigma} \left(\frac{\theta_i p_i A_i}{r}\right)^{\frac{1}{1-\theta_i}} . \tag{16c}$$

Step 3. We now derive the producer prices. Equation (13a) and (13b) together with (14a) imply that

$$\frac{1-\theta_e}{\theta_e}\frac{k_e}{l_e} = \frac{1-\theta_i}{\theta_i}\frac{k_i}{l_i}. \tag{17}$$

Plugging (16a) into (17) and using that $p_e = 1$, we obtain:

$$p_i = \frac{r}{\theta_i A_i} \left(\frac{\theta_e A_e}{r}\right)^{\frac{1-\theta_i}{1-\theta_e}} \left(\frac{1-\theta_e}{\theta_e}\frac{\theta_i}{1-\theta_i}\right)^{1-\theta_i} \tag{18}$$

for $i \in \mathcal{I}$.

This allows us to rewrite (16a)–(16c) into:

$$\frac{k_i}{l_i} = \frac{1-\theta_e}{\theta_e}\frac{\theta_i}{1-\theta_i} \left(\frac{\theta_e A_e}{r}\right)^{\frac{1}{1-\theta_e}} , \tag{19a}$$

$$\frac{k_{bi}}{l_i} = \mu \frac{1-\theta_e}{\theta_e}\frac{\theta_i}{1-\theta_i} \left(\frac{r}{r_b}\right)^{\sigma} \left(\frac{\theta_e A_e}{r}\right)^{\frac{1}{1-\theta_e}} , \tag{19b}$$

$$\frac{k_{ei}}{l_i} = (1-\mu) \frac{1-\theta_e}{\theta_e}\frac{\theta_i}{1-\theta_i} \left(\frac{r}{r_e}\right)^{\sigma} \left(\frac{\theta_e A_e}{r}\right)^{\frac{1}{1-\theta_e}} . \tag{19c}$$

It is important to point out that with this we expressed the capital-labor ratios as a function of parameters and purchase prices because (12a) and (12b) imply in the steady state that

$$r_e = \frac{1-\beta(1-\delta_e)}{\beta} P_e \tag{20a}$$

$$r_b = \frac{1-\beta(1-\delta_b)}{\beta} P_b, \tag{20b}$$

and (15) states that r depends on r_e and r_b.

Step 4. We now derive the purchase prices, which we denote by capital letters. They satisfy

$$P_s = p_s(1+\tau_s), \tag{21a}$$

$$P_b = p_b(1+\tau_b), \tag{21b}$$

$$P_g = \left(p_g + \frac{P_s}{\psi_g}\right)(1+\tau_g), \tag{21c}$$

$$P_e = \left(1 + \frac{P_s}{\psi_e}\right)(1+\tau_e). \tag{21d}$$

Combining these with (18) leads to

$$\frac{P_s}{1+\tau_s} = \frac{r}{\theta_s A_s}\left(\frac{\theta_e A_e}{r}\right)^{\frac{1-\theta_s}{1-\theta_e}}\left(\frac{1-\theta_e}{\theta_e}\frac{\theta_s}{1-\theta_s}\right)^{1-\theta_s}, \tag{22a}$$

$$\frac{P_b}{1+\tau_b} = \frac{r}{\theta_b A_b}\left(\frac{\theta_e A_e}{r}\right)^{\frac{1-\theta_b}{1-\theta_e}}\left(\frac{1-\theta_e}{\theta_e}\frac{\theta_b}{1-\theta_b}\right)^{1-\theta_b}, \tag{22b}$$

$$\frac{P_g}{1+\tau_g} = \frac{r}{\theta_g A_g}\left(\frac{\theta_e A_e}{r}\right)^{\frac{1-\theta_g}{1-\theta_e}}\left(\frac{1-\theta_e}{\theta_e}\frac{\theta_g}{1-\theta_g}\right)^{1-\theta_g} + \frac{P_s}{\psi_g}, \tag{22c}$$

$$\frac{P_e}{1+\tau_e} = 1 + \frac{P_s}{\psi_e}. \tag{22d}$$

Step 5. Next, we determine l_i by using market clearing. Note that so far we did not use any steady state conditions, but we will now. The market clearing conditions in steady state are

$$
\begin{aligned}
\sum_{i\in\mathcal{I}} l_i &= 1,\\
\delta_e \sum_{i\in\mathcal{I}} \left(\frac{k_{ei}}{l_i}\right) l_i &= A_e \left(\frac{k_e}{l_e}\right)^{\theta_e} l_e,\\
\delta_b \sum_{i\in\mathcal{I}} \left(\frac{k_{bi}}{l_i}\right) l_i &= A_b \left(\frac{k_b}{l_b}\right)^{\theta_b} l_b,\\
\frac{1}{P_{gt}} \frac{(1-\alpha)\left(\Omega_t + \frac{\alpha}{1-\alpha}\frac{P_{gt}\bar{x}_g}{1+\tau_{st}}\right)}{\frac{1-\alpha}{1+\tau_{gt}} + \frac{1}{1+\tau_{st}}\left(\alpha - (1-\alpha)\frac{P_{st}\tau_{st}}{P_{gt}\psi_g}\right)} &= A_g \left(\frac{k_g}{l_g}\right)^{\theta_g} l_g.
\end{aligned}
$$

where Ω is the steady state version of (10b)

$$
\Omega = \left(r_b - \frac{P_b\delta_b}{1+\tau_b}\right)\sum_{i\in\mathcal{I}} k_{bi} + \left(r_e - \frac{P_e\delta_e}{1+\tau_e} + \frac{\tau_s P_s \delta_e}{(1+\tau_s)\psi_e}\right)\sum_{i\in\mathcal{I}} k_{ei} + w
$$

with

$$
\begin{aligned}
\sum_{i\in\mathcal{I}} k_{ei} &= \frac{A_e}{\delta_e}\left(\frac{k_e}{l_e}\right)^{\theta_e} l_e,\\
\sum_{i\in\mathcal{I}} k_{bi} &= \frac{A_b}{\delta_b}\left(\frac{k_b}{l_b}\right)^{\theta_b} l_b.
\end{aligned}
$$

The equilibrium conditions can be turned into a linear system of equations.

$$
\begin{aligned}
&1 = l_e + l_b + l_g + l_s,\\
&A_e\left(\frac{k_e}{l_e}\right)^{\theta_e} l_e = \delta_e\left(\frac{k_{ee}}{l_e}\right) l_e + \delta_e\left(\frac{k_{eb}}{l_b}\right) l_b + \delta_e\left(\frac{k_{eg}}{l_g}\right) l_g + \delta_e\left(\frac{k_{es}}{l_s}\right) l_s,\\
&A_b\left(\frac{k_b}{l_b}\right)^{\theta_b} l_b = \delta_b\left(\frac{k_{be}}{l_e}\right) l_e + \delta_b\left(\frac{k_{bb}}{l_b}\right) l_b + \delta_b\left(\frac{k_{bg}}{l_g}\right) l_g + \delta_b\left(\frac{k_{bs}}{l_s}\right) l_s,\\
&A_g\left(\frac{k_g}{l_g}\right)^{\theta_g} l_g = \frac{1}{P_g}\frac{1-\alpha}{\frac{1-\alpha}{1+\tau_{gt}} + \frac{1}{1+\tau_{st}}\left(\alpha-(1-\alpha)\frac{P_{st}\tau_{st}}{P_{gt}\psi_g}\right)}\left[\left(r_b - \frac{P_b\delta_b}{1+\tau_b}\right)\frac{A_b}{\delta_b}\left(\frac{k_b}{l_b}\right)^{\theta_b} l_b\right.\\
&\quad\left. + \left(r_e - \frac{P_e\delta_e}{1+\tau_e} + \frac{\tau_s P_s\delta_e}{(1+\tau_s)\psi_e}\right)\frac{A_e}{\delta_e}\left(\frac{k_e}{l_e}\right)^{\theta_e} l_e + (1-\theta_e)A_e\left(\frac{k_e}{l_e}\right)^{\theta_e} + \frac{\alpha}{1-\alpha}\frac{P_g\bar{x}_g}{1+\tau_{st}}\right].
\end{aligned}
$$

We can solve this system of linear equation for the allocation of labor. Since the capital-labor ratios are the functions of the real interest are, purchase prices and parameters, the labor allocation is a function of real interest are, purchase prices and parameters, and taxes. We use this to express the quantities consumed and invested as the function of the same variables. We use these functions in the calibration where for the purchase prices we substitute the observed once.

Appendix B. Data

Appendix B.1 Data description and measurement

The benchmark study of the Penn World Tables 1996 (PWT96) has 115 countries and 31 goods categories. We exclude all countries with less one million inhabitants, namely Antigua and Barbuda, Bahamas, Bahrain, Barbados, Belize, Bermuda, Dominica, Fiji, Grenada, Iceland, Luxembourg, Qatar, Swaziland, St. Kitts and Nevis, St. Lucia, St. Vincent and Grenadines. Moreover, we exclude Mongolia because it reports zero equipment investment. This leaves 98 countries, which in this appendix we index by $j \in \{1, ..., 98\}$.

Appendix B.1.1 Goods categories and countries

We aggregate the 30 goods categories into four aggregate categories: services, construction, consumption goods, and equipment investment. We denote the sets of goods in each of these four aggregate categories by $(\mathcal{G}_s, \mathcal{G}_b, \mathcal{G}_g, \mathcal{G}_e)$, the quantities by $x^j = (x^j_s, x^j_b, x^j_g, x^j_e)$, and the prices in domestic currency by $\widetilde{p}^j = (\widetilde{p}^j_s, \widetilde{p}^j_b, \widetilde{p}^j_g, \widetilde{p}^j_e)$.[34] Quantities are in international prices, as reported by the PWT96 in Input–Table 4.5. They are aggregated by adding them up. Put differently, expressing quantities in international prices is a transformation of units such that the new international prices are ones: $\pi = (1, 1, 1, 1)$.

We now describe how we aggregate the 30 data categories into our four model cat-

[34]Note that we normalize $\widetilde{p}^j_e = 1$ in the model. It is convenient not to do this yet at this point.

egories. We set the model–category nontradable investment equal to the data–category construction. We set the model–category tradable investments equal to the data–categories personal transportation equipment and machinery/equipment. Changes in stocks contain both tradable and nontradable parts. We split this category by assuming that its nontradable share equals the share of construction in investment without changes of stocks.

We continue with the model categories tradable and nontradable consumption. We set the model–category nontradable consumption equal to the data categories gross rent and water charges, medical and health services, transportation, communication, recreation and culture, education, restaurants/cafes and hotels. We set the model–category tradable consumption equal to the data–categories food, beverages, tobacco, clothing and footwear, fuel and power, furniture and floor coverings, other household goods, household appliances and repairs. The data–category other goods and services contains both tradable and nontradable parts. We split it by assuming that its nontradable share equals the share of the nontradable consumption goods assigned thus far in all consumption goods assigned thus far.

We use average statistics from the Latin American and the twenty poorest countries in the PWT96. The Latin American countries of our sample are Bolivia, Ecuador, Peru, Panama, Venezuela, Mexico, Brazil, Chile, Uruguay, and Argentina. The twenty poorest countries of our sample are Tanzania, Malawi, Yemen, Madagascar, Zambia, Mali, Tajikistan, Nigeria, Benin, Sierra Leone, Kenya, Congo, Bangladesh, Nepal, Senegal, Vietnam, Pakistan, Cote d'Ivoire, Cameroon, and Moldova. Both sets of countries are reported here in the order of increasing real GDPs per capita.

Appendix B.1.2 Definitions of statistics used

We first describe how to aggregate within a country. Total expenditures on all 30 categories in country $j \in \{1, ..., 98\}$ can be expressed either in domestic or in international prices:

$$\widetilde{\boldsymbol{p}}^j \cdot \boldsymbol{x}^j \equiv \sum_{i=1}^{30} \widetilde{p}_i^j x_i^j,$$
$$\boldsymbol{\pi} \cdot \boldsymbol{x}^j \equiv \sum_{i=1}^{30} \pi_i x_i^j.$$

The PWT96 refer to $\widetilde{p}_i^j x_i^j$ as expenditure in national currency (Input–data 4.1) and to $\pi_i x_i^j$ as quantities in international dollars (Input–data 4.5).

Since our model economy does not have borrowing and lending, in the model these expenditure must equal GDP. This is not the case in the PWT96 where GDP in domestic and in international prices are defined as:

$$GDP^j(\widetilde{\boldsymbol{p}}^j) \equiv \widetilde{\boldsymbol{p}}^j \cdot \boldsymbol{x}^j + NFB^j(\widetilde{\boldsymbol{p}}^j),$$
$$GDP^j(\boldsymbol{\pi}) \equiv \boldsymbol{\pi} \cdot \boldsymbol{x}^j + NFB^j(\boldsymbol{\pi}).$$

NFB^j stands for net foreign balance.

Within country j, the prices of each of the four model categories $i \in \{s, g, b, e\}$ are the ratios of the expenditures in domestic currency and quantities in international prices in that category:

$$\widetilde{p}_i^j = \frac{\sum_{\iota \in \mathcal{G}_i} \widetilde{p}_\iota^j x_\iota^j}{\sum_{\iota \in \mathcal{G}_i} \pi_\iota x_\iota^j}.$$

Note that given quantities in international \$s, the price can also be written as the weighted average of the prices of all elements in that category where the relative weights are the relative quantities in international \$s:

$$\widetilde{p}_i^j = \sum_{\iota \in \mathcal{G}_i} \left(\frac{\pi_\iota x_\iota^j}{\sum_{\nu \in \mathcal{G}_i} \pi_\nu x_\nu^j} \right) \frac{\widetilde{p}_\iota^j}{\pi_\iota}.$$

The relative prices are:

$$p_i^j \equiv \frac{\widetilde{p}_i^j}{\widetilde{p}_e^j}.$$

We now explain how we aggregate across countries. Let $\mathcal{C}^{LA}$ and $\mathcal{C}^{PC}$ denote the individual countries in the two subgroups. The average construction and equipment investment shares in international prices in one of the two subgroups of countries are easy to find because we can still add quantities in international prices from different countries. So, for $i \in \{b, e\}$ and $j \in \{LA, PC\}$:

$$\frac{\pi_i^j x_i^j}{\boldsymbol{\pi}^j \cdot \boldsymbol{x}^j} \equiv \frac{\sum_{\iota \in \mathcal{C}^j} \pi_i x_i^\iota}{\sum_{\iota \in \mathcal{C}^j} \boldsymbol{\pi} \cdot \boldsymbol{x}^\iota}.$$

The methodology underlying the PWT96 does not imply how to aggregate variables across countries when the variables are in domestic prices. Since we cannot add up variables that are in different units, we aggregate only unit–free variables such as ratios or relative prices. For quantity ratios we use arithmetic averages because they add up to one (but are not transitive), whereas for relative prices we use geometric averages because they are transitive. For $i \in \{b, e\}$ and $j \in \{LA, PC\}$ the average construction and equipment shares in domestic prices are:

$$\frac{p_i^j x_i^j}{\boldsymbol{p}^j \cdot \boldsymbol{x}^j} \equiv \sum_{\iota \in \mathcal{C}^j} \left(\frac{\boldsymbol{\pi}^\iota \cdot \boldsymbol{x}^\iota}{\sum_{\nu \in \mathcal{C}^j} \boldsymbol{\pi}^\nu \cdot \boldsymbol{x}^\nu} \right) \frac{p_i^\iota x_i^\iota}{\boldsymbol{p}^\iota \cdot \boldsymbol{x}^\iota}.$$

The average service share in consumption expenditure in domestic prices is:

$$\frac{p_s^j x_s^j}{p_s^j x_s^j + p_g^j x_g^j} \equiv \sum_{\iota \in \mathcal{C}^j} \left(\frac{\pi_s x_s^\iota + \pi_g x_g^\iota}{\sum_{\nu \in \mathcal{C}^j} \pi_s x_s^\nu + \pi_g x_g^\nu} \right) \frac{p_s^\iota x_s^\iota}{p_s^\iota x_s^\iota + p_g^\iota x_g^\iota}.$$

The average relative price for good $i \in \{s, g, b\}$ is:

$$p_i^j \equiv \exp \left(\sum_{\iota \in \mathcal{C}^j} \left(\frac{\pi^\iota \cdot x^\iota}{\sum_{\nu \in \mathcal{C}} \boldsymbol{\pi}^\nu \cdot \boldsymbol{x}^\nu} \right) \ln(p_i^\iota) \right).$$

Here, we use relative GDPs (and not relative expenditure on category i) as the weights because that preserves transitivity.

Appendix B.2 Calculating sector capital shares

Appendix B.2.1 Capital shares for each industry

To calculate the capital shares for the sectors of our model, we first determine how to split the value added in each industries into capital and labor income. Then we aggregate the industries to the four sectors of our model. Finally, we calculate the capital shares of the four sectors.

We use the 1997 benchmark Input–Output Tables (IO Tables) for the U.S. from the Bureau of Economic Analysis (BEA). They report the value added of each industry as the sum of the compensation of employees, indirect business tax and nontax liabilities, and other value added. Other value added is also called gross operating surplus. It mostly contains capital income, but one of its components, "Other gross operating surplus – noncorporate" (or "proprietors' income"), contains also labor income. Since we do not have information about how much labor income is contained in proprietors' income, we assume that its share equals the industry–wide average share of labor income. Thus, we calculate the payments to capital and labor in industry i as:

$$V_{il} \equiv COMP_i + \frac{COMP_i}{COMP_i + GOS_i - OGOSN_i} OGOSN_i, \tag{26a}$$

$$V_{ik} \equiv GOS_i - \frac{COMP_i}{COMP_i + GOS_i - OGOSN_i} OGOSN_i. \tag{26b}$$

$COMP_i$ stands for compensation of employees, GOS_i for operating surplus (or other value added), and $OGOSN_i$ for other gross operating surplus – noncorporate.

The IO–tables report $COMP_i$ and GOS_i but not $OGOSN_i$. We use the BEA's "GDP–by–Industry" data to estimate $OGOSN_i$, which is available for 1998–2003. A minor complication is that the "GDP–by–Industry" Data is at the three–digit level whereas the benchmark IO Tables are at the four–digit level. We deal with this as follows. Let j be an industry index at the three digit level and i_j be an industry index at the four digit level such that the four–digit industry i is part of the three–digit industry j. First, we calculate the time average of $(OGOSN/GOS)_j$ for each industry j. Then, we assume that $OGOSN_{i_j}/GOS_{i_j} = (OGOSN/GOS)_j$ for each i_j and estimate $OGOSN_{i_j}$ as

$$OGOSN_{i_j} = GOS_{i_j} \left(\frac{OGOSN}{GOS} \right)_j .$$

Appendix B.2.2 Capital shares for model sectors

We now explain our aggregation procedure in two steps. We first describe how one can calculate the capital and labor share of a particular type of final expenditure. We then explain how to construct the four final expenditure categories that corresponds to the four sector of our model.

The IO–tables of BEA comes with a "use" and a "make" matrix. Let $\boldsymbol{B}$ be the $(m \times n)$ "use" matrix. Entries in each column show the amount of a commodity used by an industry per unit of output of that industry. Let $\boldsymbol{D}$ be the $(n \times m)$ "make" matrix. Entries in each column show, for a given commodity, the proportion of the total output of that commodity produced in each industry.[35]

Let $\mathbf{1}$ be a column vector with all of its elements equal 1. Its size may vary from formula to formula so as to ensure that the matrix operation is well defined. Now we have the following identities:

$$\boldsymbol{q} = \boldsymbol{B}\boldsymbol{g} + \boldsymbol{E}\mathbf{1}, \tag{27a}$$

$$\boldsymbol{g} = \boldsymbol{D}\boldsymbol{q}, \tag{27b}$$

where $\boldsymbol{q}$ is the $(m \times 1)$ commodity output vector, $\boldsymbol{g}$ is the $(n \times 1)$ industry output vector, and $\boldsymbol{E}$ is the $(m \times k)$ vector of final expenditures where k is the number of different types of final expenditures. We can write $\boldsymbol{e} = \boldsymbol{E}\mathbf{1}$ for the GDP vector.

[35] We use the notation of the BEA.

Combining the first and the second identity leads to:

$$\boldsymbol{g} = \boldsymbol{D}(\boldsymbol{I} - \boldsymbol{B}\boldsymbol{D})^{-1}\boldsymbol{e}, \tag{28}$$

where $\boldsymbol{I}$ is the identity matrix. The BEA calls $\boldsymbol{D}(\boldsymbol{I}-\boldsymbol{B}\boldsymbol{D})^{-1}$ the *industry–by–commodity total requirements* matrix. It shows the industry output required per unit delivered to final users. In particular, element z_{ij} of the total requirements matrix shows how much output of industry j is required to deliver one unit of commodity i to final users. Note that z_{ij} does not only include the direct effect of final expenditure on industry output, but also all direct and indirect effects from other industries. Hence the name total requirement matrix. Consequently, vector $\boldsymbol{z}_i$ shows how much industry output has to be produced so that one unit of commodity i can be sold to final expenditure.

Let g_i be the i–th element of $\boldsymbol{g}$, thus the output of industry i. Moreover, let $\boldsymbol{v}_l' = (V_{il}/g_i)$ and $\boldsymbol{v}_k' = (V_{ik}/g_i)$ be the $(1 \times m)$ row vectors of labor and capital income shares in industry output where V_{il} and V_{ik} have been calculated according to (26). Then the labor and capital incomes associated with GDP vector $\boldsymbol{e}$ are defined as

$$\begin{bmatrix} v_l \\ v_k \end{bmatrix} = \begin{bmatrix} \boldsymbol{v}_l' \\ \boldsymbol{v}_k' \end{bmatrix} \boldsymbol{D}(\boldsymbol{I} - \boldsymbol{B}\boldsymbol{D})^{-1}\boldsymbol{e}.$$

This can be used to calculate the capital share for GDP.

The same principle can be used to calculate the capital and labor incomes associated with any final expenditure vector. This is because the total requirements matrix can be multiplied by any expenditure vector to calculate the industry output requirement to sell that final expenditure vector. Note the we do not need to calculate $\boldsymbol{D}(\boldsymbol{I} - \boldsymbol{B}\boldsymbol{D})^{-1}$ because the BEA publishes all total requirements matrices. In our calculations we used the industry-by-commodity total requirements matrix.

Now we describe how we construct the four sectors corresponding to our model. We first aggregate final expenditures excluding net exports into consumption and investment. The sale of commodity i to final consumption is made up by personal and government consumption expenditures. The sale of commodity i to final investment expenditures is made up by private and government fixed investment expenditures plus changes in private inventories. In addition, we classify the sale of transportation equipment (three digit NAICS code 336) and the sale of commodities in construction (two digit NAICS code 23) as investments. Finally, we assume that the consumption and investment shares in net exports equal the industry wide average. This procedure leads to consumption and investment commodity vectors $\boldsymbol{x}_C$ and $\boldsymbol{x}_I$ that add up to the GDP vector.

Next, we classify each commodity as tradable or non-tradable. We classify all commodities sold to investment as tradable except for construction commodities, which we classify as non-tradable investment. We classify all commodities sold to consumption with a three digit NAICS code higher or equal to 420 as non-tradable. This includes all industries which are producing commodities traditionally viewed as services. In addition, we classify all commodities with the two–digit NAICS code 22 sold to consumption as non-tradable. These are the utilities (distribution of electric power, natural gas and water). Finally, we classify government services as non-tradables.

This procedure defines four final expenditure vectors nontradable services $\boldsymbol{x}_s$, non-tradable construction $\boldsymbol{x}_b$, tradable goods $\boldsymbol{x}_g$, and tradable equipment $\boldsymbol{x}_e$. These vectors satisfy $\boldsymbol{x}_C = \boldsymbol{x}_s + \boldsymbol{x}_g$, $\boldsymbol{x}_I = \boldsymbol{x}_e + \boldsymbol{x}_b$, and $\boldsymbol{x}_C + \boldsymbol{x}_I = \boldsymbol{e}$ with $\boldsymbol{1'e} = GDP$ where $\boldsymbol{1'}$ is a row vector. The capital and labor incomes of the four final expenditure vectors are now easily calculated:

$$\begin{bmatrix} v_{ls} & v_{lb} & v_{lg} & v_{le} \\ v_{ks} & v_{kb} & v_{kg} & v_{ke} \end{bmatrix} = \begin{bmatrix} \boldsymbol{v}_l' \\ \boldsymbol{v}_k' \end{bmatrix} \boldsymbol{D}(\boldsymbol{I} - \boldsymbol{BD})^{-1}[\boldsymbol{x}_s, \boldsymbol{x}_b, \boldsymbol{x}_g, \boldsymbol{x}_e]. \tag{29}$$

Given this, we can calculate the capital share for final expenditure category i as $v_{ki}/(v_{ki} + v_{li})$.

Appendix B.3 Computing the model

We can calibrate some parameters directly. We start with the sector TFPs in the U.S. To calculate them, we use that without taxes the equilibrium purchase price of equipment must satisfy:

$$P_e^{US} = 1 + \frac{P_s^{US}}{\psi_e}.$$

Rearranging this, we obtain:

$$P_e^{US} = \frac{\psi_e}{\psi_e - (P_s^{US}/P_e^{US})}.$$

Since we have already calculated ψ_e and since P_s^{US}/P_e^{US} is observable, this uniquely pins down P_e^{US}. Given we observe P_i^{US}/P_e^{US} for $i \in \{s, b, g\}$, we can now calculate the other three purchase prices. Moreover, in equilibrium the purchase price of consumption goods must satisfy:

$$P_g^{US} = p_g^* + \frac{P_s^{US}}{\psi_g}.$$

Using the purchase prices just calculated and the value of ψ_g, this implies the value of p_g^*. Since $A_e^{US}/A_g^{US} = 1/A_g^{US} = p_g^*$ and $A_i^{US}/A_g^{US} = P_i^{US}/p_g^*$ for $i \in \{s, b\}$, this also pins down A_g^{US} and A_s^{US}, A_b^{US} (3 parameters and 3 statistics).

We continue with Latin America and the Poorest Countries, so $j \in \{LA, PC\}$. We know that $A_e^j/A_g^j = p_g^*$ (2 parameters). Using the restriction $P_e^{US} = P_e^j$ and the observed relative purchase prices, we can calculate the purchase prices. Since

$$P_e^j = (1 + \tau_e^j)\left(1 + \frac{P_s^j}{\psi_e}\right), \tag{30a}$$

$$P_g^j = (1 + \tau_g^j)\left(p_g^* + \frac{P_s^j}{\psi_g}\right), \tag{30b}$$

this pins down the values of τ_g^j, τ_e^j (6 parameters and 8 statistics).

At this point, we are left with 15 parameters. We calibrate them jointly by minimizing the squared percentage deviations of the model statistics from the following 17 observed statistics of the PWT96: the U.S. over the other two per–capita GDPs in international prices (2 statistics), the 4 investment shares of buildings and equipment in domestic prices and international prices in each country (12 statistics), and the shares of services in consumption expenditure in each country (3 statistics).

Appendix C. Figures

Figure 14: Relative Purchase Prices

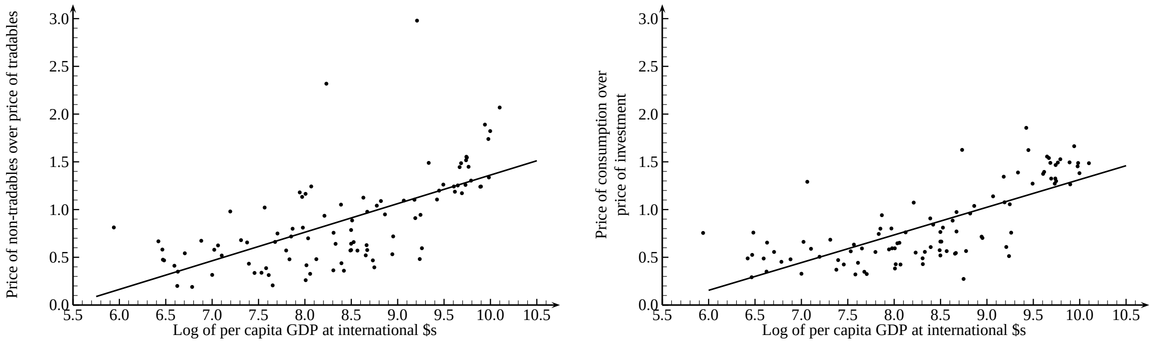

Figure 15: Construction–investment shares

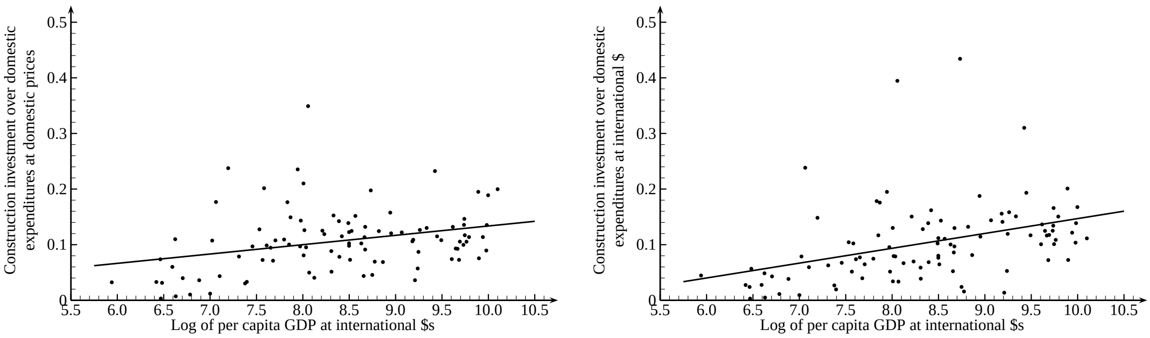

Figure 16: Equipment–investment shares

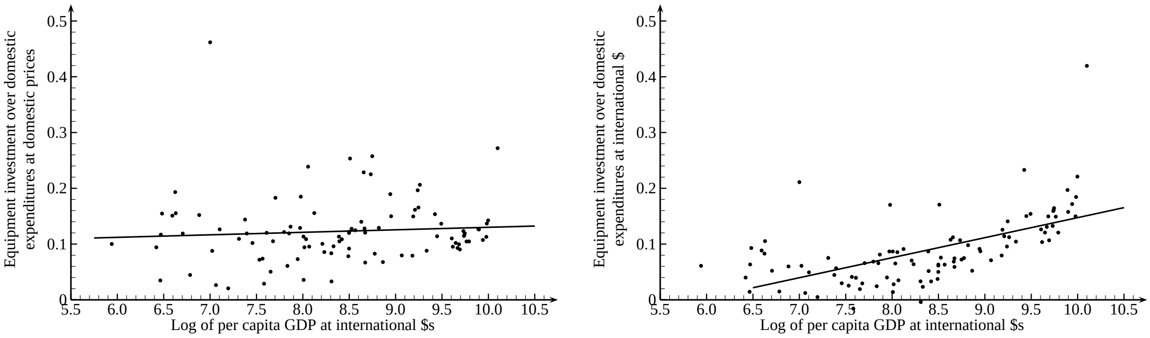

Figure 17: Services shares in consumption expenditure at domestic prices

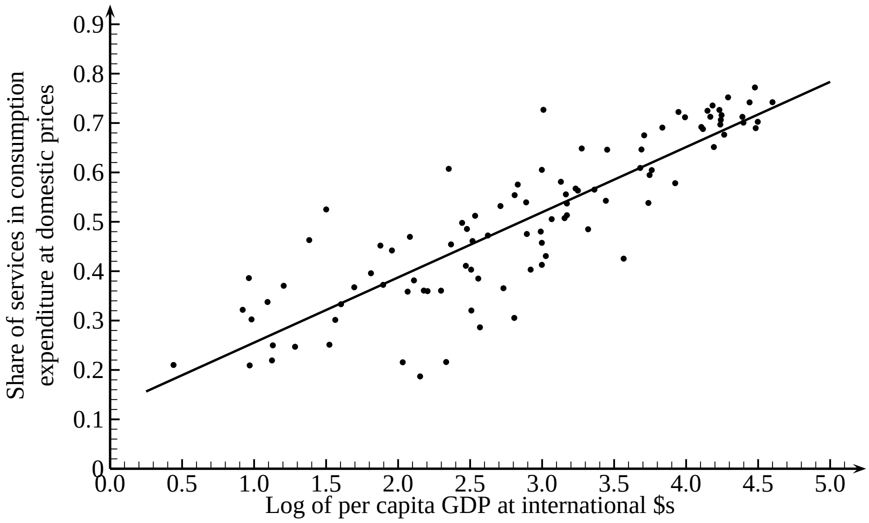

Figure 18: Purchase Prices of Equipment in U.S. $s