Which Sectors Make Poor Countries So Unproductive?*

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Abstract

Which sectors are most responsible for the low total factor productivities of developing countries? To answer this question we develop a new framework for sectoral development accounting. Applying this framework to the Penn World Table, we find that in equipment, construction, and food the sectoral TFP differences between developing countries and the United States are much larger than in the aggregate. However, in manufactured consumption the sectoral TFP differences are about equal to the aggregate TFP differences, and in services they are much smaller. We show that our level of disaggregation allows us to reconcile the results of existing studies of sectoral productivity differences, which have focused on noncomparable two-sector decompositions of the aggregate data. We also show that our results help shed light on existing theories of aggregate TFP differences.

Keywords: sectoral development accounting; sectoral TFPs; relative prices
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1 Introduction

A major question in economics is why gross domestic product (GDP) per worker differs so much across countries. Development accounting studies find that differences in total factor productivity (TFP) account for a considerable part of the differences in GDP.[1] This suggests that we need to understand why TFP differs so much across countries. In this paper we ask which sectors are most responsible for the low TFP of developing countries. We argue that the answer to this question is not only interesting in its own right but also sheds light on existing theories of aggregate TFP.

The existing literature decomposes the aggregate economy into different, noncomparable two-sector splits. For example, international trade theorists think in terms of tradables and nontradables; thus Balassa (1964) and Samuelson (1964) conjectured that the cross–country differences in labor productivity are much larger in tradable than in nontradable sectors. In contrast, development economists tend to decompose the economy into agriculture and nonagriculture, and cross-country differences in agricultural labor productivity turn out to be much larger than in nonagriculture.[2] Lastly, growth theorists find it natural to think about capital accumulation and differences in investment rates across countries, so they focus on consumption and investment goods. In this tradition, Hsieh and Klenow (2007) found that cross-country TFP differences in investment are much larger than in consumption.

We argue that the existing two-sector studies have not reached a consensus because they are not sufficiently disaggregated. Instead of two, we consider the following five sectors: food, manufactured consumption, services, equipment, and construction. As Table 1 illustrates, these five sectors naturally aggregate to the different two-sector decompositions considered in the literature. In particular, tradables consist of food, manufactured consumption, and equipment while nontradables consist of services and construction. Moreover, food is closely related to agriculture, and the aggregate of the other four sectors is closely related to nonagriculture. Lastly, consumption consists of food, manufactured consumption, and services while investment consists of equipment and construction.

The main challenge in measuring sectoral TFPs is that the available data is limited. As

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

[2]One of the classic references is Kuznets (1971).

Table 1: Different Ways of Slicing the Data

	Tradables	Nontradables
Consumption	food, manufactured consumption	services
Investment	equipment	construction
Food	food	
Nonfood	manufactured consumption, equipment	services, construction

of now, the Penn World Table is the only broad source of comparable cross-country data that includes information on both developed and developing countries. We will use the benchmark study from 1996 (PWT96), which reports final expenditures, prices, and quantities for 30 categories in about a hundred countries. What is missing for our purposes is information on the production factors (i.e., physical capital, human capital, and land) at the sectoral level.

A methodological contribution of our paper is the derivation of a development accounting framework at the sectoral level that allows us to calculate sectoral TFPs from the available data. We make three key assumptions. First, markets are competitive – as in the classic growth accounting exercise of Solow (1957). Second, production factors are mobile across the sectors of each economy, as in many multisector growth models (see e.g. Hsieh and Klenow 2007). Third, sectoral production functions are Cobb–Douglas with factor shares that are common to all countries. This is in the spirit of Hall and Jones (1999), who assumed that the aggregate production functions are Cobb–Douglas with equal factor shares in all countries. We show that, under these three assumptions, we can calculate sectoral TFPs from the available data on sectoral outputs, prices, and factor shares and from the available data on aggregate quantities of the production factors: physical capital, human capital, and land.

We find that the TFP disparity in equipment, construction, and food is larger than the aggregate TFP disparity. In contrast, the TFP disparity in manufactured consumption is about equal to the aggregate TFP disparity, and the TFP disparity in services is smaller than the aggregate TFP disparity. We also find that the disparities in sectoral TFPs are driven mainly by differences in relative prices. In contrast, differences in sectoral capital intensities seem to have little role in sectoral TFP disparity across countries.

We illustrate the usefulness of these results by showing that we can reconcile the results from existing two-sector studies when we aggregate our five sectors into different two-sector decompositions. In particular, if we aggregate as tradables versus nontradables, then tradables come out as the sector with the larger TFP disparity across countries. If we aggregate as food versus nonfood, then food has the larger TFP disparity. If we aggregate as investment versus consumption, then investment has the larger TFP disparity.

We take the view that a successful theory of aggregate TFP disparity across countries ought to be consistent with the patterns of TFP disparity at the sectoral level. Existing theories attribute the disparity in aggregate TFP to cross-country differences in human capital and policies. This raises the question of why these differences should affect equipment, construction, and food so much more than the other two sectors. We argue that this question poses more of a challenge for theories that emphasize the effects of low human capital than for theories that emphasize the effects of bad policies.

Our work is related to that of Hsieh and Klenow (2007), who asked why developing countries have lower investment rates than developed countries. Using the Penn World Table, the authors found that developing countries have particularly low TFPs in producing investment goods. Although our results regarding to the consumption–investment split are consistent with those of Hsieh and Klenow, we go beyond their analysis. In particular, we show that our level of disaggregation allows us to reconcile the results of other two-sector studies of sectoral productivity differences and to shed light on existing theories of aggregate TFP disparity.

There are also noteworthy methodological differences between Hsieh and Klenow (2007) and our study. To begin with, whereas they developed a fully specified growth model and assumed that all countries are in a steady state, our approach is more in the tradition of growth and development accounting; hence we neither specify the household side of the economy nor assume that countries are in steady state. Not imposing steady state has the advantage of enabling our approach to work for countries that are far away from their steady states (e.g., those exhibiting "growth miracles"). A second distinct feature of our approach is that we consider the implications of cross-country differences in human capital and land in addition to cross-country differences in physical capital. An interesting implication is that mismeasurement of cross-country differences in human capital does not appear to be driving the measured TFP differences.

2 Development Accounting at the Sectoral Level

2.1 Preliminaries

If we could observe production data at the sectoral level, then it would be straightforward to calculate sectoral TFPs. In particular: given observations on output, the production factors, and the factor shares at the sectoral level, all we would need for such a calculation is the common assumption that sectoral production functions are of the Cobb–Douglas form. However, instead of *production* data, the PWT96 reports *final expenditure* data. Therefore, we are missing information on the sectoral production factors.

At first sight, one might suppose we could obtain some of the missing information from other data sources. An obvious possibility is EUKLEMS, which has internationally comparable input and output data at the sectoral level for Australia, European countries, Japan, Korea, and the United States. Although this is useful in principle, EUKLEMS data are in terms of value added; thus it is not obvious how to connect such data with the final–expenditure data from the PWT96. We discussed the relationship between value added data and final–expenditure data in Herrendorf et al. (2009a), where we concluded that connecting final–expenditure data with value added data requires detailed information about the input–output structure of the economy. Unfortunately, the PWT96 does not include this information.[3]

Here we specify a development accounting framework at the sectoral level; it maps the observed expenditure data to the unobserved production factors. Our accounting framework implies that the unobserved production factors are functions of the observed sectoral outputs, prices, and factor shares. This follows from our three key assumptions: markets are competitive, production factors are mobile across the sectors of each economy, and the sectoral production functions are Cobb–Douglas with factor shares that are common to all countries.

[3]One might also think that the McKinsey Studies provide additional information that could be useful here; see Lewis (2004) for a summary. However, the same point as the one we made for EUKLEMS applies, and in any case the data underlying the McKinsey Studies are not publicly available.

2.2 Framework

There are Z countries indexed by $z \in \mathcal{Z} \equiv \{1, ..., Z\}$. In country z there are five final goods: food y_f^z, manufactured consumption y_m^z, services y_s^z, equipment y_e^z, and construction y_c^z.[4] We index the final goods by $i \in \mathcal{I} \equiv \{f, m, s, e, c\}$.

The production functions for the final goods are given by

$$y_i^z = A_i^z (k_i^z)^{\theta_i} (l_i^z)^{\phi_i} (h_i^z)^{1-\theta_i-\phi_i}. \tag{1}$$

Here A_i^z is sectoral TFP and $\theta_i, \phi_i \in (0, 1)$ are the sectoral shares of (reproducible) physical capital and land; y_i^z, k_i^z, l_i^z, and h_i^z are (respectively) sectoral output, physical capital, land, and labor. All variables are in per-worker terms, and labor is measured in efficiency units. Note the assumption that sectoral TFPs are country specific whereas sectoral factor shares are common to all countries. This assumption is standard in development accounting.

There are competitive markets for renting the production factors and for selling the final goods. We choose equipment as the numéraire and denote by p_i^z the price of goods i in country z relative to equipment in country z. Competition implies that, in each sector, the production costs are minimized while taking as given the quantity of sectoral output, the relative price of sectoral output, and the rental rates for the production factors. The first-order conditions give the standard result that, for each production factor, the marginal value products are equalized across the sectors of country z:

$$\theta_i p_i^z \frac{y_i^z}{k_i^z} = \theta_j p_j^z \frac{y_j^z}{k_j^z}, \tag{2}$$

$$\phi_i p_i^z \frac{y_i^z}{l_i^z} = \phi_j p_j^z \frac{y_j^z}{l_j^z}, \tag{3}$$

$$(1 - \theta_i - \phi_i) p_i^z \frac{y_i^z}{h_i^z} = (1 - \theta_j - \phi_j) p_j^z \frac{y_j^z}{h_j^z}. \tag{4}$$

[4] Some authors use the terms "structures and residential housing" instead of construction and "machinery and equipment" instead of equipment.

Rearranging and summing over all j, we obtain

$$k_i^z = \frac{\theta_i p_i^z y_i^z}{\sum_{j \in \mathcal{I}} \theta_j p_j^z y_j^z} \sum_{i \in \mathcal{I}} k_i^z, \tag{5}$$

$$l_i^z = \frac{\phi_i p_i^z y_i^z}{\sum_{j \in \mathcal{I}} \phi_j p_j^z y_j^z} \sum_{i \in \mathcal{I}} l_i^z, \tag{6}$$

$$h_i^z = \frac{(1 - \theta_i - \phi_i) p_i^z y_i^z}{\sum_{j \in \mathcal{I}} (1 - \theta_j - \phi_j) p_j^z y_j^z} \sum_{i \in \mathcal{I}} h_i^z. \tag{7}$$

Equation (5) states that, in country z, sector i's share in aggregate capital equals sector i's share in aggregate capital income. Equations (6) and (7) make analogous statements for land and labor. Given observations on the variables on the right-hand side of these three equations, we can calculate the sectoral production factors. Using the sectoral production factors thus calculated and the observed sectoral outputs, we can calculate sectoral TFPs from equation (1). Observe that if a sector has a relatively higher price, then this procedure infers that in this sector the production factors are relatively higher and TFP is relatively lower.

3 Data

3.1 Sectoral factor shares

For the sectoral factor shares $\{\theta_i, \phi_i\}$ we use U.S. values for 1997, which is the closest year to 1996 for which sufficient data exist. Since the PWT96 reports final–expenditure data, the appropriate factor shares to use are those in purchaser prices. This means that the factor shares in each sector are a weighted average of the factor shares of the industries that have contributed value added to the final output of that sector. To calculate these factor shares, we follow the methodology developed in Valentinyi and Herrendorf (2008). In particular, we first calculate the shares of physical capital, land, and labor in disaggregated industry value added using data from the U.S. Bureau of Labor Statistics (BLS) on payments to the production factors and from the U.S. Bureau of Economic Analysis (BEA) on input–output tables. We then aggregate these factor shares as the factor shares of the outputs of our five final sectors.[5]

[5]For the details, see Valentinyi and Herrendorf (2008). Although in that paper we disaggregated tradable consumption into agricultural and manufactured consumption, here we disaggregate tradable consumption into food and manufactured consumption. The significance of this is that food contains value added from food processing, which occurs in manufacturing instead of agriculture. The reason for considering food here is that the PWT96

Table 2 shows that the resulting sectoral factor shares vary considerably across sectors. For example, whereas food has a labor share of only 0.62, construction has a labor share as high as 0.79. This suggests that it may be important to use the precise estimates for the sectoral factor shares instead of assuming that they equal the aggregate factor shares. We will come back to this issue in Section 5.1.

Table 2: Factor Shares at the Sectoral Level

	f	*m*	*s*	*e*	*c*
Capital	0.32	0.29	0.29	0.30	0.18
Land	0.06	0.03	0.06	0.03	0.03
Labor	0.62	0.68	0.65	0.67	0.79

3.2 Production factors

We calculate the aggregate stock of physical capital per worker k^z via the perpetual inventory method, where the units are 1996 international dollars. We use a depreciation rate of 6%, which is a standard value; see, for example, Hall and Jones (1999).

Land l^z is either arable or urban. Arable land is used for agricultural production and urban land is used for nonagricultural production (e.g., residential and commercial real estate, manufacturing). For arable land, we use data from the Food and Agricultural Organization (FAO). For urban land, we use the estimate from the World Bank (2006) that urban land equals 24% of reproducible physical capital. We assume that all agricultural land is a fixed factor in food production and use the U.S. factor share of 0.03. In contrast, urban land is allocated across the five sectors as described in Section 2.2. Note that this implies that the land in food production is equal to the entire agricultural land plus the appropriate share of urban land.

We construct human capital following Hall and Jones (1999) and Caselli (2005). In each country z, human capital per worker, h^z, is an increasing function of average years of schooling per worker, s^z:

$$h^z = \exp\{g(s^z)\}, \tag{8}$$

where $g(\cdot)$ is a positive and increasing function. From Barro and Lee (2001) we obtain the

does not report agricultural consumption.

average years for schooling for the population aged 15 or older.[6] From Psacharopoulos (1994) we obtain the following piecewise linear form for $g(\cdot)$:[7]

$$g(s^z) = \begin{cases} 0.134 \times s^z & \text{if } s^z \leq 4, \\ 0.134 \times 4 + 0.101 \times (s^z - 4) & \text{if } 4 < s^z \leq 8, \\ 0.134 \times 4 + 0.101 \times 4 + 0.068 \times (s^z - 8) & \text{if } 8 < s^z. \end{cases} \quad (9)$$

3.3 Prices and quantities

For the remaining variables, $\{p_i^z, y_i^z\}$, we use data from the International Comparisons Program as reported in the 1996 Benchmark Study of the PWT96, which contains internationally comparable information about expenditures, quantities, and prices for 30 categories in 94 countries that each have more than a million inhabitants. We focus on the subset of 86 countries for which we also have the information on schooling that is needed to calculate human capital. We aggregate the 30 expenditure categories into our five sectors; the details are described in the Appendix. We calculate for each country z the prices p_i^z and quantities y_i^z at the sectoral level, where quantities are measured in international dollars.

Two remarks are in order about the data on prices and quantities from the PWT96. First, prices reported in the PWT96 are purchaser prices, so they contain certain taxes that are not included in producer prices and are not relevant to decisions about how to allocate the production factors across sectors. In this context, we can think of taxes broadly to include value added taxes, tariffs, bribes, and monopoly rents. Whereas authors such as Chari et al. (1996) and Restuccia and Urrutia (2001) attributed the entire cross-country variation in relative prices to taxes, we take the opposite view and attribute it to factors other than taxes (i.e., to differences in sectoral TFPs and factor shares). We make this choice because Hsieh and Klenow (2007) as well as Herrendorf and Teixeira (2009) found that cross-country variation in sectoral TFPs is much larger than cross-country variation in taxes.

[6]For 76 countries we use data from 1995 and for eight countries we use data from 1990. We set the value for Macedonia to the value of Yugoslavia in 1990. For all former Soviet republics for which there are no data, we use the value of the USSR in 1995.

[7]Psacharopoulos (1994) used Mincerian wage regressions to estimate the rates of return to schooling. The rate of return for the first four years of schooling is the average for sub-Saharan Africa. The rate of return for years of schooling between four and eight is the average for the world as a whole. The rate of return for more than eight years of schooling is the average for the OECD.

Second, in the tradable sectors we know that purchased quantities may differ from domestically produced quantities because there are exports and imports. Since the PWT96 does no provide information on exports and imports by final-good sectors, we proceed under the assumption that purchased quantities equal domestically produced quantities in all sectors — including the tradable ones. This has an important implication for the interpretation of our results. If a tradable good is imported, then the importing country is using the world market technology instead of its own technology. In this case, the TFP that we measure is the TFP with which the importing country obtains the good through international trade. Although the importing country could not possibly have a higher TFP if it produced the imported good itself (otherwise it would do that), it could well have a lower TFP. Therefore, our results on the cross-country TFP disparity in tradables will constitute a lower bound on the cross-country disparity that would result under autarky.

4 Results

4.1 Cross–country disparity in sectoral TFPs

Implementing the method just developed, we obtain sector i's TFP in country z, A_i^z. In order to report the results in a succinct form, we regress the logarithm of A_i^z so obtained on the logarithm of country z's GDP per worker:

$$\ln(A_i^z) = \alpha_i + \beta_i \ln(y^z) + \epsilon_i^z, \tag{10}$$

where α_i is an intercept, β_i is the elasticity of sector i's TFP with respect to GDP per worker, and ϵ_i^z is an i.i.d., mean-zero error term. Regression (10) implies that

$$\frac{A_i^z}{A_i^{\text{us}}} = \left(\frac{y^z}{y^{\text{us}}}\right)^{\beta_i} \frac{\exp\{\epsilon_i^z\}}{\exp\{\epsilon_i^{\text{us}}\}}. \tag{11}$$

Note that a larger value of β_i is associated with a larger systematic cross-country disparity in sector i's TFPs. Moreover, if $\beta_i = 0$, then there is no systematic TFP disparity in sector i; if $\beta_i = 1$, then the systematic TFP disparity in sector i is as large as the GDP disparity.

Table 3: Results for β_i

PANEL A	FIVE–SECTOR SPLIT	y	f	m	s	e	c
A.1	Benchmark	0.46	0.68	0.48	0.22	0.84	0.77
A.2.1	Perpetual inventory, $\theta_i = 0.33$	0.47	0.70	0.47	0.24	0.84	0.62
A.2.2	Steady state, $\theta_i = \theta_i^{\text{us}}$	0.43	0.65	0.45	0.20	0.82	0.75
A.2.3	Steady state, $\theta_i = 0.33$	0.44	0.67	0.44	0.21	0.82	0.60
A.3	Higher human capital disparity	0.20	0.48	0.27	0.02	0.63	0.52
PANEL B	**TWO–SECTOR SPLITS**	T	NT	F	NF	C	I
	Benchmark	0.65	0.30	0.68	0.40	0.46	0.81

The results for the benchmark exercise are shown in Panel A.1 of Table 3.[8] We can see that in food, construction, and equipment the values of β_i are larger than for the aggregate, implying that the systematic TFP disparities in these sectors are larger than the systematic aggregate TFP disparity. In contrast, the TFP disparity in manufactured consumption is about the same as the aggregate disparity, and the TFP disparity in services is smaller than the aggregate disparity. To be more concrete, we also report the value of A_i^z/A_i^{us} that equation (11) predicts for the countries at the 90th, 50th, and 10th percentile of the distribution of GDP per worker. In our sample, these countries have 0.84, 0.26, and 0.06 of U.S. GDP per capita. Since $\mathbb{E}[\epsilon_i^z] = \mathbb{E}[\epsilon_i^{\text{us}}] = 0$, regression (11) implies that the predicted relative sectoral TFP of a country at the nth percentile is given by $\mathbb{E}[A_i^{n\%}/A_i^{\text{us}}] = [y_i^{n\%}/y_i^{\text{us}}]^{\beta_i}$.

Table 4 reports the results for the different percentiles. The TFP disparity between the 10th percentile and the United States has received particular attention in the literature. We can see that, for 10th percentile, the TFP disparity in food, construction, and equipment is 2–3 times larger than the aggregate disparity. In contrast, the TFP disparity in services is only about half of the aggregate disparity. In other words, our results imply that, at the 10th percentile, there are considerable differences between aggregate and sectoral TFP disparity.

The disparity, across countries, in relative sectoral TFP is largest in equipment, which suggests that developing countries specialize. Since land is a fixed factor in food production, all countries will produce some food. Since among the tradable goods, the disparity in relative TFPs is largest in equipment and lowest in manufactured consumption, specialization implies that developing countries import equipment and export manufactured consumption. Eaton

[8] The other panels of Table 3 report additional results that we shall discuss shortly.

Table 4: Results for $\mathbb{E}[A_i^{n\%}/A_i^{\mathbf{us}}]$

	y	f	m	s	e	c
90th percentile	0.93	0.89	0.92	0.96	0.87	0.88
50th percentile	0.54	0.40	0.52	0.74	0.32	0.35
10th percentile	0.29	0.16	0.27	0.54	0.10	0.12

and Kortum (2001) provided evidence that is consistent with this pattern of specialization: only a small number of developed countries export almost all the equipment that is traded internationally.

If developing countries specialize and import their equipment, then measured TFP in equipment is the TFP with which they obtain equipment in the world market through international trade. This implies that the disparity of relative TFPs that we calculate is a lower bound on how bad developing countries would be at producing equipment under autarky. It is interesting that this lower bound already implies that equipment is the sector in which developing countries perform the worst.

4.2 Two–sector studies

In employing different two-sector decompositions of the aggregate data, the existing literature has not reached a consensus about the sectors in which developing countries have particularly low productivity. As explained in the Introduction (recall Table 1), our five-sector decomposition encompasses the various two-sector decompositions that the literature has considered. We now show that our results can reconcile the conflicting results that the literature obtained.

We calculate the sectoral TPFs corresponding to a two-sector decomposition in the same way a statistician would if observing data generated by the corresponding two-sector aggregation of our model. For example, the TFP of the aggregate sector tradables is obtained as

$$A_T^z \equiv \frac{y_T^z}{(k_T^z)^{\theta_T}(l_T^z)^{\phi_T}(h_T^z)^{1-\theta_T-\phi_T}}, \tag{12}$$

where θ_T and ϕ_T are the capital and land shares of tradables for the United States as reported in Valentinyi and Herrendorf (2008). Moreover, quantities for the aggregate tradables are the sums of the relevant quantities for food, manufactured consumption, and equipment. Consistently with the rest of our analysis, we report relative TFPs instead of relative labor productivities. This is sufficient because poorer countries generally have lower physical and human capital, so cross-country differences in sectoral TFPs are amplified and become larger cross-country differences in sectoral labor productivities.

We start with Balassa (1964) and Samuelson (1964), who conjectured that the disparity in labor productivity across countries is much larger in tradables than nontradables. In order to assess this conjecture, we define the tradable sector (T) as food, manufactured consumption, and equipment and define the nontradable sector (NT) as services and construction. Panel B of Table 3 reports the results for tradables versus nontradables. We can see that the sectoral TFP disparity for tradables is larger than for nontradables, which confirms the Balassa–Samuelson hypothesis. This result reflects that TFP disparity is larger for equipment than for construction and is larger for food and manufactured consumption than for services. The implication is that the TFP disparity is larger in the tradable sector than in the nontradable sector, yet we emphasize that there is nothing fundamental about this result. In particular, the cross-country TFP disparity in construction, which is nontradable, is larger than in food and manufactured consumption, which are tradable.

Kuznets (1971) found that cross-country differences in labor productivity are much larger in agriculture than in the aggregate of the other goods.[9] To speak to the finding of Kuznets, we distinguish between food (F) and nonfood (NF), where the latter contains the four sectors other than food. Food is closely related to agriculture, but the two are not identical; the former includes food that is processed in manufacturing whereas the latter does not include food that is processed in manufacturing. Nonetheless, we use food because the PWT96 reports the final expenditure on food but not on agricultural consumption.

Panel B of Table 3 shows that the sectoral TFP disparity for food is greater than for nonfood. The reason for this is that, compared to the United States, the differences in TFPs are relatively large in equipment and in construction but are relatively small in manufactured consumption and in services. Because manufactured consumption and services constitute a sizable part of nonfood, they offset the large TFP differences in the other two sectors. Again, there is nothing fundamental about the TFP disparity in food being greater than in nonfood, since TFP disparities in equipment and construction are greater than in food.

[9] See also Gollin et al. (2004), Caselli (2005), Restuccia et al. (2006), and Córdoba and Ripoll (2009).

Hsieh and Klenow (2007) found that the cross-country difference in sectoral TFPs is larger for investment (I) than for consumption (C).[10] We find that the TFP differences for equipment and construction are larger than for food, manufactured consumption, and services. Consequently, the TFP differences for investment must be larger than for consumption, which is confirmed in Panel B of Table 3. This result is fundamental, because the cross-country TFP difference in each investment sector is larger than in any of the three consumption sectors.

5 Robustness

We have decomposed physical capital into reproducible capital and land, we have considered human capital, and we have used the U.S. sectoral factor shares. In contrast, Hsieh and Klenow (2007) obtained physical capital from current investment under the assumption that all countries are in steady state. They abstracted from land and human capital and used the standard value of 0.33 for the aggregate capital share in all sectors and countries. In this section, we explore the quantitative importance of these differences in the two approaches.

5.1 Capital and sectoral factor shares

To calculate reproducible capital from investment under the assumption that all countries are in steady state, we continue to use 6% depreciation and use investment x_i^z in international prices as reported in the PWT96. This yields $k_i^z = x_i^z/0.06$. We find that the correlation between reproducible capital calculated via this steady-state method and reproducible capital calculated via the perpetual inventory method is 0.92. Moreover, if we plot the capital stocks calculated according to the two methods against each other, they line up closely to the 45-degree line. This suggests that the steady-state method gives a reasonable approximation to the reproducible capital stock.

Panels A.2 of Table 3 report the results when we use different measures of reproducible capital and different sectoral capital shares. Panel A.2.1 refers to the capital stock calculated via the perpetual inventory method when the sectoral production functions (1) are

$$y_i^z = A_i^z (k_i^z)^{0.33} (h_i^z)^{0.67}. \tag{13}$$

[10] For lack of better notation, C denotes consumption and c construction.

Panels A.2.2 and A.2.3 refer to the capital stock calculated via the steady-state method when the capital shares are as in the United States and as in (13), respectively. Note that A.2.3 corresponds to the approach of Hsieh and Klenow (2007), except that we consider cross-country differences in human capital and they did not.

Overall, our results prove to be fairly robust. Comparing Panels A.1 and A.2, we see that the largest difference occurs for construction if we replace U.S. sectoral capital shares with the aggregate capital share. The intuitive reason for this result is that the capital share in construction is considerably lower than the average capital share. Abstracting from this leads one to attribute too little of the cross-country differences in construction output to differences in sectoral TFP and too much to differences in sectoral capital.

Our results remain largely unchanged when we replace the sectoral production functions (1) by (13), and this provides guidance regarding the key properties of the data and model that drive our results. To see this, note that with (13) the equalization of sectoral marginal value products to factor prices in each country implies that the sectoral capital/labor ratios are equal to each other and to the aggregate capital/labor ratio in each country. Denoting international prices by π, we then have

$$y^z = A^z (k^z)^\theta (h^z)^{1-\theta}; \tag{14}$$

here $y^z = \sum_{i\in\mathcal{I}} \pi_i y_i^z$ and $A^z = \sum_{i\in\mathcal{I}} (h_i^z/h^z)\pi_i A_i^z$. In other words, aggregate TFP in country z is a weighted average of the sectoral TFPs, where the weights are the shares of sectoral employment in total employment. Expressing aggregate TFP in country z relative to the United States, we obtain

$$\frac{A^z}{A^{\text{us}}} = \left(\sum_{i\in\mathcal{I}} \frac{h_i^z}{h^z}\pi_i A_i^z\right) \Bigg/ \left(\sum_{i\in\mathcal{I}} \frac{h_i^{\text{us}}}{h^{\text{us}}}\pi_i A_i^{\text{us}}\right). \tag{15}$$

That is, aggregate TFP in country z is lower than in the United States if the weighted average of sectoral TFPs in country z is lower than in the United States.

Previously we found that aggregate TFP is considerably lower in developing countries than in the United States, which is consistent with the results of many aggregate development accounting exercises.[11] We also found the new results that the TFP differences between

[11]See, for example, Klenow and Rodriguez-Clare (1997), Prescott (1998), Hall and Jones (1999), Hendricks

developing countries and the United States are considerably smaller in services than the aggregate TFP differences but are considerably larger in food, construction, and equipment. To understand what drives these results, observe that — given competitive markets, mobile production factors across sectors, and Cobb–Douglas production functions with equal capital shares — relative sectoral TFPs are inversely related to the relative prices of sectoral outputs, $A_i^z/A_j^z = p_j^z/p_i^z$. Hence

$$\frac{A_i^z}{A_i^{\text{us}}} = \frac{A^z}{A^{\text{us}}} \left(\sum_{j \in \mathcal{I}} \pi_j \frac{h_j^{\text{us}}}{h^{\text{us}}} \frac{p_i^{\text{us}}}{p_j^{\text{us}}} \right) \Bigg/ \left(\sum_{j \in \mathcal{I}} \pi_j \frac{h_j^z}{h^z} \frac{p_i^z}{p_j^z} \right). \tag{16}$$

Therefore, the TFP difference between country z and the United States is smaller (resp. larger) in sector i than in the aggregate if the weighted average of sector i's price relative to the other sectors' prices is smaller (resp. larger) than in the United States. In other words, differences in the relative prices of sectoral outputs are the main reason that sectoral TFP differences are not equal to aggregate TFP differences. For example, we find that the TFP difference between developing countries and the United States is smaller in services than in the aggregate. This is consistent with the well-documented fact that the weighted average of the prices of services relative to other sectors is smaller in developing countries than in the United States.

5.2 Human capital

Although it is widely agreed that unmeasured cross-country differences in human capital show up as measured differences in TFP, there is no consensus regarding the magnitude of the mismeasurement. So far, we have followed the procedure of Hall and Jones (1999) in measuring human capital; however, Manuelli and Seshadri (2005) argued that this procedure underestimates the cross-country differences in human capital.[12]

If our procedure does underestimate the cross-country differences in human capital, then human capital in poorer countries is lower than what we have measured. In order to explore the implications of this possibility, we artificially blow up the log difference between measured

(2002), and Caselli (2005).

[12] See also Bils and Klenow (2000), Hendricks (2002), and Erosa et al. (2007).

human capital in country z and the United States by multiplying it by a factor $\eta > 1$:

$$[\log(h^z_{\text{red}}) - \log(h^{\text{us}}_{\text{meas}})] = \eta \left[\log\left(h^z_{\text{meas}}\right) - \log\left(h^{\text{us}}_{\text{meas}}\right)\right]. \tag{17}$$

The larger is η, the more this operation reduces country z's human capital below the human capital that we have measured. For example, if $\eta = 3$ and country z's measured human capital is 50% of U.S. human capital, then this operation reduces country z's human capital to 13% of U.S. human capital. To show that even such an extreme degree of mismeasuring human capital does not affect our qualitative conclusions, we redo our analysis for the human capital values implied by $\eta = 3$; the results are shown in Panel A.3 of Table 3. We see that increasing the human capital disparity according to $\eta = 3$ considerably decreases the TFP disparity relative to the United States at both the aggregate level and the sectoral level. Moreover, it all but eliminates the TFP disparity in services.

That for $\eta = 3$ there is hardly any TFP disparity left in service suggests that this provides an upper bound on the mismeasurement of human capital — unless one is prepared to entertain the (implausible) possibility that poorer countries are systematically more productive in services than is the United States. We can see that even for this upper bound the sectoral pattern of TFP disparity remains largely unchanged: relative to the United States, the TFP disparities in equipment, construction, and food are, as before, larger than the aggregate disparity; in contrast, the TFP disparity in manufactured consumption is close to the aggregate TFP disparity, and the TFP disparity in services is much smaller than the aggregate TFP disparity. We conclude that mismeasurement of human capital would not affect our qualitative conclusions.

6 Toward a Theory of TFP Disparity

The development literature has argued that cross-country differences in human capital and in policies may cause the observed differences in aggregate TFP. In this section, we discuss these possibilities.

6.1 Human capital

Our method relied on the assumption that the efficiency units of labor supplied by different types of workers are perfect substitutes, implying that the only factor that matters at the sectoral level is the share of aggregate efficiency units allocated to the sector. This abstracts from the possibility that different types of labor are imperfect substitutes. For example, if unskilled and skilled labor are imperfect substitutes and if the elasticity of substitution between them differs across sectors, then cross-country differences in human capital may affect the sectors in ways that are not captured by the preceding analysis.

An important example of when distinguishing between skilled and unskilled labor matters is the "appropriate technology" hypothesis. In this line of thought, Acemoglu and Zilibotti (2001) argued that developing countries do not adopt frontier technologies because they lack the skilled labor required to operate them. This could account for the pattern of sectoral TFP differences found here if technology adoption mattered relatively more in the production of equipment, construction, and food and relatively less in the production of services and manufactured consumption. Although this is perfectly plausible, we are not aware of any hard evidence that supports this possibility. We believe that providing such evidence is a fruitful area for future research.

6.2 Policies

Many authors have argued that cross-country differences in the quality of policies can explain the differences in aggregate TFP. In what follows, we suggest several examples of bad policies with implications that are consistent with our findings. To begin with, barriers to international trade affect tradable sectors directly but nontradable sectors only indirectly. Holmes and Schmitz (1995) and Herrendorf and Teixeira (2005) showed that barriers to international trade can prevent the adoption of frontier technologies and thereby reduce TFP in tradable sectors. This is particularly relevant in equipment production because our results suggest that developing countries are likely to import equipment; see the discussion at the end of Section 4.1.

There are also several bad policies that affect industry more than services and agriculture (where industry is defined as manufactured consumption, construction, and equipment). A first example is barriers to entry and rent extraction. The reason for this is that home production and black markets limit the extent to which monopoly power can arise in services and agriculture. Herrendorf and Teixeira (2009) developed a dynamic model of barriers to entry and rent extraction in the spirit of Parente and Prescott (1999), and they showed that the implications of these factors for sectoral TFPs differences are large. A second example of bad policies that affect industry more than services and agriculture is financial frictions, such as poor enforcement of contracts. This results because industry has greater need for external financing than services.Erosa and Hidalgo (2008), Buera et al. (2009), and Amaral and Quintin (2010) develop this point further.

Among these bad policies, only trade barriers directly affect food production. It is important to realize, though, that food can have low measured TFP because bad policies affect it differentially in various indirect ways. For example, bad policies may reduce relative employment in industry (Parente and Prescott 1999). Because land is a fixed factor in food production, this will lead to a low ratio of land to labor, which in turn will reduce measured TFP. Schultz (1953) called this the "food problem" of developing countries; see Gollin et al. (2006) for a more recent restatement.

Another important example of how bad policies can affect agriculture indirectly is through increasing the relative price of food. As explained before, our accounting framework translates higher food prices into lower TFP in food production. One way that bad policies can increase the relative price of food is through inappropriate infrastructure and inefficient distribution systems. Lewis (2004) and Lagakos (2009) provided evidence that this is the case in several middle-income countries. This is particularly relevant for food, which uses agricultural inputs that are produced in the countryside and so must be transported to markets or the manufacturing locations where food processing takes place.[13] A second way that bad policies can increase the relative price of food is by increasing the relative prices of manufactured intermediate inputs (e.g., fertilizer and pesticides) and of capital goods (e.g., tractors and harvesting machines). Many authors have viewed this as a major problem of agriculture in developing countries; see for example Schultz (1964), Ruttan and Hayami (1970), and Restuccia et al. (2006).

[13] Herrendorf et al. (2009b) studied the implications of this for the United States during the first half of the 19th century. Adamopoulos (2009) studied the implications of transportation costs in a cross section of countries.

7 Conclusion

Which sectors are most responsible for the low aggregate TFP of developing countries? We have observed that the existing two-sector studies do not provide a conclusive answer to this question, and we have argued that getting to the bottom of this requires that we disaggregate further to five sectors: food, manufactured consumption, services, equipment, and construction. We have specified a development accounting framework at the sectoral level, which we have connected to the data from the PWT96. We have found that, relative to the United States, the TFP disparity in equipment, construction, and food is considerably larger than the aggregate disparity. In contrast, the TFP disparity in manufactured consumption is about the same as the aggregate disparity, and the TFP disparity in services is considerably smaller than the aggregate disparity. We have shown that our level of disaggregation allows us to reconcile the results of existing studies of sectoral productivity differences, which have focused on noncomparable decompositions of the aggregate data into two sectors. We have also shown that our results help us shed light on existing theories of aggregate TFP differences.

An important selling point of our development accounting framework is that it has a fairly minimal structure. In particular, we have not specified the household side of the economy at all, and we have not imposed the condition that countries be in steady state. The second point is significant because it implies that we could apply our development accounting framework also to so-called growth miracles that are far away from steady state.

Even though this structure is fairly minimal, our results are conditional upon the implied mapping between expenditure data and production factors. Consequently, these results should be viewed as tentative, indirect evidence. We hope that, in the future, comparable data about sectoral production factors and outputs will become available for a sufficiently large number of developing countries — and that these data will yield more direct and definitive evidence on the disparity in sectoral TFPs across countries.

Appendix

The benchmark study of the Penn World Table 1996 includes 115 countries and 30 goods categories. We exclude all countries with fewer than a million inhabitants, which leaves us with 98 countries. We also exclude Bulgaria, Lebanon, Oman, and Uzbekistan, because for these countries some categories have negative values that do not make economic sense. From the remaining 94 countries we select the subset of 86 countries for which we have sufficient information on schooling.

The procedure of aggregating the 30 goods categories into our five categories of food, manufactured consumption, services, equipment, and construction is as follows. We define the category of food as food. The category of manufactured consumption comprises all other tradable consumption goods — that is, beverages, clothing and footwear, fuel and power, furniture and floor coverings, other household goods, household appliances and repairs, and tobacco. The category of services includes the nontradable consumption goods: gross rent and water charges, medical and health services, transportation, communication, recreation and culture, education, restaurants/cafes and hotels. The category of equipment contains personal transportation equipment and machinery/equipment, and the category of construction consists of construction. Changes in stocks occur for both equipment and construction; we split this category by assuming that its equipment share is equal to the share of equipment in investment without changes of stocks.

Quantities are in terms of international prices as reported by the Input Table 4.5 of the PWT96; these prices are aggregated by simply adding them up. The reason for this is that units in the PWT96 are chosen such that international prices are equal to unity — that is, $\pi_i = 1$.

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