Trade in intermediate goods and total factor productivity

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Abstract

We develop and calibrate a model where differences in factor endowments lead countries to trade intermediate goods, and gains from trade reflect in total factor productivity. We perform several output and growth decompositions, to assess the impact that barriers to trade, as well as changes in terms of trade, have on measured TFP. We find that for very poor economies gains from trade are large, in some cases representing a doubling of GDP. Also, that an improvement in the terms of trade - by allowing the use of a better mix of intermediate inputs in the production process - translates into productivity growth.

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1 Introduction

A large literature (e.g., Mankiw, Romer and Weil (1992), Prescott (1998), Klenow and Rodriguez-Clare (1997), among many) has decomposed cross-country differences in output per-capita, explaining them as the consequence of differences in the availability of alternative inputs and in total factor productivity. In these exercises, it is assumed that the technology that transforms inputs into output is the same across countries, except for a single TFP coefficient that changes the effectiveness of the overall production process, but does not change the way different inputs interact with each other. The functional forms used in these analyses are taken assuming that countries do not trade with each other, and calibrated using parameters that give a good fit to the data of developed nations.

While this approach has certainly led to valuable insights, it may be the case that ignoring the effects of international trade biases the results one gets from such a development accounting exercise. We are used to thinking about trade as the exchange of goods and services ready for final consumption, so the gains from trade are just welfare improvements. In fact, a sizeable portion of international trade is the exchange of intermediate goods and raw materials, and therefore Ricardian gains from trade can show up in productivity. By allowing a better mix of intermediate goods than under autarky, trade allows to produce more with the same inputs. Furthermore, trade in intermediate goods and raw materials affects TFP in a complex way, because – as each intermediate good is produced with a different mix of inputs – it also changes the way those inputs interact with each other.

In this paper, we quantify the impact of trade on Total Factor Productivity (TFP) using a model that allows for international trade in intermediate goods, in the same vein as Ferreira and Trejos (2006). By construction, this model predicts that trade will be of little importance for rich countries, and under autarky is homeomorphic to the standard theoretical analysis in development accounting exercises. But for a poor country, the model predicts that under free trade there is a gain in TFP, which increases with trade liberalization and with the relative price of exportable intermediate goods.

We calibrate this model and apply it to a large sample of developing countries, to assess the quantitative importance of the effects mentioned above. Because countries reap at least some of these benefits from trade, the TFP differences between rich and poor countries that are estimated with our model are larger than those emerging from more conventional output decompositions, which are performed assuming a closed economy.

For the country in our database with the lowest capital endowment per worker, Uganda, our calibrated model estimates that free trade could almost a double output. The assessed gains from trade for other African nations (Congo, Mozambique and Rwanda, among others) range between 50% and 70% of productivity; for several Asian countries, around 30%, and even among the middle income economies in Central America openness to trade can represent a boost of 8-22% in TFP. Of course, many countries waste a good part of these gains due to protectionism. For example, in 1985 we estimate that Bangladesh and India, who should have enjoyed gains from trade to the tune of 1/3 of GDP due to their capital scarcity, wasted most or all those gains with average tariffs at prohibitive levels over 90%.

Because countries can pick very different trade policies, the model adds another dimension that can explain the behavior of TFP residuals. We do not have comparable cross-country data for transportation costs, non-tariff barriers, and other phenomena that reduce the incentives to international exchange. But looking at data on tariffs we find that for some poor nations, trade barriers are large enough to waive a large portion of the gains that trade can imply for productivity. Due to the nature of the trade problem, the same tariffs would have a much bigger cost in a middle-income country than in a poor one, simply because the potential gains from trade are quantitatively very different. For instance, in 1985 Brazil and Benin had similar nominal tariff rates, under which Benin realized almost all its potential gains from trade, while the wealthier Brazil lost them.

Countries can also differ significantly in the goods in which they have comparative advantages, and therefore in the behavior of their terms of trade. In our model, terms of trade are more than the ratio at which one can exchange output for consumption (which, as shown by Kehoe and Ruhl (2008), should only affect welfare but not TFP, if the latter is correctly measured). Once we allow for countries to exchange intermediate goods, an improvement in terms of trade simply allows to use a better mix of materials in the production process, and thus to get more final output out of the same inputs. In our calibrated model, for a very capital-poor country a 1% gain in the terms of trade yields a 0.48% gain in TFP, and these effects can be larger depending on factor endowments and trade policies.[1] Hence, our model can explain the puzzle identified by Kehoe and Ruhl (2008) that show that deteriorations in the terms of trade in some countries (e.g., Mexico and U.S.) are frequently accompanied by declines in productivity although standard models cannot generate this relationship[2].

Other authors have pursued to quantify the relationship between trade and productivity, although emphasizing different transmission mechanisms. For instance, Eaton and Kortun (2002) develop a model where TFP is specific to each country and industry, so trade allows countries to allocate more resources to the industries that have drawn high productivities. Using a similar model, Lucas and Alvarez (2008) estimated that a country with 1% of world GDP would gain from openness to trade up to 41% in productivity. Using a similar model, Rodriguez-Clare (2007) obtains similar estimates, which become much higher if openness involves not only the possibility to exchange goods, but also foster the diffusion of ideas.

In Section 2 we describe and solve the model, and in Section 3 we describe the data and calibration. In Section 4, we discuss and quantify the productivity gains from international trade, and in Section 5, we perform a development

[1] In the last five years, several Latin American countries have enjoyed a very favorable improvement in their terms of trade, as the raw materials on which they have comparative advantage have hit record prices. In those countries, output and productivity have increased very dramatically in the same period. Our model poses a candidate explanation for this observation.

[2] Other possible explanations are financial market frictions (Mendonza, 2006), labor hoarding and changes in capital utilization (Meza and Quintin, 2007) and costs in shifting resources across sectors (Kehoe and Ruhl, 2006).

accounting decomposition exercise that takes those gains into account. In Section 6, we discuss the productivity effects of commercial policy, and of changes in the terms of trade. Section 7 concludes.

2 The model

We model the world as a collection of small economies that trade intermediate goods with a much larger country. The picture in our mind is that the latter corresponds to the US (or perhaps to the OECD) – a developed nation or set of nations that has a high level of capital per worker – but we focus our attention on the equilibrium allocation in the small countries. In practice, this means that we will make relative prices to be the autarkic prices of the large country, and the smaller economies to be price-takers.

Our representative small country is populated by a continuum of identical, infinitely-lived individuals. There are three goods in these economy: two non-storable, tradable intermediate products, A and B, and a a final good, Y, which can be consumed or invested, but that cannot be traded. Each good is produced, by a large number of small, competitive firms, using technologies that have constant returns to scale.

There are also two factors of production in this economy: labor in efficient units H and physical capital K. Labor and capital are used in producing A and B, and these in turn are used to produce Y. The endowment of labor, measured in efficiency units, is given by:

$$H = Lh = Le^{\phi s},$$

where L is the number of workers, h represents efficiency-units of labor per worker and s stands for schooling. The production functions of A and B are:

$$\begin{aligned} A &= K_A^{\alpha_a} H_A^{1-\alpha_a} \\ B &= K_B^{\alpha_a} H_B^{1-\alpha_b}. \end{aligned}$$

Without loss of generality, A is labor-intensive: $\alpha_a < \alpha_b$. We use B as numeraire, and the relative price of A is denoted p.

Intermediate goods are tradable, so the amounts of them that are used in the production of the final good (denoted a and b) may differ from the amounts produced (denoted A and B). Total output of Y is given by:

$$Y = \Theta a^{\gamma} b^{1-\gamma}. \tag{1}$$

All markets are perfectly competitive; in the case of intermediate products, these are not domestic but rather global markets, from which local Y producers can import intermediate products A or B provided they pay an ad-valorem tariff τ. The rate τ captures all the (policy or non-policy induced) costs of bringing imported intermediate products into the local market.

We denote $k = K/H$ in general, and in particular define k^* as the capital-labor ratio of the large, developed country where international A and B prices are set, which we shall calibrate to be the US. We restrict our analysis to small countries where $k < k^*$.

To solve for an equilibrium, derive the allocation of capital K and labor H among the A and B industries, the quantities a and b of intermediate goods used domestically, and the amount of final output Y that is produced[3]. We seek for a set of prices for all factors and goods, so that all firms maximize their profits

$$\begin{aligned} K_A, L_A &= \arg\max q K_A^{\alpha_a} L_A^{1-\alpha_a} - rK_A - wL_A \\ K_B, L_B &= \arg\max K_B^{\alpha_b} L_B^{1-\alpha_b} - rK_B - wL_B \\ a, b &= \arg\max \pi a^{\gamma} b^{1-\gamma} - qa - b \end{aligned}$$

given market clearing (that is, $K_A + K_B \leq K$, $L_A + L_B \leq L$), no arbitrage (that is, $q = (1+\tau)p$ if $A > a$, $q = p$ if $A = a$, and $q = p/(1+\tau)$ if $A < a$), free entry (that is, all firms have zero profits) and no international lending

[3]This part of the model follows Corden (1971), Ventura (1992), Deardorff (2001) and, more closely, Ferreira and Trejos (2006).

(that is, $pa + b = pA + B$). Because intermediate goods are assumed to be non-storable, all production functions are homogeneous of degree one, and the final good is not tradable, this is a static problem. The relevant part of the solution, for our present purposes, can just be summarized as an equilibrium mapping

$$Y = \Theta F(K, H|\tau, p)$$

that relates final output with factor endowments. The mapping F is not a production function, in the sense that it does not describe a technology: it describes an equilibrium relationship that takes into account the technologies and markets for all the products, and the equilibrium effects of trade in the intermediate goods in the optimal choice for final good producers. Notice then that Θ plays the role of Total Factor Productivity, but also that changes in τ or p, by affecting F without changing inputs, can also affect *measured* TFP.

It is standard for the two-sector Hecksher-Ohlin model that one can derive functions s, x, Ω_i such that the equilibrium mapping F can be written as[4]

$$F(K, H|\tau, p) = \begin{cases} \Omega_1(\tau, p) K^{\alpha_a} H^{1-\alpha_a} \text{ if } k < s(\tau, p) \\ \Omega_2(\tau, p) K + \Omega_3(\tau, p) H \text{ if } k \in [s(\tau, p), x(\tau, p)] \\ \Omega_4 K^{\overline{\alpha}} H^{1-\overline{\alpha}} \text{ if } k \in [x(\tau, p), k^*], \end{cases}$$

where $\overline{\alpha} = \gamma\alpha_a + (1-\gamma)\alpha_b$. The proof is very similar to that in Ferreira-Trejos (2006).

In other words, if the economy has a very low capital-labor ratio, it will only produce the labor-intensive intermediate good A, export some of it, and import all the b that it uses to make final goods from the capital-richer country. In that case, the mapping F is just proportional to the value of A production, and thus takes the shape of a Cobb-Douglas with the lower capital share α_a. For higher k the economy diversifies –although the country is still an exporter of A and importer of B– and as a consequence of the Factor Price Equalization

[4] We derive the function $F(K, H|\tau, p)$ only for values of $k < k^*$ because this is the relevant interval for the groups of countries we study. The derivation for values of $k > k^*$ is straightforward.

Theorem, F is linear in K and H for an interval.[5] Even higher k implies that the factor endowment is too close to that of the larger trading partner, so that the benefits from trade are not enough to compensate for the trading cost τ, and thus the economy is in autarky. In that case, F is a Cobb-Douglas, with a capital share equal to the weighted average $\overline{\alpha}$. Of course, for the large economy that is a price setter rather than a price taker, the equilibrium mapping is $Y = \Omega_4 K^{\overline{\alpha}} H^{1-\overline{\alpha}}$ for all values of k.

One should notice that Ω_1, Ω_2 and Ω_3 are decreasing in τ; in other words, reductions in the cost of trade increase output. The reason is that τ induces a distortion on p, the relative price of the intermediate goods, that makes the imported intermediate good more expensive domestically. Because we restrict our analysis to countries that are more labor abundant than the economy where prices are set (that is, $k < k^*$), the imported intermediate good is the capital intensive good B, and thus this distortion inefficiently shifts to the B industry resources that could be used more efficiently producing A, while also inducing the Y industry to use a higher a/b mixture as inputs. Similarly, Ω_1, Ω_2 and Ω_3 are increasing in p, the relative price of the labor intensive intermediate good A in which our labor-abundant small countries have comparative advantage. Hence, when terms of trade improve, output of final goods increases. Finally, s and x are also decreasing in τ and, in the limit, $x \to 0$ as $\tau \to \infty$. In other words, under a high enough tariff even a very capital-poor country, that would gain a lot from trade, goes to autarky, at a large loss.

In our model, ignoring the effects of trade on F biases the measurement of productivity for poor countries. Consider a country with very little capital, for instance, where $k < s(\tau, p)$. Then, instead of being given by $Y = \Theta\Omega_4 K^{\overline{\alpha}} H^{1-\overline{\alpha}}$, output is enhanced by a factor $\Gamma_\tau = \Omega_1 K^{\alpha_a - \overline{\alpha}}/\Omega_4 > 1$. If one performs a TFP decomposition for a small, trading country using a production function estimated to work for the US, one may attribute to productivity (that is, to a

[5] When the factor endowment is inside the diversification cone, the capital intensity for each industry in the price-taking market becomes a constant, pinned down by international prices. Then, alternative values of K/H just change the mix across industries, but not within industries; factor prices are then set and production of Y is linear in K and H, a result analogous to the Factor Price Equalization Theorem.

higher value of Θ) what really are the gains from trade (that is, Γ_τ), and ends up with an over-estimation of Θ.

3 Data and calibration

We use the Penn-World Tables (PWT) data for national income accounts. For schooling, we use the average education attainment of the population aged 15 years and over, from the database gathered by Barro and Lee (2000). Finally, for tariffs we use the sample gathered by the World Bank (2005).[6] We perform our calculations for two years: 1985 and 2000, and restrict the analysis to the countries where the estimated k ratio is less than the US level.

To construct the capital series, we use the Perpetual Inventory Method, estimating the capital stock in the first year, following Hall and Jones (1999), among many, by $K_0 = I_0/[(1+g)(1+n) - (1-\delta)]$, where depreciation is $\delta = 3.5\%$ (as in Ferreira, Pessoa and Veloso (2008)), $g = 1.54\%$ is the trend-growth rate of output in the US, and n is the population growth for each country. To construct the data on human capital, we use a Mincer function of schooling, of the form $h = e^{\phi s}$, and set the return of schooling to $\phi = 0.099$, following Psacharopoulos (1994).

According to convention, we match the capital share of the richer, price-setting economy to be $\overline{\alpha} = 1/3$. This pins down the average $\overline{\alpha}$, but leaves freedom in choosing γ, α_a and α_b. These parameters are particularly important, as the quantitative effects of all trade-related phenomena are bound to be larger with a big spread between α_a and α_b, given $\overline{\alpha}$. In particular, the

[6] From the model, one can infer that ideally we seek for cross-country data that reflect the cost of performing international trade, whether induced by policy, distance or other factors. Clearly, the World Bank tables are a lower bound, for several reasons. First, unweighted averages are biased down because they usually include the very low tariffs for non-tradeables. Second, as extensively documented in the survey by Anderson and van Wincoop (2004), non-tariff barriers and transportation costs can be quite expensive according to several estimates. However, no uniform measurement or estimation of these other costs for a large sample of countries seems to exist.

gains from trade

$$\Gamma_\tau = \frac{F(K, H|p, \tau)}{F(K, H|\tau = \infty)}$$

increase with $\alpha_b - \alpha_a$, and $\Gamma_\tau \to \infty$ as $\alpha_b - \alpha_a \to 1$. We choose conservatively the values of α_a, α_b and γ to limit the size of Γ_τ within reasonable bounds. Picking $\gamma = 1/2$, $\alpha_a = 0.19$ and $\alpha_b = 0.477$, one assures that $\overline{\alpha} = 1/3$, that exports of intermediate goods are never more than half of their output, and that $\Gamma_0 = 1.01$ for Mexico in our 1985 data. We find this calibration to be conservative, as Kehoe and Kehoe (1995) found that total gains from exploiting comparative advantage by joining NAFTA would amount to about 1% of GDP for Mexico, and Γ_0 corresponds to the gains of total trade liberalization. As we shall see, even though Γ_τ assumes such modest levels for middle-income country with comparatively high k like Mexico, it can also be very high for the world's poorest countries.

To calibrate for p we look for the autarkic relative price of A when $k = k^*$. For k^* we pick the level of capital that corresponds to steady state in a standard growth model, with 6.1% return on capital and a production function $Y = \Omega_4 K^{1/3} L^{2/3}$.

3.1 Gains from trade

The gains from trade a country perceives are proportional to the difference between the international prices at which it can exchange goods, and the prices for the same goods that it would have in its local market if it was in autarky. Hence, a country with a very different factor endowment than its trading partners, and potentially very different domestic prices, would benefit very significantly from trade. Trading with one's similars is not as convenient.

In our model, the relevant differences are the ones in the capital-labor ratio, k. A very poor country with low $k < s(p, \tau)$ would be able to produce the labor intensive good, A, at much lower cost than its large, rich trading partner, and in fact would specialize and not produce B at all. The country would acquire all the B it needs from the international market at a much lower opportunity cost, and hence the large gain from trade. In a less capital-poor country, where $s(p, \tau) < k < x(p, \tau)$, firms still find it profitable to produce more A than needed by the local market, yet some B gets produced domestically as well. In this case, gains are smaller as k is not that different from k^*. Finally, a rich enough country, where $k > x(p, \tau)$, will simply not trade. In that case, τ is bigger than the difference between the international prices and the local prices that prevail without trade.

Figure 1 shows the functions $s(p, \tau)/k^*$ and $x(p, \tau)/k^*$ as they vary with the tariff rate τ, under the calibrated level of p. One can verify that under free-trade, countries with less than 47% of the US levels for k would be fully specialized in A, and this means in 1985 every country below Ecuador's reported k ratio, or 55 out of the 67 members of the sample. Again, $\tau = 0$ would imply that all 67 countries would do at least some trade. As τ increases, however, the gains from trade (and the set of countries enjoying them) shrink. For example, if $\tau = 0.28$, the average value of τ in our sample, we would find that only 28 countries would choose to be fully specialized; 14 of the countries would not trade at all.

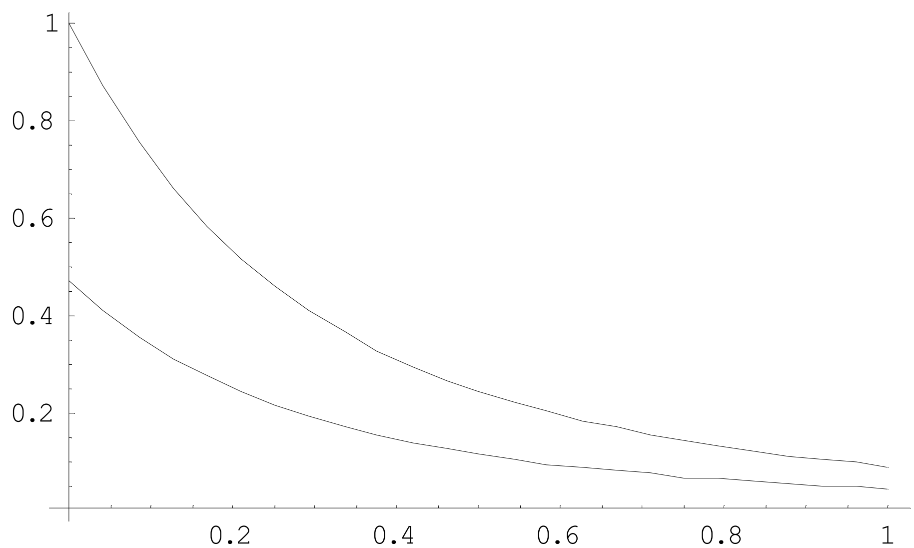

Figure 1: $s(p, \tau)$ and $x(p, \tau)$ as a function of τ

Just how big are those gains from trade? The following table shows the potential gains under free trade[7], Γ_0, for a representative sub-sample of economies (the full sample appears in the Appendix).

Table 1: Gains from openness

COUNTRY	Γ_0	COUNTRY	Γ_0
Bangladesh	1.32	Philippines	1.18
Brazil	1.01	Rwanda	1.67
China	1.42	South Africa	1.01
Haiti	1.53	Togo	1.46
India	1.36	Uganda	1.99
Malaysia	1.09	Zimbabwe	1.07

For the poorest nations trade can almost double output (in the case of Uganda, the estimated increase in output under free trade is 98.6%), although Γ_0 is less than 2% for a dozen countries in our sample which, like South Africa and Brazil, are relatively capital-rich.

Of course, it does not take very high barriers to trade to make much of these gains to go away. For the same countries (again, find the rest in the Appendix), we list in the next table the levels of τ that make Γ_τ to be a third of Γ_0, half of Γ_0, or disappear altogether.

[7] Given by

$$\Gamma_0 = \frac{F(K, H|p, 0)}{F(K, H|\tau = \infty)}.$$

Table 2: Loss from barriers to trade

COUNTRY	τ needed for Γ_0 to fall by			Actual τ	k/k^*
	1/3	1/2	100%		
Bangladesh	65.6	72.7	91.9	94.5	0.10
Brazil	5.17	7.33	10.4	47.1	0.71
China	89.4	98.0	122.0	49.5	0.06
Haiti	118.8	129.5	159.6	27.7	0.04
India	77.0	84.8	106.3	91.0	0.08
Malaysia	17.9	21.8	30.9	14.0	0.39
Philippines	35.1	40.4	53.7	29.2	0.22
Rwanda	155.6	169.1	207.7	33.0	0.02
South Africa	6.0	7.4	10.5	21.2	0.70
Togo	101.4	110.9	137.3	19.5	0.05
Uganda	245.5	272.3	336.8	25.0	0.01
Zimbabwe	15.5	19.1	27.3	9.4	0.43

Clearly, most countries in the list have high tariffs and waste most of the gains from trade. For instance, in the case of Bangladesh, the potential contribution to output from free trade would be a boost of 32%, and it would take $\tau = 65.6\%$ for a third of those gains to go away, and of $\tau = 92\%$ to wipe them out. The actual tariff rate of 94.5%, however, is enough to waste completely that boost in TFP. Similarly, India is losing more than half its potential gains from trade because of restrictive commercial policy.

On the other hand, Uganda and Rwanda are so scarce in k that one needs tariffs above 300% and 200%, respectively, to shut them from trade. Are such rates completely unrealistic? Perhaps not. As Anderson and van Wincoop (2004) mention, measures of tariffs significantly underestimate the actual cost of doing trade, because they ignore transportation costs and many policy-induced non-tariff barriers. Recent direct measurement by Malherbe (2007) quantified the cost of shipping cargo in and out of Rwanda, a landlocked country whose trucks have to go through Uganda and Kenya before reaching an international port in Mombassa. They found that the land-shipping alone cost about 80% of the value of exports. For imports this percentage is much higher (since containers come full inwards and half-empty outwards), and it has been quoted that bringing cargo into Kigali (Rwanda) from Mombassa can cost upwards of $6.500 per container. After adding the shipping cost to Mombassa, plus tariffs, non-tariff barriers and the financial cost of nearly a month for the turnaround trip, the 207% prohibitive rate that appears in the previous table does not seem farfetched.

In contrast, in countries such as Brazil and South Africa, in which k is relatively high, the tariff necessary to shut them from trade is very small. In fact, in both cases the observed tariff in 1985 is well above this level, so that they lost all the potential gains from trade.

4 Productivity decomposition

We proceed now to make the decomposition. The usual approach yields

$$Y = \widehat{\Theta} K^{\overline{\alpha}} H^{1-\overline{\alpha}}$$

where $\widehat{\Theta} = \Theta\Gamma_\tau$ – and is usually labeled TFP in level decomposition exercises – and Γ_τ is the increase in productivity due to trade as we just saw. If an economy is in autarky, then $\Gamma_\tau = \Gamma_\infty = 1$, and thus $\widehat{\Theta} = \Theta$. However, if tariffs are low enough, then $\Gamma_\tau > 1$, and thus one may overestimate the true TFP, Θ, if one ignores the impact of international trade.

Dividing by the number of workers, L, we get output per worker, or

$$\frac{Y}{L} = \widehat{\Theta} \left(\frac{K}{H}\right)^{\overline{\alpha}} \frac{H}{L}$$

Now, if the country does trade, and thus reaps the gains from trade, we can rewrite the previous equation as

$$\frac{Y}{L} = \left(\frac{K}{H}\right)^{\overline{\alpha}} \frac{H}{L} \Gamma_\tau \Theta.$$

We use this expression in a otherwise standard level decomposition exercise, in which income difference with respect to the US is measured as

$$\frac{Y_i/L_i}{Y_{US}/L_{US}} = \left(\frac{K_i}{H_i}/\frac{K_{US}}{H_{US}}\right)^{\overline{\alpha}} \times \left(\frac{H_i}{Li}/\frac{H_{US}}{L_{US}}\right) \times \Gamma_{i,\tau} \times \frac{\Theta_i}{\Theta_{US}}$$

The two first components in the right hand side are standard in level decomposition exercises; first comes the effect of different levels of capital per efficiency unit of labor, and then the amount of efficiency units of labor per worker. i.e., human capital. The product of the last two components is $\widehat{\Theta}$, what usually appears for productivity, which we separate in in two parts: the productivity *gain* from trade and the TFP residual. The decomposition for our highlighted countries appears in the next table, and again the full sample in the Appendix.

Table 3: Development accounting

COUNTRY	y	k	h	$\widehat{\Theta}$	$\boldsymbol{\Gamma}_\tau$	$\boldsymbol{\Theta}$
Bangladesh	0.087	0.469	0.425	0.435	1.000	0.435
Brazil	0.342	0.891	0.482	0.797	1.000	0.797
China	0.054	0.396	0.549	0.247	1.388	0.178
Haiti	0.048	0.330	0.457	0.318	1.520	0.209
India	0.075	0.431	0.487	0.358	1.133	0.317
Malaysia	0.291	0.731	0.578	0.690	1.070	0.645
Philippians	0.161	0.607	0.643	0.411	1.148	0.358
Rwanda	0.045	0.271	0.416	0.401	1.650	0.243
South Africa	0.497	0.890	0.567	0.984	1.000	0.984
Togo	0.066	0.366	0.449	0.399	1.458	0.273
Uganda	0.031	0.180	0.418	0.414	1.974	0.210
Zimbabwe	0.156	0.755	0.449	0.459	1.064	0.431

As expected, quite a few countries have $\Gamma_\tau \approx 1$, either because they are relatively rich and can expect little gains from trade (e.g., Brazil and Barbados), or because their tariffs are so high that they waste most of them (e.g., Bangladesh and Pakistan). In this case $\Theta \approx \widehat{\Theta}$. On the other hand, for many countries Γ_τ happens to be very large, so even though some of the potential gains from trade are wasted due to protectionism, most are realized. For instance, in the usual decomposition TFP in Rwanda is 41% of TFP in the U.S. However, once we take into account the gains from trade that such a poor country can enjoy (estimated as a boost of 65% in output) TFP is really much lower, 24%. Other noteworthy cases are those of Congo, Haiti, Mozambique, Rwanda and Sierra Leone. In these countries Θ is around or below 65% of $\widehat{\Theta}$. On average, the trade-corrected TFP estimate Θ in our sample is around 85% of $\widehat{\Theta}$.

Is there a way in which one can say that our estimated Θ is a *better* number than the usual $\widehat{\Theta}$? In particular, is there any puzzling aspect of $\widehat{\Theta}$ as it is conventionally measured, that gets explained once we divide the trade and non-trade components of productivity? When we consider (by running a simple OLS regression, for instance) the relationship between income per capita and standard closed-model TFP, $\widehat{\Theta}$, we find high positive correlation, as expected, but a large number of outliers countries for which TFP is either much higher or smaller than expected for its income level. Some examples would be Sierra Leone, Jordan, Uganda and Mozambique and Guatemala. However, for the case of the trade-corrected measure of TFP, Θ, this phenomena is less pronounced and the relationship between y and Θ is much smoother. Hence, a large part of the relationship between y and $\widehat{\Theta}$ was due to international exchange, and once we correct for the gains from trade, estimated TFP falls. The R-squared of the regression of Θ on y (both relative to the U.S.) is higher and, more importantly, the sum of squared residual is 43% smaller than that of the regression of $\widehat{\Theta}$ on y, and indication of a better fit.

5 TFP effects of changes in terms of trade

We now proceed to quantify the effects on gains from trade, and measured productivity, from variations in p, the international relative price of the labor-intensive good. Clearly, p is related to the terms of trade of the labor-abundant nations that make up our model, and therefore we are looking for productivity effects from improvements in the terms of trade.

It is important to be precise about what we are looking for. Other researchers, and in particular Kehoe and Ruhl (2007), have asked whether the welfare gains associated with being able to import more with the same exports, can be interpreted as improvements in productivity in standard models. According to their argument, the answer is no: the apparent impact of terms of trade on productivity emerges from the specific way output is measured in most countries, but if one uses a chain-based price index to measure GDP, this impact goes away. In that paper, on the other hand, countries trade final goods. Since in our model gains from trade show up in the mix of intermediate goods available for production there is a different transmission mechanism, that is related with the actual efficiency of the production process, and thus potentially a real link between terms of trade and TFP. Hence, we have a candidate explanation for the puzzle these authors identified, as in many countries (e.g., Mexico and U.S.) shocks to terms of trade are translated in shocks to productivity.

The solid line in the next figure shows the percentage increase in $\widehat{\Theta}$ coming from a 1% increase in p, for alternative values of k, under $\tau = 0$.

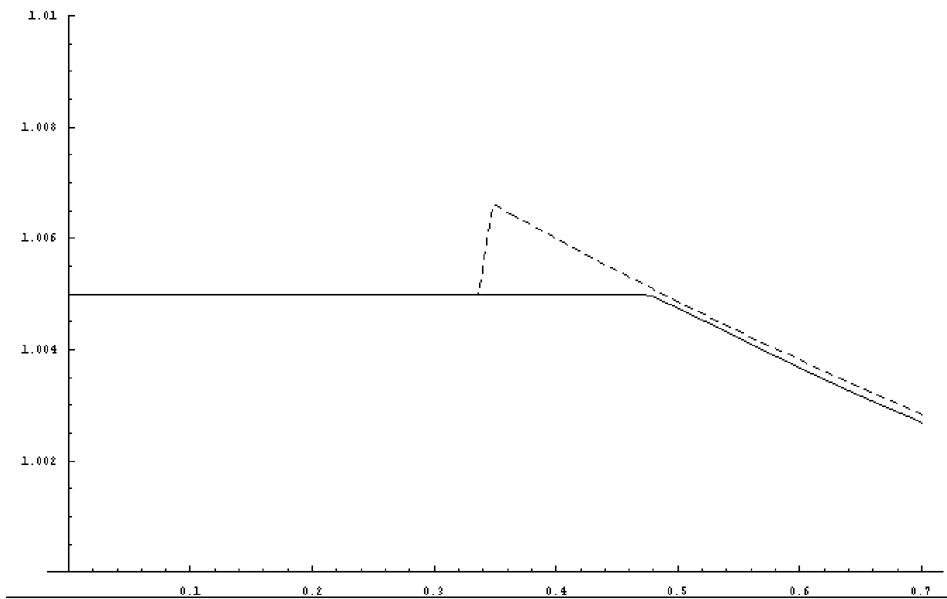

Figure 2: The variation of TFP due to an increase of 1% in p ($\tau = 0$ and $\tau = 0.1$)

Under our calibration, one can see that a very poor economy that only produces the labor-intensive intermediate good A will get nearly 0.5% increase in Γ_0, and thus in $\widehat{\Theta}$, from such a change in p. The gains will be smaller, but still relevant, for an economy with higher k, and therefore that produces at least some B. As the k gets closer to that of the developed country it trades, the gains from a variation of terms of trade falls as expected. That is, rich economies that fail to trade are not affected by changes in p.

The dotted line in the same figure redoes the calculation assuming that $\tau = 10\%$. For very low values of k, the results are the same. The impact of p on Γ_τ may actually be stronger for intermediate values of k. This is the case because the increase in terms of trade has an effect similar to that of reducing τ. Hence, it partially offsets trade distortion and allows the economy to produce a more efficient mix of intermediate inputs, reducing B output and increasing that of A, at the same that that the exports (imports) of A (B) increases (reduces).

In our dataset there are 22 countries with positive terms of trade shock in the 1985-2000 period. In this group, $\widehat{\Theta}$ growth was 15.5 percent points higher, on average, than in the rest of the sample, while Θ was 13.5 points higher. Moreover, on average these countries experienced positive TFP growth in both measures, while in remaining economies $\widehat{\Theta}$ fell by 7% and Θ by 2%[8]. These facts match the predictions of the model.

6 Conclusion

In this paper we presented evidence that gains from trade are very relevant. We used a very simple version of the Hecksher-Ohlin model so that the only reason countries trade are factor differences. This contrasts with Eaton and Kurtum (2002) Ricardian trade model in which there is a continuum of goods and countries have differential access to technology. In that model efficiency varies across commodities and countries. As opposed to Rodriguez-Clare (2006), which builds on Eaton and Kurtun(2002), there is no diffusion in our model. Nonetheless, the model is able to capture some important features of the international commerce - poor countries do trade because of factor differences - and so our measured gains from trade may be seen as a (large) lower bound of the gains from openness. As a matter of fact, they are close to those Rodriguez-Clare (2007) obtained in the pure trade model.

Moreover, the methodology we use does not capture the fact that barriers to trade do affect investment decisions and so capital stocks, something we have shown in a previous paper (Ferreira and Trejos (2006)). In this sense, the current exercise is also limited as it takes stocks as given but does not consider that, if it were not for trade restrictions, they would be considerably larger.

Of course, the fact that poor countries with high tariffs are still enjoying most of the gains from trade could be reverted if we have more realistic data,

[8]Note also that most countries that faced an improvement in the terms of trade after 2000 due to the observed increase in commodities prices they export (for instance, soy, iron, oil, copper, etc.) also experienced fast growth in the same period: Argentina, Chile, Brazil, Angola, among many.

and not only nominal tariffs data. Anderson and van Wincoop (2004) survey the literature on trade costs and show that for the OECD economies they are quite large and well above nominal tariffs. We wanted, however, to use homogeneous data and the only source we know for this is the WorldBank database on nominal tariff. A natural extension of this work is to use (and construct in some cases) data of trade cost based on gravitation models for a large set of economies.

References

[1] Alvarez, F. and R. Lucas (2005), "General Equilibrium Analysis of the Eaton-Kortun Model of International Trade," *NBER Working Paper* No. 11764.

[2] Anderson, J. and E. van Wincoop (2004), "Trade Costs", *Journal of Economic Literature* 42(3), 691-751.

[3] Barro, R. and J. W. Lee (2000), "International Data on Educational Attainment: Updates and Implications," *NBER Working Paper* No. 7911.

[4] Corden, W. (1971), "The effects of trade on the rate of growth", in Bhagwati, Jones, Mundell and Vanek, Trade, *Balance of Payments and Growth*, (North-Holland), 117-143.

[5] Deardorff, A. (2001), "Rich and Poor Countries in Neoclassical Trade and Growth," *The Economic Journal*, 111(April), 277-294.

[6] Eaton, J. and S. Kortum (2002), "Technology, Geography, and Trade," *Econometrica* 70(5), 1741-1780.

[7] Ferreira, P. C., Pessoa, S. A., and F. Veloso (2008), "The Evolution of International Output Differences (1970-2000): From Factors to Productivity," *The B.E. Journal of Macroeconomics*, Vol. 8 : Iss. 1 (Topics), Article 3.

[8] Ferreira, P. C. and A. Trejos (2006), "On the Long-run Effects of Barriers to Trade." *International Economic Review,* 47(4), 1319-1340.

[9] Hall,R. and C. Jones (1999), "Why Do Some Countries Produce So Much More Output per Worker Than Others?," *Quarterly Journal of Economics*, 114(1): 83-116.

[10] Kehoe, P. J. and T. J. Kehoe. (1994) "Capturing NAFTA's Impact With Applied General Equilibrium Models," *FRB Minneapolis - Quarterly Review*, 18(2), 17-34.

[11] Kehoe, T. and K. Ruhl (2008), "Are Shocks to the Terms of Trade Shocks to Productivity?," *FRB of Minneapolis Staff Report* No. 391

[12] Kehoe, T. J. and K. J. Ruhl (2006), "Sudden Stops, Sectorial Reallocations, and Real Exchange Rates," University of Minnesota and University of Texas at Austin.

[13] Klenow, P. J. and A. Rodriguez-Clare (1997), "The Neoclassical Revival in Growth Economics: Has it Gone Too Far?," in Ben S. Bernanke and Julio J. Rotemberg, eds, *NBER Macroeconomics Annual 1997* (Cambridge, MA: The MIT Press), 73-103.

[14] Malherbe, S. (2007), "A Diagnostic Analysis of the Kigali-Mombassa Transport Corridor", Genesis, South Africa.

[15] Mankiw, N. G., Romer, D. and D.Weil (1992), "A Contribution To The Empirics of Economic Growth," *Quarterly Journal of Economics*, 107 (2): 407-437.

[16] Mendoza, E. G. (2006), "Endogenous Sudden Stops in a Business Cycle Model with Collateral Constraints: a Fisherian Deflation of Tobin's Q," manuscript, University of Maryland.

[17] Meza, F and E. Quintin (2007), "Financial Crises and Total Factor Productivity," *The B.E. Journal of Macroeconomics*, 7:1 (Advances), article 33.

[18] Prescott, E. (1998), “Needed: a Total Factor Productivity Theory,” *International Economic Review*, 39(3): 525-552.

[19] Psacharopoulos, G. (1994), “Returns to Investment in Education: A Global Update,” *World Development*, 22(9): 1325-1343.

[20] Rodriguez-Clare, A. (2007), "Trade, Diffusion and the Gains from Openness," *NBER Working Paper* No. 13662.

[21] Trejos, A. (1992), “On the Short-Run Dynamic Effects of Comparative Advantage Trade,” manuscript, University of Pennsylvania.

[22] Ventura, J. (1997), “Growth and Interdependence”, *Quarterly Journal of Economics*, 112(1): 57-84

[23] WorldBank(2005), "World Development Indicators," The WorldBank, Washington, D.C.

Table A.1: Gains from openness

COUNTRY	Γ_0	COUNTRY	Γ_0
Benin	146.6	Jordan	110.3
Botswana	115.3	Korea	108.1
Cameroon	130.3	Malaysia	108.7
Cent. Afric. Rep.	143.9	Nepal	142.2
Congo	154.1	Pakistan	129.3
Egypt	121.9	Papua New	117.3
Ghana	133.9	Philippines	117.8
Guinea Bisseau	138.2	Sri Lanka	131.9
Kenya	135.2	Syria	112.0
Lesotho	146.2	Taiwan	112.2
Malawi	144.1	Thailand	115.6
Mali	138.4	Turkey	113.9
Mauritius	114.3	Barbados	101.0
Mozambique	170.2	Bolivia	118.08
Niger	139.9	Brazil	101.3
Rwanda	166.7	Chile	108.3
Senegal	138.4	Colombia	112.2
Sierra Leone	161.7	Costa Rica	110.6
South Africa	101.3	Dominican	115.6
Tanzania	134.7	Ecuador	105.9
Togo	146.4	El Salvador	118.3
Tunisia	103.2	Guatemala	114.7
Uganda	198.6	Guyana	108.1
Zambia	118.7	Haiti	153.1
Zimbabwe	107.2	Honduras	122.4
Bangladesh	131.7	Jamaica	107.4
China	141.6	Mexico	101.0
Fiji	108.3	Nicaragua	113.7
Hong Kong	102.5	Panama	106.3
India	136.5	Paraguay	115.3
Indonesia	130.5	Peru	102.2
Iran	101.1	Uruguay	102.5

Table A.2: Loss from barriers to trade

COUNTRY	τ needed for Γ_0 to fall by			Actual τ	k/k^*
	1/3	1/2	100%		
Benin	97.0	111.4	136.9	48.3	0.05
Botswana	27.3	35.0	45.8	30	0.26
Cameroon	58.8	69.5	86.9	30.2	0.11
Cent. Afric. Rep.	90.5	104.3	128.3	32	0.06
Congo	115.8	132.3	161.9	22.6	0.03
Egypt	40.5	49.4	63.1	47.4	0.18
Ghana	66.9	78.3	97.4	26.3	0.09
Guinea Bisseau	76.9	89.3	110.5	27.8	0.07
Kenya	69.9	81.6	101.3	39.9	0.09
Lesotho	96.2	110.5	135.7	17.4	0.05
Malawi	90.9	104.7	128.8	31.6	0.05
Mali	77.4	89.8	111.1	17	0.07
Mauritius	25.3	32.8	43.1	36.2	0.28
Mozambique	158.2	179.6	264.7	15.6	0.02
Niger	80.9	93.7	115.7	18.5	0.07
Rwanda	148.8	169.1	219.6	33	0.02
Senegal	77.2	89.7	110.9	13.2	0.07
Sierra Leone	135.5	154.2	188.5	25.8	0.02
South Africa	5.2	7.4	5.1	21.2	0.70
Tanzania	68.8	80.4	99.9	28.5	0.09
Togo	96.5	110.9	136.3	19.5	0.05
Tunisia	8.5	12.1	14.3	25.9	0.57
Uganda	186.5	272.3	733.7	25	0.01
Zambia	34.1	42.4	54.7	29.9	0.21
Zimbabwe	13.4	19.1	25.3	9.4	0.43
Bangladesh	61.8	72.7	90.8	94.5	0.10
China	84.9	98.0	120.9	49.5	0.06
Fiji	14.9	20.9	27.8	12.4	0.40
Hong Kong	7.4	10.6	11.7	0	0.61
India	72.9	84.8	105.2	91	0.08
Indonesia	59.3	70.0	87.6	30.2	0.11

Table A.2 (cont.): Loss from barriers to trade

COUNTRY	τ needed for Γ_0 to fall by			Actual τ	k/k^*
	1/3	1/2	100%		
Iran	4.8	6.8	8.7	20.7	072
Jordan	18.2	24.8	32.9	15.2	0.35
Korea	14.7	20.7	27.5	21	0.41
Malasya	15.6	21.8	29.0	14	0.39
Nepal	86.15	99.8	122.9	21.9	0.06
Pakistan	56.5	66.9	83.9	72.2	0.12
Papua NewGuine	31.2	39.3	51.0	14.2	0.23
Philippines	32.2	40.4	52.3	29.2	0.22
SriLanka	62.3	73.2	91.4	36.2	0.10
Syria	21.1	28.1	37.2	14.8	0.32
Taiwan	21.6	28.6	37.9	23.3	0.31
Thailand	27.8	35.6	46.5	38.1	0.26
Turkey	24.6	32.0	42.1	27.9	0.28
Barbados	4.4	6.3	9.1	17.3	0.74
Bolivia	32.6	40.7	52.8	17.6	0.22
Brazil	5.2	7.3	10.4	47	0.71
Chile	14.9	21.0	27.9	20.8	0.40
Colombia	21.5	28.5	37.8	36.7	0.31
Costa Rica	18.7	25.3	33.7	19.5	0.35
Dominican Rep	27.9	35.6	46.5	27.8	0.25
Ecuador	11.8	16.9	22.0	34.3	0.47
El Salvador	33.2	41.4	53.5	20	0.22
Guatemala	26.2	33.7	44.2	19.4	0.27
Guyana	14.7	20.6	27.4	18.7	0.41
Haiti	113.3	129.5	158.6	27.7	0.04
Honduras	41.7	50.7	64.7	51.3	0.17
Jamaica	13.7	19.5	25.8	17.9	0.43
Mexico	4.6	6.5	1.6	19.7	0.73
Nicaragua	24.3	31.6	41.6	22.1	0.29
Panamá	12.2	17.5	22.9	12.8	0.49
Paraguay	27.4	35.0	46.9	11	0.26
Peru	6.9	9.7	10.1	37.6	0.64
Uruguay	7.3	10.4	11.3	36.3	0.62

Table 3: Development accounting

COUNTRY	y	k	h	$\widehat{\Theta}$	$\boldsymbol{\Gamma}_\tau$	$\boldsymbol{\Theta}$
Benin	0.054	0.365	0.401	0.366	1.438	0.255
Botswana	0.254	0.368	0.487	0.817	1.102	0.741
Cameroon	0.154	0.480	0.449	0.716	1.292	0.554
CentAfrican Rep.	0.066	0.381	0.403	0.432	1.426	0.303
Congo	0.035	0.325	0.445	0.241	1.533	0.157
Egypt	0.215	0.561	0.485	0.789	1.122	0.703
Ghana	0.068	0.451	0.487	0.308	1.330	0.232
GuineaBisseau	0.024	0.418	0.368	0.155	1.372	0.113
Kenya	0.062	0.440	0.474	0.296	1.333	0.222
Lesotho	0.058	0.367	0.496	0.318	1.458	0.218
Malawi	0.031	0.380	0.453	0.181	1.427	0.127
Mali	0.058	0.417	0.372	0.372	1.380	0.270
Mauritius	0.257	0.651	0.572	0.690	1.053	0.655
Mozambique	0.031	0.258	0.378	0.319	1.697	0.188
Niger	0.037	0.407	0.375	0.245	1.394	0.175
Rwanda	0.045	0.271	0.416	0.401	1.650	0.243
Senegal	0.073	0.417	0.429	0.408	1.381	0.295
Sierra Leone	0.068	0.290	0.417	0.565	1.607	0.351
South Africa	0.497	0.890	0.567	0.984	1.000	0.984
Tanzania	0.028	0.444	0.457	0.136	1.337	0.102
Togo	0.066	0.366	0.449	0.399	1.458	0.273
Tunisia	0.324	0.831	0.474	0.823	1.000	0.823
Uganda	0.031	0.180	0.418	0.414	1.974	0.210
Zambia	0.069	0.596	0.505	0.228	1.161	0.197
Zimbabwe	0.156	0.755	0.449	0.459	1.064	0.431
Bangladesh	0.087	0.469	0.425	0.435	1.000	0.435
China	0.054	0.396	0.549	0.247	1.388	0.178
Fiji	0.275	0.739	0.691	0.539	1.069	0.505
Hong Kong	0.499	0.849	0.750	0.783	1.025	0.763
India	0.075	0.431	0.487	0.358	1.133	0.317
Indonesia	0.127	0.478	0.505	0.525	1.294	0.406
Iran	0.322	0.898	0.478	0.750	1.000	0.750

Table 3 (cont.): Development accounting

COUNTRY	y	k	h	$\widehat{\Theta}$	$\mathbf{\Gamma}_\tau$	$\mathbf{\Theta}$
Jordan	0.415	0.707	0.562	1.043	1.086	0.960
Korea	0.342	0.741	0.770	0.600	1.039	0.577
Malasya	0.291	0.731	0.578	0.690	1.070	0.645
Nepal	0.051	0.391	0.392	0.331	1.415	0.234
Pakistan	0.103	0.489	0.425	0.496	1.106	0.448
PapuaNewGuine	0.135	0.613	0.421	0.524	1.171	0.448
Philippines	0.161	0.607	0.643	0.411	1.148	0.358
Sri Lanka	0.115	0.467	0.597	0.413	1.303	0.317
Syria	0.263	0.683	0.528	0.731	1.110	0.658
Taiwan	0.371	0.679	0.698	0.784	1.085	0.722
Thailand	0.134	0.634	0.562	0.375	1.063	0.363
Turkey	0.239	0.657	0.491	0.741	1.090	0.680
Barbados	0.438	0.905	0.691	0.700	1.000	0.700
Bolivia	0.173	0.605	0.542	0.527	1.176	0.448
Brazil	0.342	0.891	0.482	0.797	1.000	0.797
Chile	0.298	0.738	0.643	0.627	1.042	0.602
Colombia	0.288	0.680	0.533	0.795	1.022	0.778
Costa Rica	0.283	0.703	0.572	0.703	1.076	0.653
Dominican Rep.	0.220	0.634	0.509	0.681	1.117	0.609
Ecuador	0.275	0.777	0.599	0.591	1.000	0.591
El Salvador	0.232	0.601	0.487	0.794	1.178	0.674
Guatemala	0.267	0.646	0.453	0.913	1.136	0.803
Guyana	0.134	0.741	0.678	0.312	1.048	0.298
Haiti	0.048	0.330	0.457	0.318	1.520	0.209
Honduras	0.161	0.555	0.509	0.570	1.108	0.515
Jamaica	0.149	0.752	0.523	0.379	1.043	0.364
Mexico	0.493	0.902	0.562	0.973	1.000	0.973
Nicaragua	0.209	0.659	0.478	0.663	1.111	0.597
Panama	0.355	0.771	0.638	0.723	1.046	0.692
Paraguay	0.278	0.637	0.562	0.775	1.152	0.673
Peru	0.294	0.860	0.604	0.566	1.000	0.566
Uruguay	0.338	0.852	0.655	0.606	1.000	0.606