

Trade and Sectoral Productivity

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Preliminary Version

Abstract

What do we know about cross country differences in sectoral productivity? Not much, even though they are at the heart of trade theory and many stories explaining cross country income differences. In this paper we fill this gap by using a Hybrid-Ricardo-Heckscher-Ohlin trade model and bilateral sectoral trade and production data to overcome the data problem that has plagued previous studies. We provide a comparable set of sectoral total factor productivities (TFP) for 24 manufacturing sectors and more than fifty countries at all stages of development. Our results show that TFP differences in manufacturing sectors between rich and poor countries are substantial and far more pronounced in skill intensive sectors.

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1 Introduction

Sectoral Productivity Differences across countries are at the heart both of trade theory and of many theories on growth and development. The Ricardian approach to International Trade emphasizes those productivity differences as the main reason for cross country flows of goods, while many models in the growth literature stress factors such as adequate technologies (Acemoglu and Zilibotti (2001)), external financial dependence (Rajan and Zingales (1998)), and institutions that have clear predictions on the form of sectoral differences in total factor productivity (TFP). Nevertheless, due to data limitations, almost nothing is known about the form of sectoral productivity differentials across countries outside the industrialized world.

In this paper we try to overcome the data problem faced by the traditional approach of TFP measurement which requires comparable data on outputs and inputs at the sectoral level by using trade theory and data. To our knowledge we are the first to provide a comparable and - as we will argue - reliable set of sectoral productivities for twenty four manufacturing sectors in more than fifty countries at all stages of development. To this aim we extend the Romalis (2004) model - that combines Heckscher-Ohlin trade with trade due to increasing returns and love for variety - to sectoral differences in TFP and many asymmetric countries. In this way, we are able to back out sectoral productivity differences as observed trade that cannot be explained by differences in factor intensities and factor prices or by differences in trade barriers across countries. Our results give evidence that cross country TFP differences in manufacturing sectors are large - in general even larger than the substantial variation across countries at the aggregate economy level that has been found in the development accounting literature (see for example Hall and Jones (1999)). In addition, we show that productivity differences are systematically related to sectoral skill intensity but not to

the sectoral capital intensity of production. Productivity gaps are far more pronounced in high skill sectors such as Transport equipment, Electrical- and Non-electrical Machinery and Printing and Publishing, than in low skill sectors such as Apparel, Textiles or Furniture. Finally, we find that our estimated sectoral total factor productivity is correlated with some measures of specialization like the Balassa (1965) and Balassa (1986) measures of revealed comparative advantage.

There is a large number of papers that study sectoral productivity differences by specifying a production possibility frontier and using data on sectoral inputs and outputs. Some of the earlier contributions that use sectoral value added as an output measure are Dollar and Wolff (1993) and Maskus (1991). Those studies are limited to OECD countries and do not disentangle sectoral price indices, which are usually unavailable, from output quantities. As a consequence, variation in product prices across countries is wrongly attributed to differences in TFP. Another line of investigation that tries to tackle this issue is the research done by the International Comparison Project at the University of Groningen. Economist working in this project have constructed comparable sectoral price indices for a number of countries and years. Recent studies within this project have computed sectoral productivity indices for up to 30 countries. However, they include mainly OECD members and compare mostly labor productivities. Acemoglu and Zilibotti (2001) calculate productivity indices for 27 3-digit manufacturing sectors in 22 developed and developing countries, using data from the United Nations. They realize that their indices are a mixture of output prices and TFP differences, but do not try to separate the two parts.

In the trade literature there is also an important amount of articles trying to compute productivity differences at various levels of aggregation. Harrigan (1997) and Harrigan (1999) computes sectoral TFP indices for 8 (6) sectors, in 10 (8) OECD countries in various years to test the fit of

a generalized neoclassical trade model that allows for both Ricardian and Heckscher-Ohlin trade and finds support for it.

Golub and Hsieh (2000) compute labor productivities to test a Ricardian model of trade using data for OECD countries, while Eaton and Kortum (2002) develop a multi-country Ricardian model with a probabilistic technology specification that they calibrate to fit trade between OECD countries. Chor (2006) extends their model to also allow for differences in factor proportions and differences in other characteristics like financial dependence, volatility, etc., across sectors. While these models are close in spirit to ours, they do not allow to compute measures of sectoral productivity differences that go beyond a probabilistic description of technology.

Trefler (1993), Trefler (1995) and Davis and Weinstein (2001) have shown convincingly that differences in total factor productivity at the country - or factor and country - level can help to substantially improve the fit of the Heckscher-Ohlin-Vanek model but they do not permit sector specific productivity differences.

Finally, Antweiler and Trefler (2002) provide some evidence for the importance of increasing returns to scale at the sectoral level using again the Heckscher-Ohlin-Vanek framework.

The main advantage of the trade approach to compute sectoral TFP differences is the fact that we are able to construct a sectoral TFP index of the exporting country vis a vis every importing country, which enables us to calculate standard errors of our estimates. Another important point is that trade theory makes it possible to disentangle cross country differences in value shipped that are due to differences in prices from disparities that are due to differences in quantities. In this way we can overcome the problem of mixing prices and quantities from which most previous studies have suffered.

The next section introduces the theoretical model and provides some intuition of the economic forces at work in general equilibrium. Section 3 develops a multi-country, multi-sector version of the model and a methodology for computing sectoral productivity indices. Section 4 discusses the data and section 5 presents the empirical results. The final section concludes.

2 A Simple Model

In order to use trade data to back out sectoral TFP differences we need a model in which bilateral trade is determined. A convenient way to get this is to follow Krugman (1979) in assuming that consumers have love for variety and that production is monopolistic because of increasing returns.¹ We add three more ingredients to be able to talk about sectoral productivity differences. First, we assume that sectors use different factor proportions when faced with the same input prices, which gives rise to Heckscher-Ohlin style trade between countries. Second, we add bilateral transport costs. As Romalis (2004) points out, this makes locally abundant factors relatively cheap and strengthens the link between factor abundance and trade. While without transport costs, trade is undetermined in the Heckscher-Ohlin model as long as the number of factors is smaller than the number of goods and countries are not fully specialized, in this model there is a cost advantage to produce more in those sectors that use the abundant factors intensively, which creates the prediction that countries export more in those sectors. Finally, we add sectoral differences in TFP, which introduces a motive for Ricardian style trade. Countries that have a high productivity in a sector, have a cost advantage relative to their foreign competitors and charge lower prices. Because

¹An alternative specification has been developed by Eaton and Kortum (2002). In their Ricardian style model there is perfect competition and every good is sourced from the lowest cost supplier that may differ across countries because of transport costs. We do not follow their approach because the probabilistic description of technology in their model, which makes it difficult to conceptualize sectoral TFPs.

the elasticity of substitution between varieties is larger than one, demand shifts towards the varieties of those country and leads to a larger world market share in that sector. Having explained the main features of the model, let us now develop the details.

2.1 Demand

The setup of the model is very close to Romalis (2004). Consumers in country i have two tiered utility functions. The first level is assumed to be a Cobb-Douglas utility function over K sectoral sub-utility functions, which implies that consumers spend a constant fraction of their income, σ_{ik} , on each sector.

$$U_i = \prod_{k=0}^K u_{ik}^{\sigma_{ik}} \quad (1)$$

Sectors 1 to K are tradable, while sector 0 is a non-tradable sector. Sectoral sub-utility is a symmetric CES aggregate of sectoral varieties, which implies that consumers value each of the available varieties of goods in a sector in the same way. Note also that utility is strictly increasing in the number of sectoral varieties available in a country. $\epsilon_k > 1$ denotes the sector specific elasticity of substitution between varieties and B_{ik} is the set of varieties available in sector k available to consumers in country i .

$$u_{ik} = \left[\sum_{b \in B_{ik}} x_{bk}^{\frac{\epsilon_k - 1}{\epsilon_k}} \right]^{\frac{\epsilon_k}{\epsilon_k - 1}} \quad (2)$$

A standard result of this setup is that the demand function of country i consumers of a sector k variety produced in country j has a constant price elasticity, ϵ_k , and is given by the following expression.

$$x_{ijk} = \frac{\hat{p}_{ijk}^{-\epsilon_k} \sigma_{ik} Y_i}{P_{ik}^{1-\epsilon_k}}, \quad (3)$$

where $\hat{p}_{ijk} = \tau_{ijk}p_{jk}$ is country i 's market price of a sector k good produced in country j ; τ_{ijk} is the sectoral transport cost between countries j and i and finally P_{ik} is the sector k price index in country i .

$$P_{ik} = \left[\sum_{b \in B_{ik}} \hat{p}_b^{1-\epsilon_k} \right]^{\frac{1}{1-\epsilon_k}} \quad (4)$$

2.2 Supply

Firms can freely invent varieties and have to pay a fixed cost to operate. Because of the demand structure and the existence of increasing returns, production is monopolistic as it is always more profitable to invent a new variety than to compete in prices with another firm in the same variety. Firms in country j use both capital, K , with price r_j and labor, L , with price w_j to produce. In addition, there is a country and sector specific total factor productivity, A_{jk} . Firms' production possibilities in sector k of country j are described by the following total cost function.

$$TC(q_{jk}) = (f_{jk} + q_{jk}) \frac{1}{A_{jk}} \left(\frac{w_j}{1 - \alpha_k} \right)^{1-\alpha_k} \left(\frac{r_j}{\alpha_k} \right)^{\alpha_k} \quad (5)$$

The form of the cost function implies that sectoral production functions are Cobb-Douglas with sectoral factor intensities α_k and that the sector specific fixed cost, f_{jk} , is such that it uses capital and labor in the same combination as the constant variable cost.

2.3 Example: 2 Countries

Let us now look at the prediction of the model in a simple two country general equilibrium setup.

There are two countries, Home and Foreign (*). Transport costs are allowed to be sector specific and asymmetric and are denoted by τ_k and τ_k^* . The total number of varieties at the world level is

$$N_k = n_k + n_k^*.$$

It follows from (4) that the Home price index in sector k is.

$$P_k = \left[n_k p_k^{1-\epsilon_k} + n_k^* (p_k^* \tau^*)^{1-\epsilon_k} \right]^{\frac{1}{1-\epsilon_k}} \quad (6)$$

A similar expression holds for the Foreign sector price index.

The revenue of a Home firm is given by the sum of domestic and foreign revenue, and using the expressions for Home and Foreign demand (3), we get:

$$p_k q_{jk} = \sigma_k Y \left(\frac{p_k}{P_k} \right)^{1-\epsilon_k} + \sigma_k^* Y^* \left(\frac{p_k \tau_k}{P_k^*} \right)^{1-\epsilon_k} \quad (7)$$

An analogous expression applies to Foreign firms.

Given the demand structure firms optimally set prices as a fixed markup over their marginal cost.

$$p_k = \frac{\epsilon_k}{\epsilon_k - 1} \frac{1}{A_{jk}} \left(\frac{w_j}{1 - \alpha_k} \right)^{1-\alpha_k} \left(\frac{r_j}{\alpha_k} \right)^{\alpha_k} \quad (8)$$

Since firms can enter freely, in equilibrium they make zero profits and price at their average cost. Combining this with (8), it is easy to solve for equilibrium firm size, which depends positively on the fixed cost and the elasticity of substitution.

$$q_{jk} = q_k = f_k(\epsilon_k - 1) \quad (9)$$

Let us now solve for partial equilibrium in a single sector. For convenience, define the relative price of Home varieties in sector k , to be $\tilde{p}_k \equiv \frac{p_k}{p_k^*}$ and the relative fixed cost in sector k as $\tilde{f}_k \equiv \frac{f_k}{f_k^*}$.

Dividing the Home market clearing condition by its Foreign counter part, one can derive an expression for $\frac{n_k}{n_k^*}$, the relative number of home varieties in sector k .

A sector will not always be located in both countries. In fact, if Home varieties are too expensive relative to Foreign ones, Home producers will not be able to recoup the fixed cost of production and will not enter this sector at Home.

Consequently, if $\tilde{p} \geq \underline{p}_k$ we have that $n_k = 0$ and $n_k^* = \frac{\sigma_k(Y+Y^*)}{f_k^*(\epsilon_k-1)}$ while if $\tilde{p} \leq \underline{p}_k$ the whole sector is located in Home, $n_k = \frac{\sigma_k(Y+Y^*)}{f_k(\epsilon_k-1)}$ and $n_k^* = 0$.

For intermediate relative prices of Home varieties, sectoral production is split across both countries, and the relative number of home varieties is given by the following expression:

$$\frac{n_k}{n_k^*} = \frac{[\sigma_k Y(\tilde{p}_k \tilde{f}_k - \tilde{p}_k^{1-\epsilon_k} (\tau_k^*)^{\epsilon_k-1}) + \sigma_k^* Y^*(\tilde{p}_k \tilde{f}_k - \tilde{p}_k^{1-\epsilon_k} \tau_k^{1-\epsilon_k})]}{[\sigma_k^* Y^* \tilde{p}_k^{1-\epsilon_k} (\tau_k^*)^{\epsilon_k-1} (\tilde{p}_k \tau_k^{1-\epsilon_k} - \tilde{p}_k \tilde{f}_k) - \sigma_k Y \tilde{p}_k^{1-\epsilon_k} \tau_k^{1-\epsilon_k} (\tilde{p}_k \tilde{f}_k - \tilde{p}_k^{1-\epsilon_k} (\tau_k^*)^{\epsilon_k-1})]} \quad (10)$$

for $\tilde{p}_k \in (\underline{p}_k, \bar{p}_k)$, where

$$\underline{p}_k = \left[\frac{(\sigma_k^* Y^* + \sigma_k Y)(\tau_k^*)^{\epsilon_k-1} \tau_k^{1-\epsilon_k}}{\sigma_k Y \tau_k^{1-\epsilon_k} \tilde{f}_k + \sigma_k^* Y^* (\tau_k^*)^{\epsilon_k-1} \tilde{f}_k} \right]^{1/\epsilon_k} \quad (11)$$

and

$$\bar{p}_k = \left[\frac{\sigma_k^* Y^* \tau_k^{1-\epsilon_k} + \sigma_k Y (\tau_k^*)^{\epsilon_k-1}}{\tilde{f}_k \sigma_k^* Y^* + \tilde{f}_k \sigma_k Y} \right]^{1/\epsilon_k}. \quad (12)$$

Defining the Home revenue share in industry k $v_k \equiv \frac{n_k p_k x_k^s}{n_k p_k x_k^s + n_k^* p_k^* x_k^{s*}}$, we can derive that $v_k = 0$ if $\tilde{p}_k \geq \bar{p}_k$. On the other hand, v_k is given by $\frac{1}{1+(\frac{n}{n^*})^{-1} \tilde{p}^{-1} \tilde{f}^{-1}}$ if $\tilde{p}_k \in (\underline{p}_k, \bar{p}_k)$ and finally $v_k = 1$ if $\tilde{p}_k \leq \underline{p}_k$.

The model is closed by substituting the pricing condition (8) into $\tilde{p}$ and the expressions for v_k in the factor market clearing conditions for Home and Foreign.

$$\sum_{k=1}^K (1 - \alpha_k) v_k \sigma_k (Y + Y^*) + (1 - \alpha_{NT}) \sigma_{NT} Y = wL \quad (13)$$

$$\sum_{k=1}^K \alpha_k v(k) \sigma_k (Y + Y^*) + \alpha_{NT} \sigma_{NT} Y = rK \quad (14)$$

$$\sum_{k=1}^K (1 - \alpha_k) (1 - v_k) \sigma_k (Y + Y^*) + (1 - \alpha_{NT}) \sigma_{NT} Y^* = w^* L^* \quad (15)$$

$$\sum_{k=1}^K \alpha_k (1 - v_k) \sigma_k (Y + Y^*) + \alpha_{NT} \sigma_{NT} Y^* = r^* K^* \quad (16)$$

Normalizing one relative factor price, we can use 3 factor market clearing conditions to solve for the remaining factor prices.

One can show that the home revenue share in sector k , v_k , is decreasing in the relative price of Home varieties $\tilde{p}_k$. This implies that countries have larger revenue shares in sectors in which they can produce relatively cheaply. Cost advantages may arise both because a sector uses the relatively cheap factor intensively and because of high sectoral Home productivity compared to Foreign.

2.3.1 Romalis' Model

In the special case that sectoral productivity differences are absent, $\frac{A_k}{A_k^*} = 1$ for all $k \in K$, relative fixed costs of production are equal to one, $\tilde{f}_k = 1$ for all $k \in K$, sectoral elasticities of substitution

are the same in all sectors, $\epsilon_k = \epsilon$, and trade costs are symmetric and identical across sectors $\tau_k = \tau_k^* = \tau$, $b_k = b_k^*$, the model reduces to Romalis (2004)' model.

In his framework, the relative price of Home varieties, $\tilde{p}_k = \frac{\left(\frac{w}{1-\alpha_k}\right)^{1-\alpha_k} \left(\frac{r}{\alpha_k}\right)^{\alpha_k}}{\left(\frac{w^*}{1-\alpha_k}\right)^{1-\alpha_k} \left(\frac{r^*}{\alpha_k}\right)^{\alpha_k}}$, is decreasing in the capital intensity, α_k , if and only if Home is relatively abundant in capital $\frac{K}{L} > \frac{K^*}{L^*}$.

Factor prices are not equalized across countries because of transport costs, which gives Home a cost advantage in the sectors that use its abundant factor intensively. This in turn leads to a larger market share of the Home country in those sectors as consumers shift their expenditure towards the relatively cheap Home varieties.

2.3.2 A Ricardian Model

If we make the alternative assumption that all sectors use labor as the only input, $\alpha_k = 0$ for all $k \in K$, and we order sectors according to Home comparative advantage, such that $\frac{A_k}{A_k^*}$ is increasing in k we obtain a Ricardian model. The advantage of this model is that because of love for variety, consumers are willing to buy both Home and Foreign varieties even if they do not have the same price. The setup implies that $\tilde{p}_k = \frac{w}{w^*} \frac{A_k^*}{A_k}$ is decreasing in k , so that Home offers lower relative prices in sectors with higher k . Consequently, Home captures larger market shares in sectors with larger comparative advantage since v_k is decreasing in $\tilde{p}_k$ and $\tilde{p}_k$ is decreasing in $\frac{A_k}{A_k^*}$.

2.3.3 The Hybrid Ricardo-Heckscher-Ohlin Model

In the more general case, comparative advantage is driven both by differences in factor endowments and by differences in sectoral productivities. Note that $\tilde{p}_k$ is given by the following expression:

$$\tilde{p}_k = \frac{\frac{1}{A(k)} \left(\frac{w}{1-k} \right)^{1-k} \left(\frac{r}{k} \right)^k}{\frac{1}{A^*(k)} \left(\frac{w^*}{1-k} \right)^{1-k} \left(\frac{r^*}{k} \right)^k} \quad (17)$$

Assume again that Home is relatively capital abundant, $\frac{K}{L} > \frac{K^*}{L^*}$. Then, conditional on $\frac{w}{r}, \frac{w^*}{r^*}$, Home has lower prices and a larger market share in sectors where $\frac{A_k}{A_k^*}$ is larger. In addition, factor prices depend negatively on endowments unless the productivity advantages are systematically much larger in sectors that use the abundant factor intensively. A very high relative productivity in the capital intensive sectors can increase demand for capital so much that $\frac{w}{r} < \frac{w^*}{r^*}$ even though $\frac{K}{L} > \frac{K^*}{L^*}$. As long as this is not true, locally abundant factors will be relatively cheap and - holding constant productivity differences - this increases market shares in sectors that use the abundant factor intensively.

The model is illustrated in figure 1. In this example, $\epsilon_k = 4$, Home is relatively capital abundant, $K = 2/3, L = 1/3, K^* = 1/3, L^* = 2/3$ and the transport cost is symmetric and identical for all sectors, $\tau_k = \tau_k^* = 2$. The figure plots Home's relative productivity, sectoral revenue share, relative prices, as well as net exports, exports relative to production and imports relative to production against the capital intensity of the sectors, which is ordered on the zero-one interval. In the first case (solid lines) there are no productivity differences between Home and Foreign. Because Home is capital abundant it has lower rentals and higher wages which leads to lower prices and larger revenue shares in capital intensive sectors. In addition, Home is a net importer in labor intensive

sectors and a net exporter in capital intensive ones and its exports relative to production are larger in capital intensive sectors, while its imports relative to production are much larger in labor intensive sectors. This illustrates neatly the Quasi-Heckscher-Ohlin prediction of the model.

In the second case (dashed lines) - besides being more capital abundant - Home also has higher productivities in more capital intensive sectors. This increases Home's comparative advantage in capital intensive sectors even further. The consequence of higher productivity is an increased demand for both factors that increases Home factor prices and makes it even less competitive in labor abundant sectors, while the relative price in capital abundant sectors is lower than without productivity differences. The result is a higher revenue share in capital intensive sectors and more extreme import and export patterns than without productivity differences.

Figure 2 is an example of the Quasi-Rybczynski effect. Initially, both Home and Foreign have the same endowments, $K = 1/3, L = 1/3, K^* = 1/3, L^* = 1/3$ and Home has a systematically higher productivity than Foreign in capital intensive sectors (solid lines), which explains Home's larger market share in those sectors. In the case with the dashed lines Home has doubled its capital stock to $K' = 2/3$. This leads to an expansion of production and revenue shares in the capital intensive sectors and a decline in production in the labor intensive sectors. The additional capital is absorbed both through more capital intensive production and an expansion of production in capital intensive sectors. The increased demand for labor in those sectors drives up wages and makes Home less competitive in labor intensive sectors.

Summing up, the general prediction of the Hybrid-Ricardo-Heckscher-Ohlin model is that exporting countries capture larger market shares in sectors in which their abundant factors are used intensively (Quasi-Heckscher-Ohlin prediction) and they have high productivities relative to the

rest of the world (Quasi-Ricardian prediction). In addition, the model has a Quasi-Rybczynski effect. Holding productivities constant, factor accumulation leads to an increase in revenue shares in sectors that use the factor intensively and a decrease in those sectors that use little of the factor.

Having discussed the two country model that gives some intuition of the economic forces at work, let us extend the model to many countries in order to implement our productivity estimation exercise.

3 Estimation of the Sectoral Productivities

For the empirical implementation and estimation of the sectoral productivities we consider a generalization of the model to many countries and three production factors: Skilled labor (S), unskilled labor (U), and capital (K)². This implies that firms' total cost function is now given by

$$TC(q_{jk}) = (f_{jk} + q_{jk}) \frac{1}{A_{jk}} \left(\frac{w_j}{\alpha_{u,k}} \right)^{\alpha_{u,k}} \left(\frac{w_j}{\alpha_{s,k}} \right)^{\alpha_{s,k}} \left(\frac{r_j}{\alpha_{cap,k}} \right)^{\alpha_{cap,k}} \quad (18)$$

The sectoral volume of bilateral trade measured at destination prices - imports of country i from country j in sector k - can be written as

$$M_{ijk} = \hat{p}_{ijk} x_{ijk} N_{jk} = p_{jk} \tau_{ijk} x_{ijk} N_{jk}, \quad (19)$$

where again p_{jk} is the price of country j in sector k ; τ_{ijk} is the transport cost between countries i and j in sector k ; x_{ijk} is the demand of country i of a sector k variety produced in country j and

²We can extend the model allowing for a fourth factor of production: raw materials. The main difficulty consists in computing factor intensities.

N_{jk} is the number of firms of country j in sector k . Substituting the demand x_{ijk} from (3)

$$M_{ijk} = \frac{(p_{jk}\tau_{ijk})^{1-\epsilon_k}\sigma_{ik}Y_i}{P_{ik}^{1-\epsilon_k}}N_{jk}. \quad (20)$$

Under optimal pricing, (8), firms' factory gate prices are a constant markup over the marginal cost that depends negatively on the elasticity of substitution ϵ_k . Finally, substituting the marginal cost function obtained from (18), we can write the bilateral sectoral trade volume as

$$M_{ijk} = \left[\frac{\frac{\epsilon_k}{\epsilon_k-1} \left(\frac{w_j^u}{\alpha_{k,u}} \right)^{\alpha_{k,u}} \left(\frac{w_j^s}{\alpha_{k,s}} \right)^{\alpha_{k,s}} \left(\frac{r_j}{\alpha_{k,cap}} \right)^{\alpha_{k,cap}} \tau_{ijk}}{A_{jk}P_{ik}} \right]^{1-\epsilon_k} \sigma_{ik}Y_iN_{jk}. \quad (21)$$

Equation (21) makes clear that bilateral trade in sector k measured in dollars depends positively on importing countries' consumers' expenditure share on k goods, σ_{ik} , and their total income, Y_i . On the other hand, because the elasticity of substitution between varieties is larger than one, the value of trade is falling in the price charged by exporting firms, p_{jk} . This combined with the pricing rule implies that trade is decreasing in the production cost of the exporter. If a factor is relatively expensive in a country, this entails a cost disadvantage for exporting firms in sectors where this factor is used intensively, while a high productivity in a sector implies a lower cost and an increase in the value of exports. All of the previous statements hold conditional on the number of firms active in the sector in the exporting country. Since we do not have reliable data on the number of firms active in exporting countries but we observe the value of sectoral production, we can use the model to solve for the number of firms given total production. The monetary value of total production of sector k in country j ($Output_{jk}$) is equal to the monetary value of production of each firm times the number of firms, and using equilibrium firm size (9), we can solve for the equilibrium

number of firms. Then:

$$\begin{aligned} p_{jk}q_{jk}N_{jk} &= Output_{jk} \\ N_{jk} &= \frac{Output_{jk}}{p_{jk}(\epsilon_k - 1)f_{jk}} \end{aligned} \quad (22)$$

We substitute for N_{jk} in the import equation, obtaining:

$$M_{ijk} = \left[\frac{\frac{\epsilon_k}{\epsilon_k - 1} \left(\frac{w_j^u}{\alpha_{k,u}} \right)^{\alpha_{k,u}} \left(\frac{w_j^s}{\alpha_{k,s}} \right)^{\alpha_{k,s}} \left(\frac{r_j}{\alpha_{k,cap}} \right)^{\alpha_{k,cap}}}{A_{jk}} \right]^{-\epsilon_k} \left[\frac{\tau_{ijk}}{P_{ik}} \right]^{1-\epsilon_k} \sigma_{ik} Y_i \frac{Output_{jk}}{(\epsilon_k - 1)f_{jk}} \quad (23)$$

Notice that this holds for every country j . If we establish a benchmark country for comparisons (for example the US)³ all the terms that do not depend on j (i.e. σ_{ik}, Y_i, P_{ik}) cancel. For each importer i we can express the productivity of country j in sector k relative to the US measured using imports of country i :

$$\begin{aligned} \frac{\tilde{A}_{ijk}}{\tilde{A}_{iUSk}} &= \\ &= \frac{A_{jk}}{A_{US,k}} \left(\frac{f_{jk}}{f_{US,k}} \right)^{1/\epsilon_k} \left(\frac{\tau_{ijk}}{\tau_{i,US,k}} \right)^{\frac{1-\epsilon_k}{\epsilon_k}} = \\ &= \left(\frac{M_{ijk}}{M_{i,US,k}} \frac{Output_{US,k}}{Output_{jk}} \right)^{1/\epsilon_k} \left(\frac{w_j^u}{w_{US}^u} \right)^{\alpha_{k,u}} \left(\frac{w_j^s}{w_{US}^s} \right)^{\alpha_{k,s}} \left(\frac{r_j}{r_{US}} \right)^{\alpha_{k,cap}} \end{aligned} \quad (24)$$

$\frac{\tilde{A}_{ijk}}{\tilde{A}_{iUSk}}$ is a combination of relative productivity, relative fixed costs and relative transport costs.

Intuitively, country j is measured to be more productive than the US in sector k if, controlling for the relative cost of factors, j exports a greater fraction of its production in sector k to country

³As a reference country, we need to use a country that exports in all sectors to all countries. Few countries fulfill this requirement. Changing the reference country to Germany or Japan does not alter the results.

i than the US. Note that we can compute this measure vis a vis every importing country using only data on relative imports, and exporters' production and factor prices. This "raw" measure of relative productivities contains also relative sectoral transport costs and fixed costs of production. While relative transport costs vary with importing countries, exporters' relative productivities are invariant to the importing country. Consequently, it is easy to separate the two parts using regression techniques. Taking logarithms, and assuming for the moment that fixed costs are equal across countries,⁴ we obtain:

$$\log \left(\frac{\tilde{A}_{ijk}}{\tilde{A}_{i,US,k}} \right) = \log \left(\frac{A_{jk}}{A_{US,k}} \right) + \frac{1 - \epsilon_k}{\epsilon_k} \log \left(\frac{\tau_{jk}^i}{\tau_{US,k}^i} \right). \quad (25)$$

We assume that sectoral transport costs τ_{ijk} between two countries are a log-linear function of bilateral variables - i.e. distance, common language, common border, free trade arrangements, tariffs, etc.- plus a random term. For each sector k we have the following panel data structure:

$$\begin{aligned} \log \left(\frac{\tilde{A}_{ij}}{\tilde{A}_{i,US}} \right) &= \log \left(\frac{A_j}{A_{US}} \right) + \beta_1 (\log Dist_{ij} - \log Dist_{i,US}) + \\ &\quad + \beta_2 (\log Tariff_{ij} - \log Tariff_{i,US}) + \\ &\quad + \beta_3 CommonLang_{ij} + \beta_4 CommonLang_{i,US} + \dots + \epsilon_{ij} \end{aligned} \quad (26)$$

where β represents the effect of the vector of control variables on total relative transport cost, multiplied by the negative term $\frac{1-\epsilon_k}{\epsilon_k}$. Thus, if we consider several importing countries we have a panel in which the dependent variable is the "raw" productivity computed for each country and the exporter dummy is precisely the relative total factor productivity of country j in sector k -

⁴We will relax this assumption later.

relative to TFP of the US in this sector. For each exporter-sector, $\tilde{A}_{jk}$ varies for each importing country, but much of this variation is explained by the bilateral variables. The TFP in sector k is computed as

$$\frac{A_{jk}}{A_{US,k}} = \exp \left[\log \left(\frac{\tilde{A}_{ijk}}{A_{i,US,k}} \right) - \beta_{FE}^k X_{ijk}^- \right] \quad (27)$$

where the means are calculated across our (at most) 36 importing countries⁵. Notice that, as we are computing sectoral productivities relative to US, bilateral variables should also consider the relative difference with respect to the US. That is, when we compute the relative TFP of country j using imports to i we control not only for the distance between countries j and i but for the relative distance between those countries and the US. The same applies to tariffs. In the case of dummy variables like Common Language or Common Border, we opt for including a dummy for coincidence between exporter and importer country and another dummy variable for coincidence between the US and the importer country⁶.

Our measure of relative TFP is transitive in the sense that if country j has a TFP - relative to US - of A_k in sector k and country j' has a TFP of $\frac{A_k}{2}$ in the same sector then we can say that country j is twice as productive as country j' in that sector, so numbers are comparable *within* sectors. However, we cannot compare TFP in any country *between* sectors k and k' because this would mean to compare productivities across different goods.

⁵For many countries, the maximum number of importers is 35 because productivity could not be computed using data of the own country.

⁶So, for example in the regression, one expects $\beta_3 > 0$ and $\beta_4 < 0$.

4 The Data

In this section we describe all the inputs needed to construct our measures of sectoral productivity. Bilateral sectoral trade data (M_{ijk}) are obtained from the Nicita and Olarreaga (2007) World Bank Trade, Production and Protection database. This database merges trade flows and production data available from different sources into a common classification: the International Standard Industrial Classification (ISIC), Revision 2. The database potentially covers 100 developing and developed countries over the period 1976-2004. We use trade and production data averaged over the years 1994-1996, considering 36 importing countries and 64 exporting countries. Those 36 importing countries represent more than $\frac{2}{3}$ of the world imports⁷. For the 28 sectors in the ISIC classification, we exclude, Tobacco (314), Petroleum Refineries (353), Miscellaneous Petroleum and Coal products (354) and Other manufactured products not classified elsewhere (390) because trade data do not properly reflect the productivity in those sectors.

For each sector in each country we need the monetary value of production, $Output_{jk}$ ⁸. We also take these data from the Trade, Production and Production Database. The source of the production data in the database is the United Nations Industrial Development Organization (UNIDO) Industrial Statistics Database. UNIDO provides consistent data by collecting annual data directly from all member countries. For the years 1994-1996 some data have been updated by Mayer and Zignago (2005)⁹. The production data published by UNIDO is by no means complete, which is

⁷As we have to exclude the US as an importer country because we use them as our benchmark country, those countries represent more than 80% of the remaining imports.

⁸Gross Output represents the value of goods produced in a year, whether sold or stocked. It is reported in current dollars.

⁹They have updated a previous version of the Trade and Production Database. As in the latest version of the Trade, Production and Protection Database, data for the years 94-96 remain the same, the Mayer & Zignago database of 2005 is more complete than the Nicita & Olarreaga database of 2006.

the main reason why we could work only with 64 exporting countries¹⁰. UNIDO also collects data on establishments that we could have used directly, instead of using Gross Output data. However, these data are less complete than the production data and are more influenced by the fact that different countries use different threshold firm sizes when reporting data to the UNIDO¹¹.

Sectoral elasticities of substitution (ϵ_k) are obtained from Broda and Weinstein (2006). They construct elasticities of substitution across imported goods for the US at the Standard International Trade Classification (SITC) 5 digit level of disaggregation for the period 1990-2001. We transform those elasticities to our 3 digit ISIC Rev. 2 level of disaggregation using correspondences of the TPP database and UNIDO, and weighting elasticities by the US import share in 1995.

Factor intensities ($a_{k,u}; \alpha_{k,s}; \alpha_{k,cap}$) are assumed to be fixed across countries. This assumption allows us to use factor income share data for just one country, i.e. the US. To proxy for skill intensity, we follow Romalis (2004), by using the ratio of non-production workers to total employment, obtained from the NBER-CES Manufacturing Industry Database constructed by Bartelsman et al. (2000) and converting USSIC 87 categories to ISIC rev 2. Capital intensity is computed as 1 less the share of total compensation of labor in value added, from the same source. In our three factor model intensities are re-scaled such that $\sum \alpha_{k,i} = 1$; $i = u, s$ and cap ¹².

Table I shows the computed skill and capital intensities, and elasticities of substitution for our 24 industries. The capital share in manufacturing is significantly higher than the one for the whole economy ($\frac{2}{3}$ against $\frac{1}{3}$), and all sectors have a capital intensity higher than 0.5. There is a high

¹⁰Besides this, we require exporting countries to export at least to 5 importing countries in any given sector during the period 1994-1996.

¹¹While the fact that some countries do not consider micro-firms, whereas others do does not change aggregate output numbers much, the number of establishments is indeed severely affected by this inconsistency. For a description of UNIDO's data issues see Yamada (2005).

¹²As in Romalis (2004), $\alpha_{k,cap} = cap.intensity$; $\alpha_{k,S} = skill.intensity * (1 - \alpha_{k,cap})$ and $\alpha_{k,U} = 1 - \alpha_{k,S} - \alpha_{k,cap}$

correlation between capital and skill intensities (0.63) and in general, industries with relatively high capital intensities also have relatively high skill intensities¹³. It can be seen that elasticities of substitution vary relatively little, which is consistent with the finding of Broda and Weinstein (2006) that the lower the level of disaggregation, the less the variation in computed elasticities.

Wages and rental rates at the country level are computed using the methodology proposed by Caselli (2005), Caselli and Coleman (2006) and Caselli and Feyrer (2006). The definition of the rental rate is consistent with a dynamic version of our model in which firms solve an inter-temporal maximization problem and capital markets are competitive¹⁴. Total payments to capital in country j are $\sum_k p_{jk} MPK_{jk} K_k = p_{jk} MPK_{jk} \sum_k K_k = r_j K_j$ where K_j is the country j 's capital stock in physical units. Since $\alpha_{j,cap} = \frac{r_j K_j}{P_Y Y}$ where Y is GDP in Purchasing Power Parities, the following equation follows immediately:

$$r_j = \alpha_{j,cap} \frac{GDP_j}{K_j}$$

Capital stock in physical units is computed by the permanent inventory method using investment data from the Penn World Tables (PWT). GDP_j is also obtained from the PWT and is expressed in current dollars. $\alpha_{j,cap}$ is the country's capital income share, taken from Bernanke and Gürkaynak (2002) and Gollin (2002). These estimates compute the capital share as one minus the labor share in GDP. In turn, the labor share is employee compensation in the corporate sector from the National Accounts plus a number of adjustments to include the labor income of the self-employed

¹³Beverages is the sector that has both the highest capital and the highest skill intensity.

¹⁴Firms set the marginal value product equal to the rental rate $p_{jk} MPK_{jk} = P_{Kj}(interest_j + \delta)$, where P_{Kj} is the price of capital goods in country j , $interest_j$ is the net interest rate in country j and δ is depreciation. This can be seen considering the decision of firms in sector k in country j to buy an additional unit of capital. The return from such an action is $\frac{p_{jk}(t) MPK_{jk}(t) + P_{Kj}(t+1)(1-\delta)}{P_{Kj}(t)}$. Abstracting from capital gains, firms will be indifferent between investing in the firm or in an alternative investment opportunity that has a return $interest_j$, when the above relationship holds. Because capital is mobile across sectors within a country the marginal value product must be equalized across sectors.

and non-corporate employees.

To compute the skilled and unskilled wages we use the the following result for the labor share:

$$(1 - \alpha_{j,cap}) = \frac{w_u L_u + w_u \frac{w_s}{w_u} L_s}{GDP_j} \quad (28)$$

Total labor share is equal to total payments to both skilled and unskilled workers over total GDP.

Skilled and unskilled workers are expressed in efficiency units of non-educated workers and workers with complete secondary education.¹⁵ Thus,

$$L_u = L_{noeduc} + e^{\beta * \frac{prim.dur.}{2}} L_{prim.incomp.} + e^{\beta * prim.dur.} L_{prim} + e^{\beta * lowsec.dur.} L_{lowsec.}$$

$$\text{and } L_s = L_{secondary} + e^{2\beta} L_{ter.incomp.} + e^{4\beta} L_{tertiary}$$

Educational attainment of workers over 25 years at each educational level are taken from Barro and Lee (2001) and Cohen and Soto (2001). Duration of each level of schooling in years by country is taken from the UNESCO¹⁶. The skill premium β for each country is obtained from Bils and Klenow (2000) and Banerjee and Duflo (2005). The wage premium $\frac{w_s}{w_u}$ equals $e^{\beta * (prim.dur. + lowsec.dur.)}$. Figure 3 shows the computed skilled and unskilled wages, the wage premium, the capital stock per worker and the rental rate for the countries in our sample. We observe that although wages of both skilled and unskilled workers are much higher in rich countries, the wage premium is negatively related with per capita GDP, so rich countries have a relative advantage in skilled labor intensive sectors.

¹⁵Changing the base of skilled workers from completed secondary to completed primary, incomplete secondary or incomplete tertiary education does not alter the results significantly. Further details on the construction of the wages and rental rates can be found in the referenced papers of Caselli.

¹⁶Notice that for non-complete levels, we assume that duration is half of the complete level (except when we have data of lower secondary duration). For tertiary education we consider 4 years given lack of data for most of the countries

The relation between the rental rate and per capita GDP is slightly positive. The absence of a strong relationship between the marginal product of capital and income per capita is similar to Caselli and Feyrer (2006) once they correct for price differences and natural capital. Although we do not correct for the fraction of income that goes to natural capital in our three factor model, we do correct for the price level of GDP.

Having obtained our measure of "raw" productivity, we proceed to run the regression in (26). We obtain bilateral variables from two sources: Rose (2004) and Mayer and Zignago (2005). We include bilateral distance from the latter, who have developed a distance database which uses city-level data in the calculation of the distance matrix to assess the geographic distribution of population inside each nation. The basic idea is to calculate distance between two countries based on bilateral distances between cities weighted by the share of the city in the overall country's population. Those authors also provide a bilateral sectoral tariff database. Tariffs are measured at the bilateral level for each product of the HS6 nomenclature of the TRAINS database from UNCTAD. Tariffs are aggregated from TRAINS data in order to match the ISIC Rev.2 industry classification using the world imports as weights for HS6 products.

5 Results

Table II shows the regression results. We run a stepwise fixed effect panel regression¹⁷, so that at the end we keep only variables that are significant at 90 percent confidence level. Recall that the sign of the coefficients reflect the impact of the variable on transport cost times a negative

¹⁷Stepwise procedure starts with the full model with all the variables and one by one discard variables that are not significant at 10 percent of significance (and add again variables that become significant after other variables have been dropped).

term given by $\frac{1-\epsilon_k}{\epsilon_k}$. Of all the coefficients estimated for the 24 sectors that are significant, only one has a contra-intuitive sign (a dummy for common official language between the US and the importer country in Footwear). (Difference in) distances and tariffs are always significant (mostly at 1 percent) and negative¹⁸. We also include a dummy for common border between exporter and importer and between US and importer, a dummy for common colony between exporter and importer and a dummy for common border between importer and exporter¹⁹. The dummy for common language is mostly significant, as well as common colony and common border between exporter and importer (those three variables are always positive). For all industries, these variables explain always more than 30 percent of the variation of "raw" productivities within exporters, and in some industries, the explained variation is higher than 50 percent. Next, our measure of productivity is constructed using (27).

Overall, we compute almost 1500 sectoral total factor productivities (24 by country, 64 countries²⁰). Table III summarizes some information about these productivities. We present the unweighted and weighted (by output) country mean TFP across industries, the standard deviation and the sectors with maximum and minimum TFP for each country of our sample. Plastics (Sector 356), Metals (381) and Transports (384) are the sectors in which most of the poor countries are the least productive, while Footwear (324) and Furniture (332) are those sectors in which rich countries have the lowest productivities, although the pattern is not as clear as in poor nations. Many poor countries are the most productive in Food (311) and Apparel (322) while, again, there is no clear

¹⁸There is only one sector in which tariffs are not significant at 90% confidence level (Other Chemicals).

¹⁹We exclude dummies for Canada, Mexico and UK (common border and common colony with the US respectively) because they are almost never significant.

²⁰In some countries we do not compute 24 TFPs either because we do not have data on production for that sector or because we do not have enough data on trade (countries that exports to less than 6 countries in a sector). Ivory Coast is the country with the smallest number of sectors (16) and only 14 countries have less than 20 sectors.

pattern in which sectors rich countries are the most productive. Productivity differences between rich and poor countries are large -the lowest observed productivities are 7% while the highest ones are 1.67 of US productivities²¹.

Figure 4 plots estimated productivities against (the log of) GDP per capita for 8 out of the 24 sectors (the first sector of each 2 digit classification, i.e. 311, 321, 331....)²². There is a high correlation between TFP and GDP per capita in all sectors. Many European countries seem to be more productive than the US in most manufacturing sectors while in general, poor countries are far below the US productivity level in all sectors.

Our estimated TFPs allow us to construct "Ricardian" style curves of relative productivity between country j and the US. On the horizontal axis we order sectors with respect to relative TFP from the maximum to the minimum. Figure 5 presents this kind of graphic for 4 representative countries: Argentina, Germany, Malaysia and Zimbabwe. Thus, we can see that Zimbabwe is less productive than the US in all sectors, and in the relatively most productive one, the TFP of Zimbabwe is just $\frac{1}{4}$ of the US. Those sectors are Metals, Iron Steel and Apparel. The lowest productivity in Zimbabwe is around 7 percent of the US level for Rubber, Transport and Metal Products. Argentina and Malaysia - which represent medium income economies - are less productive than the US with the exception of one sector (Food and Apparel respectively). Germany has comparative advantages in textiles and metals and is less productive than the US in furniture, plastics and footwear. Given the transitivity property of our estimated TFP measure, one can construct analogous graphs of bilateral comparative advantages between any country pair by just

²¹The lowest ones are: Bangladesh in sector 332, Jordan in 356, Romania in 385 and Zimbabwe in 381. The largest ones are: Denmark in 332 and Sweden in 356

²²We present just 8 scatters to exemplify our results. The same applies to other results. Complete data are available upon request and will soon be on-line at <http://www.pablofleiss.com>

dividing relative TFPs of those two countries. Relative advantages with respect to the rest of the world could also be constructed by taking the weighted mean (by GDP) of relative TFPs.

As a robustness check, first we want to make sure that our estimated measures of sectoral TFP do not just reflect the ratio of trade over production. We plot - in Figure 6 - the whole sample of estimated TFPs against the ratio of exports over production. Although the correlation is positive and significant ($\rho = 0.43$), it is not one-to-one. As predicted by our theory, a significant proportion of trade over production is explained by transport cost and factor proportions. Only the remaining part is due to productivity. For example, if a country sells almost all its production in a given sector to a single importer (and very few to the rest of the world), the ratio of exports to output will be close to one, but since we estimate TFP as a fixed effect over many importing countries, the sectoral productivity will be estimated to be relatively low in this country because the exporter is not competitive in most markets.

As a second step, we compare our estimates with a battery of measures of specialization that have been proposed in the literature. Although our estimated productivity is not a measure of specialization, our theory predicts a relatively high correlation between productivity and specialization in the sense that countries will export most of their production in sectors with high productivities (with respect to the rest of the world). Therefore, we construct a relative productivity with respect to weighted average world productivity (with weights given by output shares). We do this because a country could be less productive than the US but nevertheless be relatively more productive than the rest of the world, if productivity of US is relatively high in this sector²³. Then, for each country,

²³The correlation between relative production with respect to the US and with respect to the weighted world average is 0.99.

we compute the correlation between relative TFP and several measures of specialization²⁴.

Our first measure of specialization is the coefficient of specialization proposed by Gustavsson et al. (1999). It is defined as the ratio of production to consumption

$$r_{jk} = \frac{Q_{jk}}{C_{jk}} = \frac{C_{jk} + X_{jk} - M_{jk}}{C_{jk}} = 1 + \frac{X_{jk} - M_{jk}}{C_{jk}} \quad (29)$$

This indicator is zero when all the consumption corresponds to imported products and tends to infinity when a country exports all its production and consumes nothing.

Balassa (1986) presents a variation of this measure, $1 + \frac{X_{jk} - M_{jk}}{X_{jk} + M_{jk}}$, that scales net exports by total trade rather than consumption.

A further measure is the revealed comparative advantage proposed by Balassa (1965), which is defined as:

$$RCA_{jk} = \frac{X_{jk} / \sum_j X_{jk}}{\sum_k X_{jk} / \sum_j \sum_k X_{jk}} \quad (30)$$

The numerator represents the percentage share of a given sector in national exports²⁵ and the denominator represents the percentage share of a given sector in world exports. Thus, the RCA index contains a comparison of national export structure (the numerator) with the world export structure (the denominator). When RCA equals 1 for a given sector in a given country, the percentage share of that sector is identical with the world average. When RCA is above 1 the country is said to be specialized in that sector and vice versa if RCA is below 1. However, since the RCA turns out to produce an output which cannot be compared on both sides of 1, the index is

²⁴So, each correlation has a maximum of 24 observations.

²⁵Recall X_{jk} are exports of country j in sector k .

made symmetric, by constructing the ratio $(RCA_{jk} - 1)/(RCA_{jk} + 1)$. This measure ranges from -1 to +1 and is labeled Revealed Symmetric Comparative Advantage (RSCA)²⁶.

The Michaely index (see Michaely (1967)) is defined as: $X_{jk}/\sum_j X_{jk} - M_{jk}/\sum_j M_{jk}$. The first part of the formula represents the percentage share of a given sector in national exports, while the latter part represents the percentage share of a given sector in national imports. The measure ranges between [-1;1] with a neutral value of zero. If the value of the index is positive, a country is specialized in a sector, while given a negative value, a country is said to be under-specialized in a sector.

Finally, Redding (2002) argues that the share of value added in total value added is a theory-consistent measure of specialization in an industry. Table IV shows the correlation between our relative (with respect to the world weighted average) TFPs and the set of measures of specialization²⁷. We also include the ratio of exports to total production by country. On average, relative TFP is highly correlated with the mentioned ratio of export to production and the two Balassa coefficients. The correlation with the Michaely index and with the coefficient of specialization is lower and there is very little correlation between the value added share and relative TFP.

As an application, we relate differences in sectoral TFP to factor intensities of production. Acemoglu and Zilibotti (2001) find that sectoral TFP differences are more pronounced in less skill intensive sectors, which supports their theory of adequate technology. Following their approach, we divide countries in two groups: "rich" countries, with GDP per capita higher than US\$ 8,000 (24 countries in our sample) and "poor" countries with income per capita lower than the mentioned

²⁶See Laursen (1998) for further details.

²⁷We exclude Zimbabwe because we have no data on aggregate exports and imports. For Germany and Guatemala we have no data on value added.

value (the remained 40 countries)²⁸. Subsequently, we compute the ratio of average sectoral productivities between these two groups. Figure 7 plots rich countries' relative productivities against the skill and the capital intensities of our three factor model. It is apparent that there is a positive relation between $a_{k,S}$ (the skill intensity of sector k) and the ratio of mean productivities between rich and poor countries. This means that poor countries are relatively less productive in skill intensive sectors (or from the other point of view, more productive in sectors with low skill intensity)²⁹, which is exactly the opposite of the results of Acemoglu and Zilibotti (2001). Plotting the ratio of mean TFP against $a_{k,cap}$, the capital intensity of sector k , the relation is slightly negative but not significant, which means that poor countries have not special relative disadvantage in capital intensive sectors.

The differences in relative productivities in poor and rich countries in skilled intensive and non-intensive sectors can also be seen in figure 8. In each scatter we present the relation between income per capita and TFP in two different sectors, a skill intensive and a non skill intensive one. Arrows from the non skill intensive sector's TFP to the skill intensive sector's TFP reflect productivity differences. In the left scatter we compare Textiles - ratio of non-production workers to total employment equals 0.16 - with Machinery (0.35) and on the right we compare Furniture (0.19) with Other Chemicals (0.44). In poor countries, arrows are mostly descending (which means that poor countries have a relative lower TFP in skill intensive sectors), while the pattern is not that clear in rich countries. Some arrows go up while others (not many) go down.

²⁸The results are robust to choosing another break point to divide the sample in rich and poor countries.

²⁹Although on average, rich countries are at least twice as productive as poor countries.

6 Conclusion

Starting from a hybrid Ricardo-Heckscher-Ohlin model with transport costs and using trade and production data, we have estimated sectoral -3 digit manufacturing- productivity as observed trade that cannot be explained by differences in factor intensities and factor prices or by differences in trade barriers across countries. The advantage of our methodology is that we can estimate comparable sectoral productivities for a broad set of developed and developing countries, with no need of sectoral input data or output price series. Furthermore, the use of bilateral trade data allows us to obtain a measure of sectoral productivity of the exporting country with respect to every importer, which enables us to assess the reliability of our estimates.

Productivity differences in manufacturing sectors are large and systematically related to income per capita. In addition, productivity variation between rich and poor countries is more pronounced in skill intensive sectors. Some poor countries have higher productivities than the US in a small set of sectors. Moreover, our methodology permits to compute bilateral rankings of comparative advantage that are due to productivity for any two countries. Finally, there is a robust correlation between sectoral productivities and various measures of specialization.

We plan to extend the paper by using the productivity estimates to address several counterfactual scenarios in general equilibrium. First, the effect of factor accumulation on welfare and income per capita and second, the effect of lowering trade barriers on the same variables. Other possible extensions are to use country specific factor income shares in the sectoral production functions and to deal with the issue of how cross country differences in sectoral fixed costs affect our productivity measures. In addition, we plan to do a more careful analysis how differences in sectoral productivities relate to different theories of development.

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Figure 1
Quasi-Heckscher-Ohlin and Quasi-Ricardo

Example: $K=2/3$; $L=1/3$; $K^*=1/3$; $L^*=2/3$

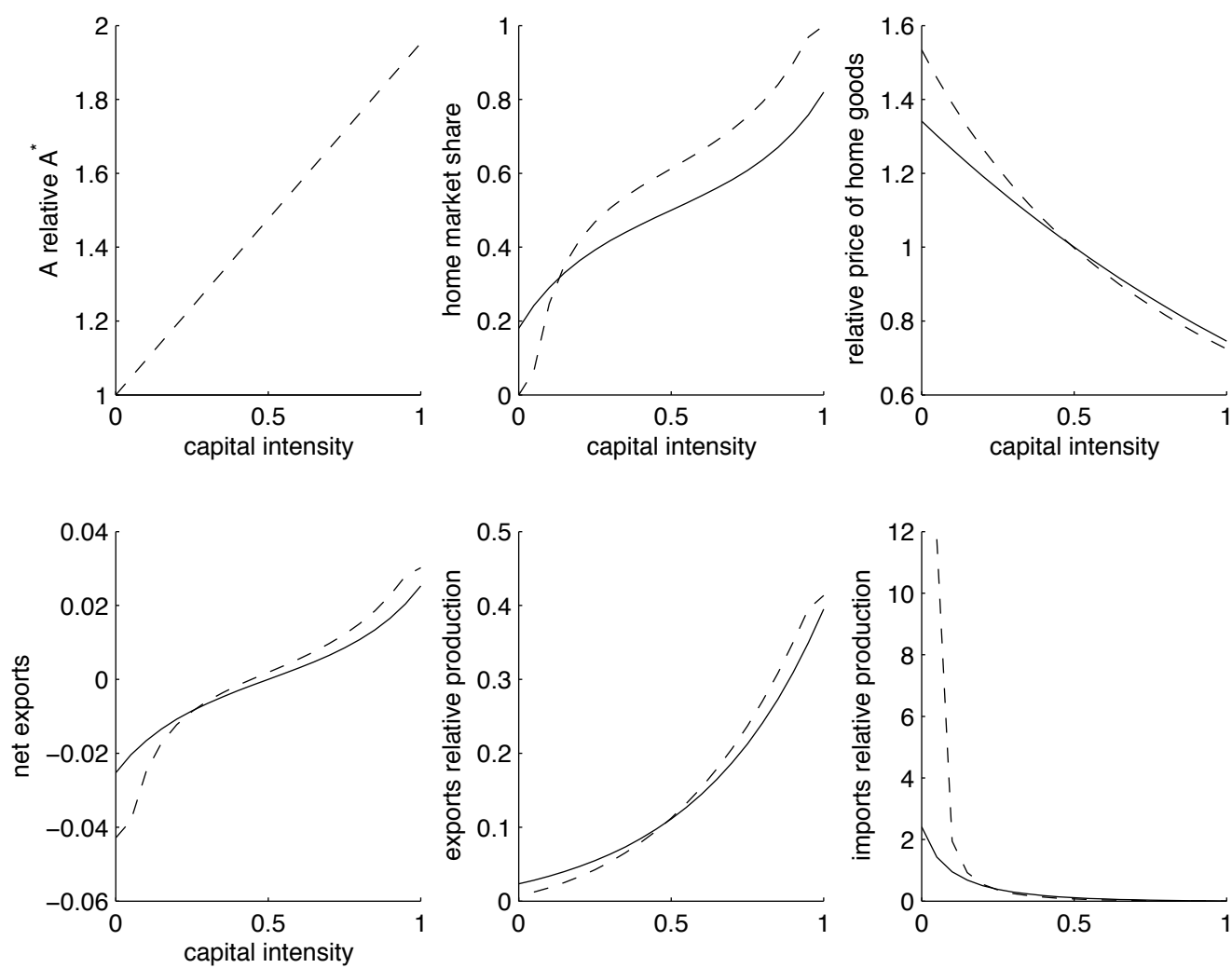


Figure 2
Quasi-Rybczynski Effect

Example: $K=1/3$; $L=1/3$; $K^*=1/3$; $L^*=1/3$; Home doubles Capital stock $K'=2/3$

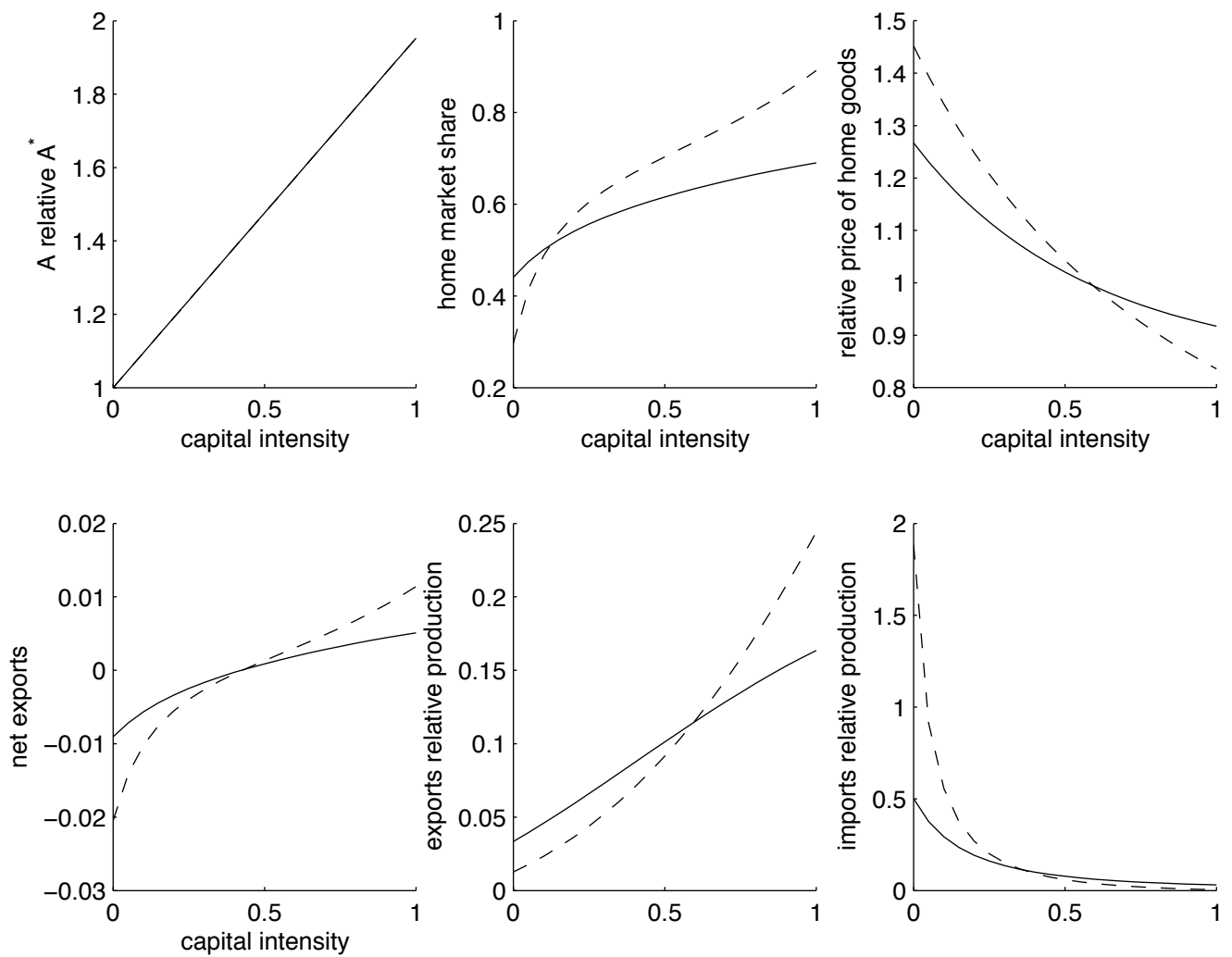


TABLE I: INDUSTRY STATISTICS

ISIC Rev. 2	Sector Name	Skill Intensity	Capital Intensity	Elasticity of Substitution
311	FOOD	0.24	0.77	5.33
313	BEVERAGES	0.49	0.85	3.72
321	TEXTILES	0.15	0.59	3.27
322	APPAREL	0.16	0.60	2.90
323	LEATHER	0.17	0.63	3.80
324	FOOTWEAR	0.15	0.60	3.29
331	WOOD	0.17	0.59	8.38
332	FURNITURE	0.19	0.55	2.29
341	PAPER	0.23	0.72	4.72
342	PRINTING	0.47	0.64	2.73
351	IND.CHEMICALS	0.41	0.82	3.77
352	OTHER.CHEMICALS	0.45	0.82	3.27
355	RUBBER	0.22	0.62	3.80
356	PLASTIC	0.23	0.68	1.81
361	POTTERY	0.18	0.57	3.26
362	GLASS	0.18	0.66	3.38
369	MINERALS	0.25	0.65	4.52
371	IRON.STEEL	0.21	0.63	7.58
372	METALS	0.22	0.66	12.68
381	METAL.PRODUCTS	0.25	0.56	3.54
382	MACHINERY	0.35	0.62	4.19
383	ELECTRICAL.MACH	0.35	0.70	3.39
384	TRANSPORT	0.32	0.62	3.86
385	SCIENTIFIC.EQUIP	0.47	0.67	3.17
MEAN		0.27	0.66	4.28

Source: Own computations using data of Bartelsman et al (2000) and Broda & Weinstein (2006). Skill Intensity is defined as the ratio of non-production workers over total employment. Capital intensity is defined as 1 minus the share of total compensation in value added.

Figure 3

Factor Prices

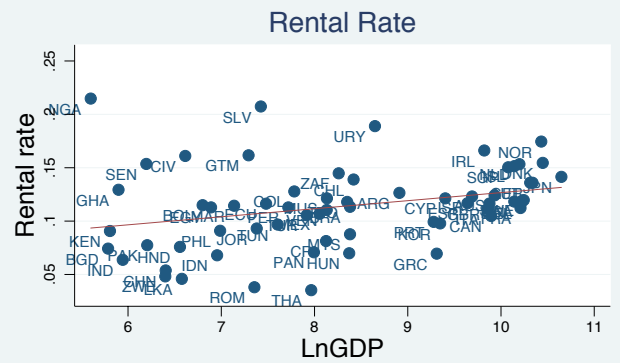
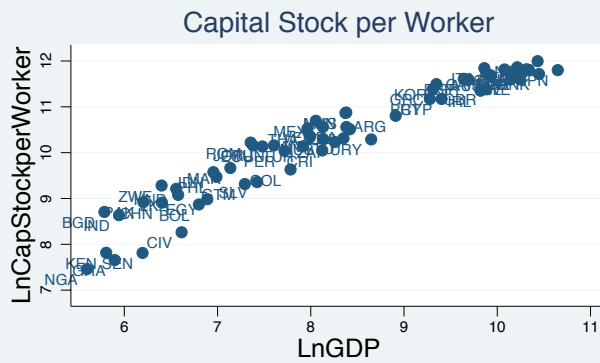
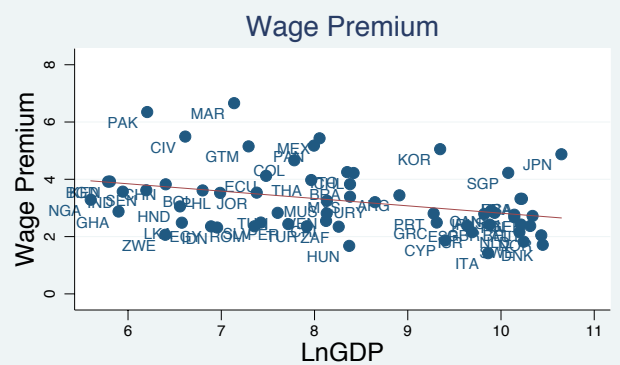
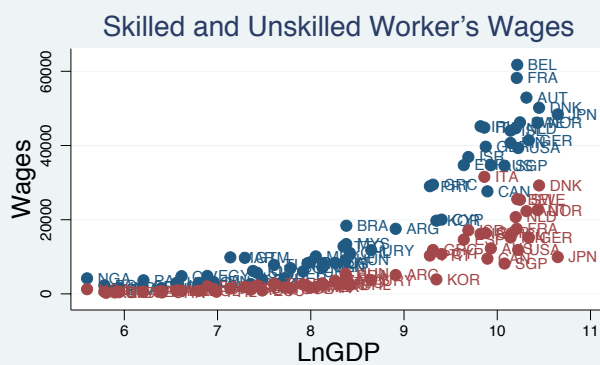


TABLE II: REGRESSION COEFFICIENTS

Dependent Variable: "Raw" Measure of Productivity

ISIC	311	313	321	322	323	324	331	332
Diff Ln(Distance)	-0.28 (28.45)***	-0.30 (15.23)***	-0.41 (25.92)***	-0.41 (15.98)***	-0.30 (20.21)***	-0.30 (13.23)***	-0.15 (20.58)***	-0.53 (17.65)***
Diff Tariff	-0.003 (3.07)***	-0.003 (1.95)*	-0.02 (8.23)***	-0.03 (8.68)***	-0.03 (10.44)***	-0.01 (4.98)***	-0.02 (7.93)***	-0.10 (12.20)***
Common Lang.	0.09 (3.49)***	0.22 (4.64)***	0.18 (4.44)***	0.19 (3.75)***	0.18 (4.45)***	0.18 (3.39)***	0.09 (5.86)***	0.22 (3.52)***
Common Lang. US	-0.10 (5.91)***	-0.07 (2.34)**	-0.11 (4.15)***		-0.06 (2.10)**	0.09 (2.50)**		
Common Colony	0.24 (5.93)***	0.18 (2.38)**	0.25 (4.56)***	0.37 (5.34)***	0.26 (4.79)***		0.06 (2.65)***	0.40 (4.65)***
Border		0.20 (2.53)**				0.37 (4.18)***	0.12 (3.97)***	0.23 (2.00)**
R-squared	0.4	0.34	0.48	0.43	0.4	0.32	0.42	0.54
Observations	2041	1417	2016	1959	1839	1423	1823	1656
Number of Contries	63	58	63	63	61	57	63	60
ISIC	341	342	351	352	355	356	361	362
Diff Ln(Distance)	-0.37 (33.72)***	-0.41 (21.67)***	-0.37 (29.75)***	-0.39 (34.27)***	-0.29 (19.92)***	-0.73 (24.10)***	-0.29 (14.85)***	-0.41 (25.53)***
Diff Tariff	-0.02 (5.71)***	-0.06 (6.52)***	-0.01 (2.46)**		-0.06 (12.19)***	-0.06 (12.89)***	-0.04 (11.52)***	-0.03 (7.54)***
Common Lang.	0.10 (3.22)***	0.54 (9.97)***	0.09 (2.07)**	0.31 (6.84)***	0.19 (5.08)***	0.47 (6.18)***	0.26 (5.75)***	0.20 (3.98)***
Common Lang. US		-0.45 (14.31)***	-0.12 (4.67)***	-0.09 (3.29)***	-0.05 (1.77)*	-0.10 (1.94)*		
Common Colony		0.49 (6.45)***	0.15 (2.48)**	0.20 (3.59)***		0.26 (2.41)**	0.17 (2.41)**	0.13 (1.98)**
Border		0.25 (3.00)***			0.15 (2.34)**			0.19 (2.54)**
R-squared	0.52	0.57	0.39	0.4	0.52	0.56	0.39	0.52
Observations	1601	1706	1891	1800	1577	1762	1586	1533
Number of Contries	62	60	62	61	59	62	57	57
ISIC	369	371	372	381	382	383	384	385
Diff Ln(Distance)	-0.29 (23.17)***	-0.19 (30.09)***	-0.14 (28.35)***	-0.36 (27.70)***	-0.25 (24.64)***	-0.29 (21.64)***	-0.29 (16.65)***	-0.25 (18.87)***
Diff Tariff	-0.02 (4.98)***	-0.02 (6.15)***	-0.01 (4.24)***	-0.04 (11.69)***	-0.02 (5.89)***	-0.04 (12.43)***	-0.04 (9.55)***	-0.02 (6.48)***
Common Lang.	0.08 (2.55)**			0.20 (5.54)***	0.20 (7.07)***	0.25 (6.22)***	0.13 (2.83)***	0.27 (6.81)***
Common Lang. US			-0.04 (4.41)***	-0.09 (4.19)***	-0.11 (5.60)***	-0.05 (2.01)**		-0.14 (5.47)***
Common Colony	0.09 (2.26)**	0.09 (3.55)***	0.08 (5.09)***	0.27 (5.26)***	0.20 (4.83)***	0.25 (4.60)***	0.24 (3.21)***	0.27 (4.39)***
Border	0.13 (2.53)**						0.17 (2.40)**	
R-squared	0.47	0.47	0.5	0.55	0.4	0.43	0.36	0.37
Observations	1540	1420	1415	1862	1953	1935	1797	1741
Number of Contries	60	55	51	61	60	61	62	56

Absolute value of robust t statistics in parentheses * significant at 10%; ** significant at 5%; *** significant at 1%
This table shows the coefficients of the stepwise fixed effect panel regression of the raw measure of productivity against the distance between importer and exporter (relative to the distance between US and importer). The tariff between Imp. & Exp. (relative to the tariff between US and Imp.), and dummies for common language between Imp. & Exp., common language between US and Imp., common colony and common border between Imp. & Exp.

TABLE III: DESCRIPTIVE STATISTICS OF OUR CONSTRUCTED RELATIVE TFP

Country	Mean			S.D.			Weighted			Country	Mean			S.D.			Weighted			Country	Max			Min			
	TFP	TFP	TFP	TFP	TFP	TFP	TFP	TFP	TFP		TFP	TFP	TFP	TFP	TFP	TFP	TFP	TFP	TFP		ISIC	TFP	ISIC	TFP	ISIC	TFP	ISIC
Argentina	0.47	0.25	0.65	311	1.21	356	0.08	Italy	1.16	0.19	1.09	322	1.55	352	0.88												
Australia	0.88	0.29	0.96	321	1.61	324	0.53	Jordan	0.26	0.11	0.26	313	0.46	356	0.07												
Austria	1.06	0.25	1.05	322	1.61	332	0.50	Japan	0.82	0.25	0.90	355	1.27	324	0.31												
Belgium	1.11	0.28	0.99	352	1.51	361	0.44	Kenya	0.16	0.07	0.18	311	0.27	355	0.08												
Bangladesh	0.15	0.09	0.17	356	0.38	332	0.07	Korea, Rep.	0.55	0.14	0.59	355	0.85	332	0.31												
Bolivia	0.32	0.23	0.33	361	1.21	356	0.08	Sri Lanka	0.21	0.06	0.24	332	0.36	384	0.11												
Brazil	0.51	0.20	0.58	311	1.04	361	0.23	Morocco	0.27	0.10	0.32	372	0.49	356	0.13												
Canada	0.70	0.14	0.73	341	1.01	324	0.41	Mexico	0.43	0.14	0.45	313	0.77	384	0.23												
Chile	0.47	0.30	0.70	313	1.26	356	0.13	Mauritius	0.39	0.15	0.59	311	0.77	332	0.24												
China	0.19	0.07	0.17	356	0.40	384	0.10	Malaysia	0.62	0.24	0.61	322	1.47	384	0.35												
Cote d'Ivoire	0.37	0.18	0.53	311	0.90	381	0.15	Nigeria	0.32	0.25	0.21	351	1.00	381	0.08												
Colombia	0.28	0.13	0.35	311	0.60	356	0.08	Netherlands	1.34	0.15	1.32	313	1.60	361	0.93												
Costa Rica	0.29	0.10	0.35	372	0.52	356	0.09	Norway	1.12	0.27	1.15	341	1.50	342	0.56												
Cyprus	0.64	0.22	0.63	384	1.30	356	0.39	Pakistan	0.22	0.17	0.26	322	0.72	384	0.08												
Denmark	1.38	0.21	1.42	332	1.67	362	1.00	Panama	0.33	0.09	0.32	351	0.52	356	0.19												
Ecuador	0.27	0.13	0.36	311	0.61	356	0.07	Peru	0.29	0.17	0.41	311	0.83	324	0.10												
Egypt	0.28	0.09	0.31	372	0.47	356	0.14	Philippines	0.29	0.12	0.30	332	0.65	355	0.12												
Spain	0.84	0.12	0.83	369	1.09	356	0.58	Portugal	0.63	0.14	0.64	313	0.97	332	0.35												
Finland	0.88	0.20	0.97	341	1.23	324	0.38	Romania	0.12	0.04	0.13	371	0.21	385	0.07												
France	0.95	0.16	0.92	313	1.51	324	0.69	Senegal	0.33	0.21	0.39	322	0.86	381	0.10												
UK	0.92	0.17	0.89	313	1.47	356	0.62	Singapore	1.15	0.29	1.08	355	1.66	361	0.57												
Germany	1.03	0.13	1.01	321	1.33	324	0.71	El Salvador	0.62	0.25	0.52	361	1.29	356	0.20												
Ghana	0.23	0.13	0.25	311	0.62	381	0.08	Sweden	1.22	0.22	1.19	356	1.67	342	0.84												
Greece	0.44	0.12	0.47	385	0.68	356	0.26	Thailand	0.27	0.11	0.26	332	0.59	313	0.14												
Guatemala	0.40	0.19	0.54	322	0.85	356	0.14	Trinidad	0.45	0.18	0.56	313	0.89	383	0.23												
Honduras	0.23	0.14	0.20	384	0.65	381	0.09	Tunisia	0.24	0.08	0.26	372	0.39	356	0.08												
Hungary	0.37	0.08	0.38	371	0.50	356	0.18	Turkey	0.32	0.10	0.36	311	0.51	356	0.12												
Indonesia	0.36	0.17	0.36	332	0.80	384	0.15	Uruguay	0.63	0.28	0.85	322	1.24	356	0.17												
India	0.19	0.11	0.19	332	0.57	356	0.10	US	1.00	-	1.00	372	0.59	356	1.00												
Ireland	1.15	0.24	1.21	352	1.56	362	0.70	Venezuela	0.28	0.13	0.36	372	0.59	356	0.09												
Iceland	0.90	0.28	0.97	371	1.34	332	0.27	South Africa	0.53	0.21	0.61	311	0.92	342	0.03												
Israel	0.90	0.24	0.89	385	1.43	361	0.48	Zimbabwe	0.14	0.05	0.13	372	0.23	381	0.07												

1st column shows the (unweighted) mean across 24 industries for each country. Third Column shows the weighted mean (weighted by output).

Last four columns shows the value and the industry for country's maximum and minimum TFP.

Figure 4
Relative TFP Selected Sectors

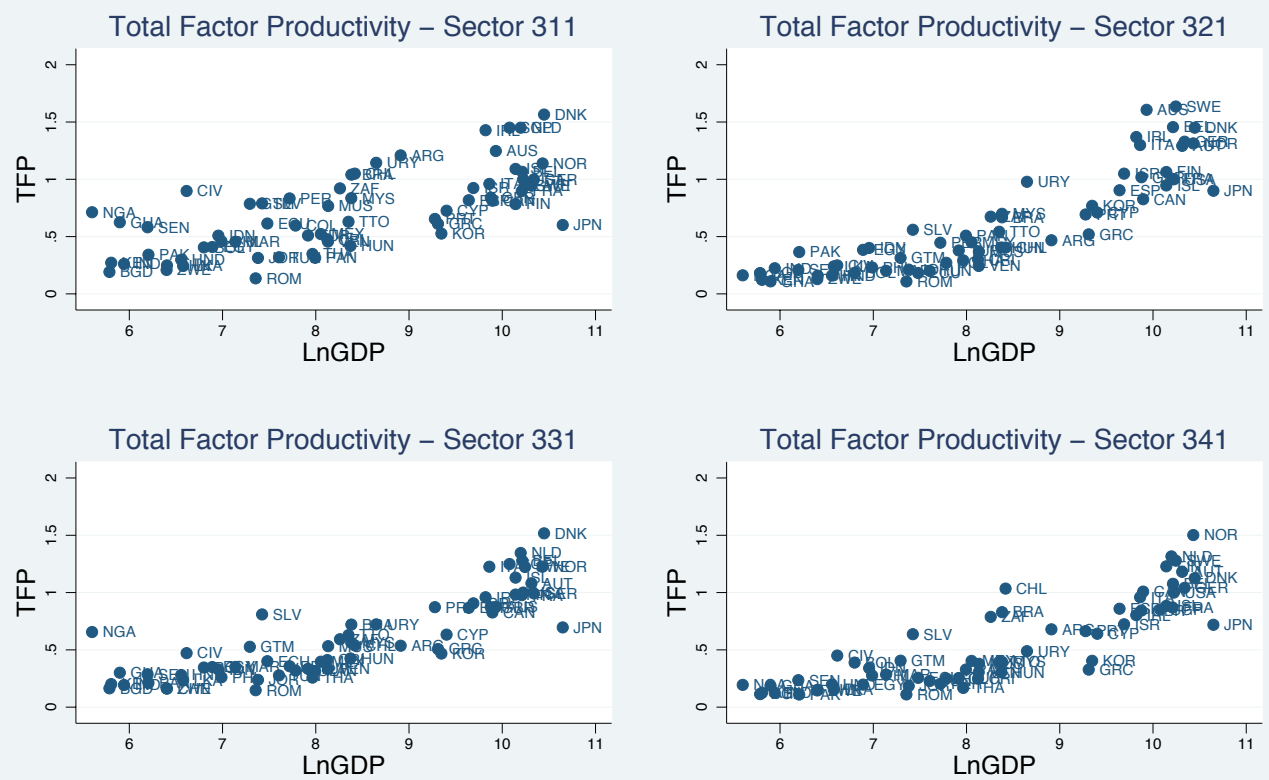


Figure 4 – Cont.
Relative TFP Selected Sectors

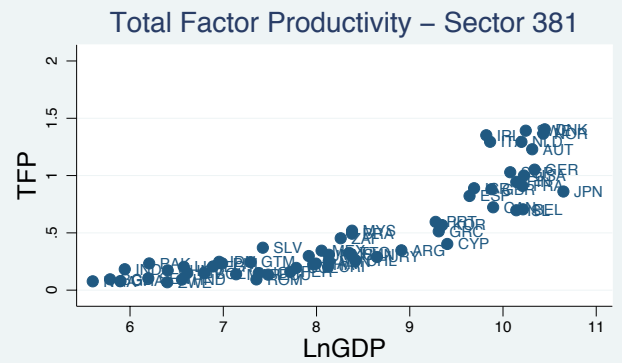
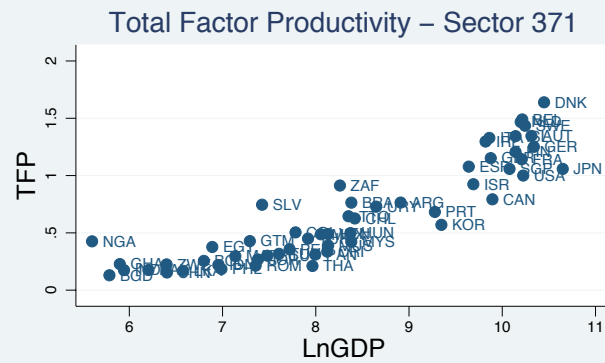
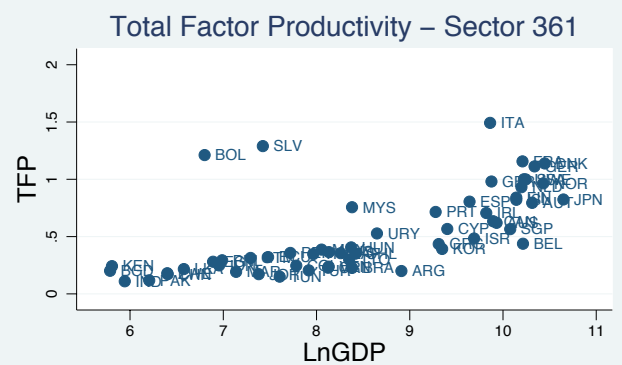
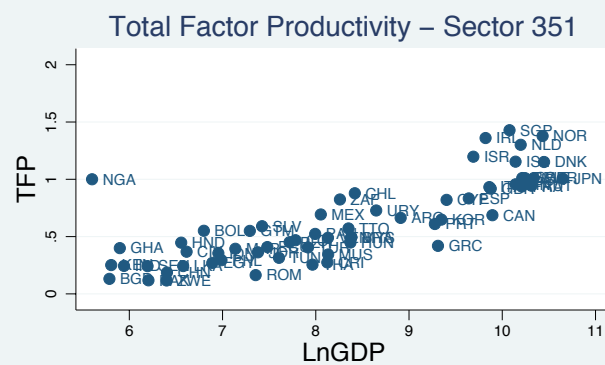
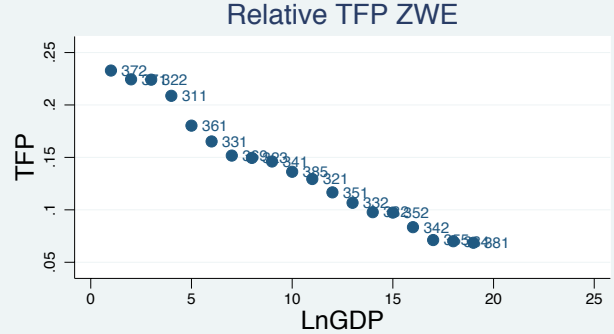
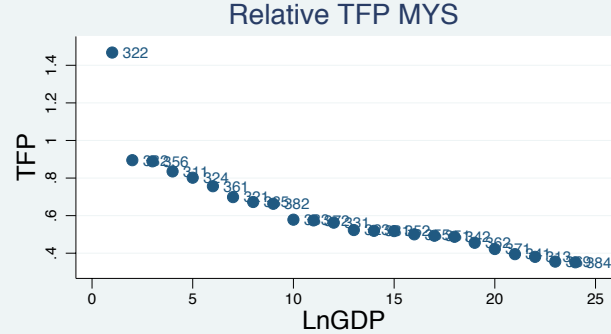
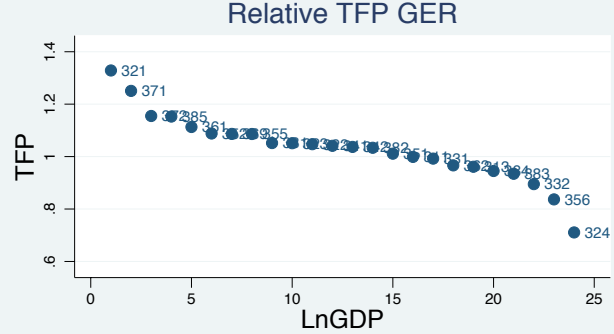
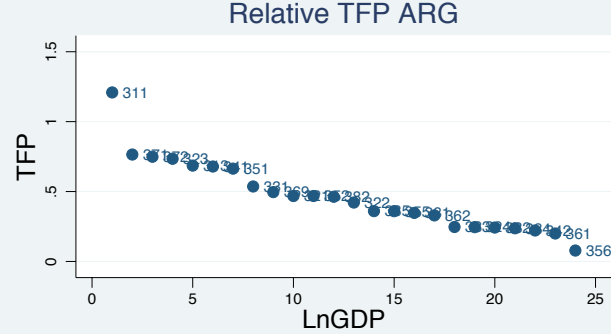


Figure 5
Relative TFP Selected Countries



Y axis are not in the same scale

Figure 6

TFP and Ratio exports/production

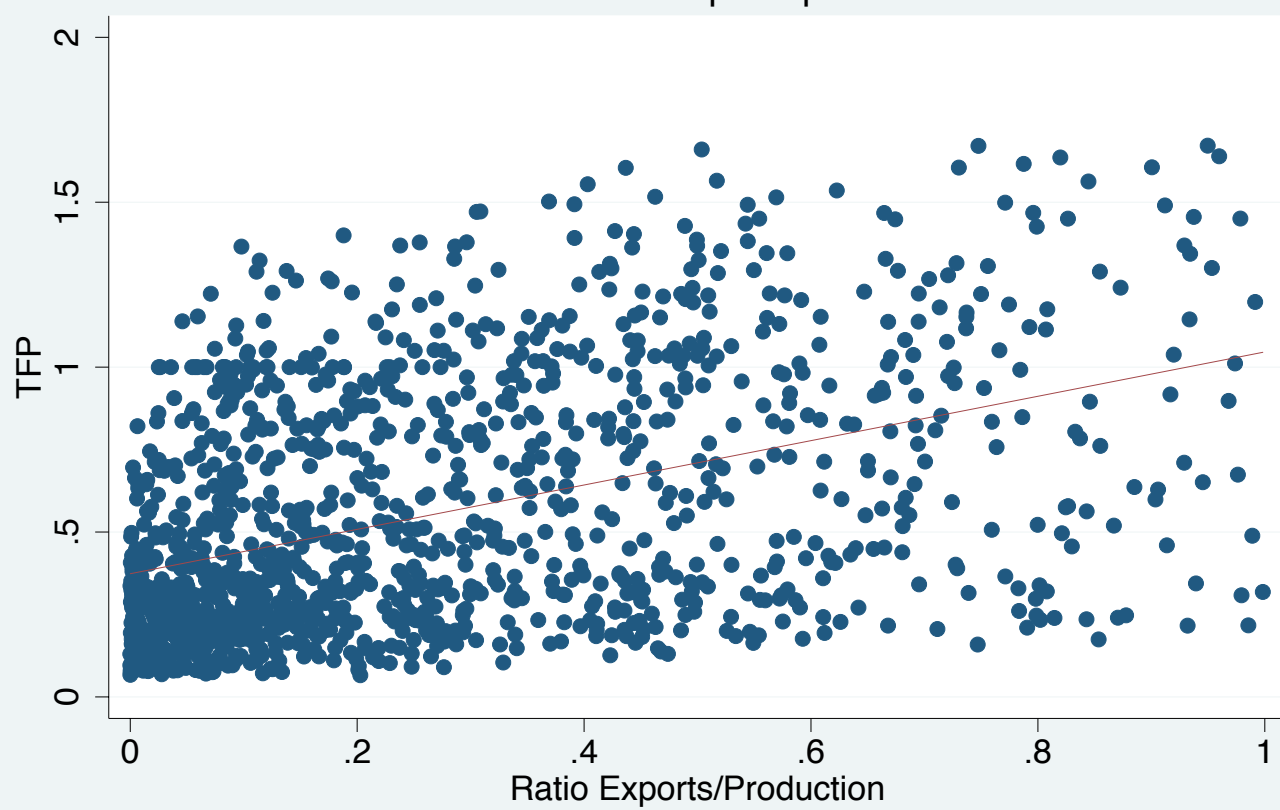


TABLE IV: CORRELATION BETWEEN ESTIMATED SECTORAL TFP AND MEASURES OF SPECIALIZATION

Country	Ratio Exp/Prod	Coef. Spec.	Spec. Balassa	RSCA	MI	Share VA	Country	Ratio Exp/Prod	Coef. Spec.	Spec. Balassa	SRCA	MI	Share VA
Argentina	0.51	0.49	0.69	0.71	0.67	0.51	Italy	0.10	0.68	0.67	0.68	0.59	- 0.21
Australia	0.78	0.38	0.79	0.83	0.45	0.31	Jordan	0.29	- 0.24	- 0.01	- 0.04	0.12	0.08
Austria	0.37	- 0.08	0.05	0.19	0.08	- 0.07	Japan	0.74	0.73	0.87	0.88	0.50	0.34
Belgium	0.63	0.25	0.14	0.09	0.26	- 0.43	Kenya	0.17	- 0.23	0.22	0.19	0.35	0.42
Bangladesh	0.51	- 0.06	0.24	0.26	0.20	0.04	Korea, Rep.	0.61	0.58	0.70	0.66	0.31	0.22
Bolivia	0.81	- 0.11	0.14	0.12	0.16	- 0.01	Sri Lanka	0.43	0.12	0.55	0.41	0.39	0.18
Brazil	0.63	0.56	0.60	0.76	0.62	0.17	Morocco	0.61	0.23	0.40	0.40	0.43	0.32
Canada	0.27	0.59	0.52	0.46	0.32	0.26	Mexico	0.28	0.05	0.18	0.02	- 0.21	0.20
Chile	0.53	0.39	0.70	0.69	0.44	0.61	Mauritius	0.54	0.49	0.73	0.72	0.62	0.51
China	0.56	0.36	0.48	0.47	0.51	- 0.29	Malaysia	0.40	0.56	0.64	0.27	0.34	- 0.07
Cote d'Ivoire	0.37	0.03	0.42	0.30	0.71	0.62	Nigeria	0.32	- 0.06	- 0.09	- 0.02	- 0.20	- 0.23
Colombia	0.36	0.09	0.23	0.37	0.48	0.41	Netherlands	0.44	- 0.20	0.04	0.17	0.14	- 0.11
Costa Rica	0.48	0.18	0.43	0.09	0.40	0.32	Norway	0.51	0.10	0.43	0.41	0.21	- 0.08
Cyprus	0.30	- 0.21	0.07	- 0.11	- 0.15	- 0.05	Pakistan	0.69	0.09	0.69	0.55	0.36	0.05
Denmark	0.33	0.49	0.49	0.49	0.51	0.21	Panama	0.15	- 0.30	0.11	- 0.08	- 0.09	- 0.07
Ecuador	0.50	0.32	0.59	0.38	0.61	0.28	Peru	0.64	0.42	0.76	0.83	0.67	0.53
Egypt,	0.53	0.43	0.61	0.56	0.35	0.01	Philippines	0.50	0.74	0.69	0.58	0.38	0.03
Spain	0.01	0.51	0.62	0.59	0.21	- 0.08	Portugal	0.11	0.53	0.57	0.58	0.53	0.11
Finland	0.38	0.57	0.47	0.60	0.51	0.54	Romania	0.55	0.27	0.81	0.78	0.59	0.15
France	0.21	0.72	0.60	0.50	0.32	0.27	Senegal	0.40	- 0.53	- 0.28	- 0.33	- 0.11	0.13
U.K.	0.04	0.24	0.34	0.43	0.21	0.24	Singapore	0.15	- 0.02	0.52	0.22	- 0.02	0.02
Germany	0.18	- 0.15	0.07	0.02	- 0.30	- 0.35	El Salvador	0.47	- 0.37	- 0.05	- 0.15	0.07	- 0.32
Ghana	0.43	0.61	0.59	0.58	0.33	0.24	Sweden	0.50	0.07	0.16	0.22	0.11	- 0.08
Greece	0.55	0.24	0.49	0.48	0.53	0.35	Thailand	0.57	- 0.04	0.72	0.66	0.43	- 0.22
Guatemala	0.35	0.10	0.21	0.04	0.43	0.01	Trinidad	0.18	0.32	0.50	0.36	0.23	0.34
Honduras	0.81	- 0.18	0.12	- 0.18	0.01	0.01	Tunisia	0.06	0.20	0.19	- 0.01	0.14	0.17
Hungary	0.05	- 0.05	- 0.04	- 0.05	0.04	0.03	Turkey	0.51	0.35	0.48	0.58	0.36	0.33
Indonesia	0.44	0.49	0.70	0.62	0.37	- 0.15	Uruguay	0.28	0.58	0.64	0.61	0.63	0.45
India	0.47	- 0.28	0.31	0.18	0.31	- 0.14	Venezuela	0.64	0.53	0.60	0.64	0.60	0.65
Ireland	0.33	0.19	0.27	0.37	0.37	0.37	South Africa	- 0.42	0.02	- 0.14	- 0.03	- 0.18	0.49
Iceland	0.44	0.17	0.44	0.46	0.26	0.08	MEAN	0.40	0.21	0.40	0.37	0.30	0.13
Israel	0.71	0.12	0.43	0.65	0.37	0.01	MEDIAN	0.44	0.22	0.47	0.41	0.35	0.12

Note: Correlation between estimated relative sectoral TFP with respect of a world average (weighted by income) and measures of specialization. See the text for explanation about the construction of the variables. In bold, values of country correlation higher than 0.5

Figure 7

Relative average TFP between rich and poor countries and factor intensities

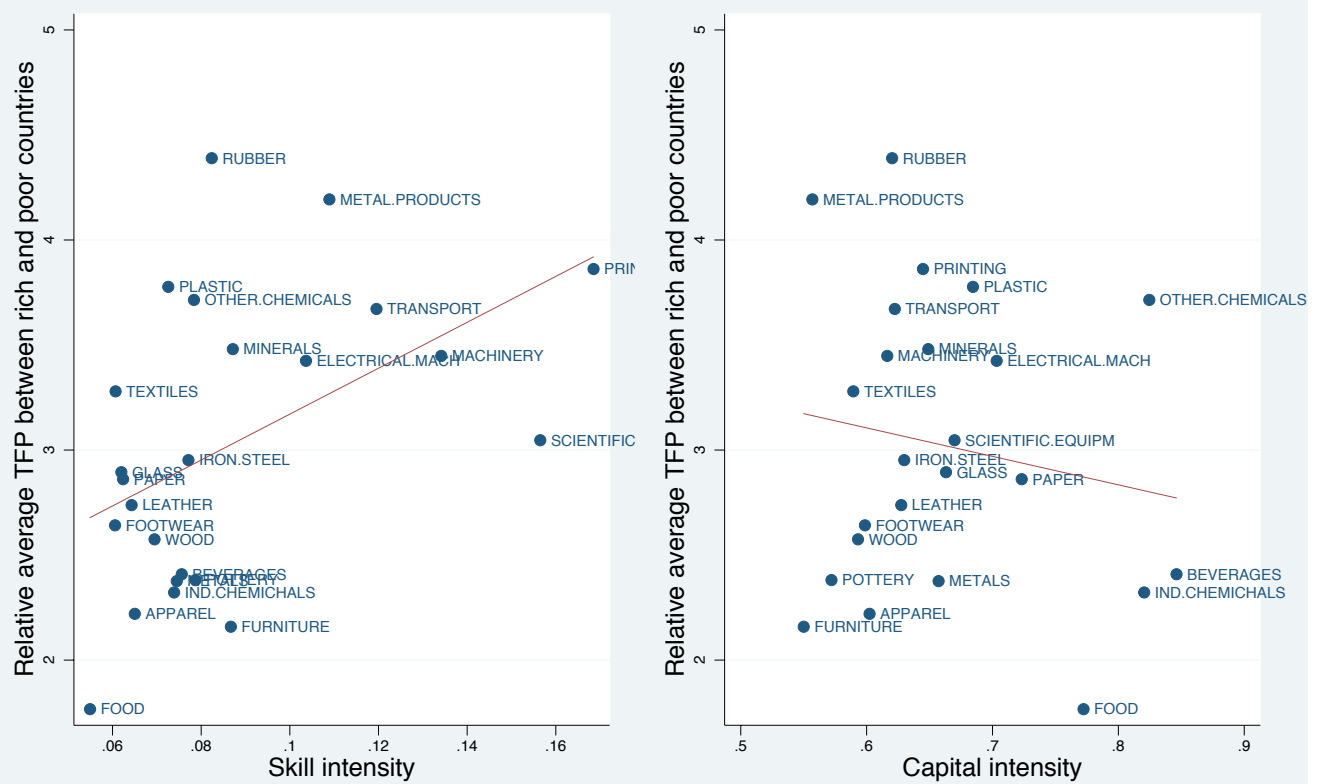
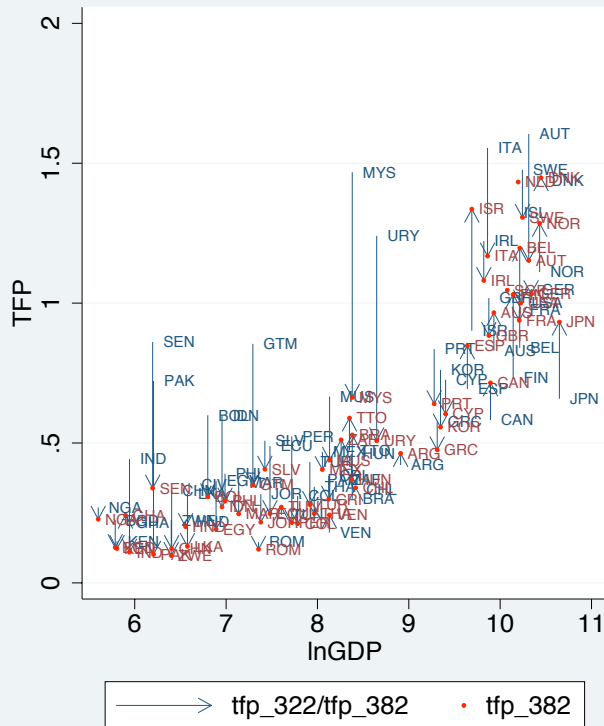


Figure 8

Relative TFP in skill intensive and non intensive sectors

TFP Apparel and Machinery



TFP Furniture and Chemicals

