Discussion Paper No. 944

DEVELOPMENT ACCOUNTING AND INTERNATIONAL TRADE

Hirokazu Ishise

August 2015

The Institute of Social and Economic Research
Osaka University
6-1 Mihogaoka, Ibaraki, Osaka 567-0047, Japan

Development Accounting and International Trade

Hirokazu Ishise*

August 21, 2015

Abstract

Development accounting shows that a significant part of cross-country income differences is attributed to differences in total factor productivity (TFP), but the sources of TFP differences are not well understood. This paper considers the role of international trade to explain cross-country income differences in TFP. By using a multi-country Ricardian trade model, I distinguish trade costs and trade policy factors from a pure technology factor in TFP. Under the baseline parameterization, my model shows that conventional TFP measures overestimate fundamental productivity differences by 30%. I then show that trade costs significantly influence welfare: small European countries enjoy 10–15% higher welfare through their proximity to larger and more productive neighboring countries, while Oceanian and countries in southern Africa suffer from 10–20% lower welfare due to their remoteness. Trade policy also has impacts: tariffs decrease welfare by 1–10%, while free-trade agreements increase welfare by 1–5%. These gains from trade are considerably smaller if general equilibrium effects are not considered.

Keywords: Development accounting; Total factor productivity; Cross-country income differences; Ricardian trade model; Gains from trade; General equilibrium effects.
JEL Codes: E22, E23, F11, O40, O47.

1 Introduction

Development accounting shows that cross-country income differences are explained by differences in the observable factors of capital and labor but also attributed to differences in total

*Institute of Social and Economic Research, Osaka University. Address: 6-1 Mihogaoka, Ibaraki, Osaka 567-0047, Japan; Phone: +81-6-6879-8581; Email to: ishise@iser.osaka-u.ac.jp; I would appreciate comments made by Takumi Naito, Ray Riezman, Katsuya Takii, and seminar/conference/workshop participants at Hitotsubashi U.; Osaka U.; Kyoto Development Economics Workshop; Spring 2015 JEA meeting; Spring 2015 Midwest International Trade Meeting; Osaka Workshop on Economics of Institutions and Organizations; 2015 Summer Workshop of Economic Theory. This work is supported by JSPS KAKENHI Grant Number 26885043. All errors are mine.

factor productivity (TFP) (see, e.g., Caselli, 2005; Hsieh and Klenow, 2010). This decomposition leads us to an important question: what can best explain cross-country TFP differences? This paper considers the role of international trade to explain cross-country differences in TFP. By introducing a multi-country Ricardian international trade structure in the standard development accounting model, I show that conventional TFP measures overestimate fundamental productivity differences by 30%. I then show that trade plays an important role in determining economic welfare. Small European countries enjoy 10–15% higher welfare through their proximity to large, productive countries, while Oceanian and South African countries suffer from 10–20% lower welfare due to their remoteness. Moreover, average tariff rates and free-trade agreements change welfare by as much as 10% for some developing countries.

My model combines the scheme of development accounting with Alvarez and Lucas's (2007b) specification of Eaton and Kortum's (2002) multi-country Ricardian trade model. I assume that technology difference in the intermediate goods production sector is the fundamental source of the TFP differences across countries.[1] Countries internationally trade intermediate goods to produce intermediate composite goods. The intermediate composite goods are used to produce consumption goods, investment goods, and intermediate goods. Through this chain of input-output, the aggregate output, and hence aggregate measured TFP, of each country depends not only on its own technology but also that of the other countries.

The autarky version of my model implies that standard development accounting is an appropriate method to calculate the underlying technology parameter.[2] The reason is that in a model with intermediate inputs, TFP of the aggregate production function is a weighted mean of the productivity of sectors (Hulten, 1978). In my model, intermediate goods are the only source of productivity, and hence the aggregate TFP directly corresponds to the fundamental technology parameter.

This simple correspondence between aggregate TFP and technology parameter does not hold under equilibrium with international trade. Yet, I can calculate productivity parameters for each country. I calibrate the model using data of 140 countries in 2005. Analogous to development accounting, the model isolates productivity of countries from observed income of countries. I then compare the productivity parameters obtained from standard development accounting to the parameters derived from a model under open-economy. Under the baseline parameterization, my model shows that the differences in cross-country productivity required to explain cross-country income difference are 30% smaller than the corresponding values from the standard development accounting exercise. The input-output chain mechanism amplifies small differences in the underlying technology to large differences in the aggregate measured

[1]Including variations in TFP in other sectors is technically possible. I do not include these additional variations in order to elucidate the mechanism driven by trade.

[2]Waugh (2010) obtains the analogous expression in his model, but does not highlight the result in this manner. See below for a brief discussion of how my paper differs from his.

TFP, which echoes the closed-economy models of Jones (2011, 2013).

Next, I explore the roles of trade costs and trade policies in determining welfare of a country, and find that these trade barriers play important roles. The calculations are as follows. First, I solve the equilibrium of the model under alternative (hypothetical) trade barrier assumptions while fixing baseline productivity parameters. Second, I calculate hypothetical utility values for various scenarios. Finally, I compare the consumption-equivalent welfare changes of two alternative scenarios, and measure the effects of various trade barriers on the economic welfare of countries. The results show large gains from trade, some effects of geography, and even smaller impacts from trade policy. The results also show that trade gains quantitatively depend on whether consideration is given to general equilibrium effects (through changes in wages of countries).

Average trade gains are large. Trade gains are especially large for small, developing countries: for some countries, current welfare is more than four times the welfare under autarky. By comparison, trade gains for large countries are much smaller. In addition, trade gains with general equilibrium effects are generally larger than gains without these effects.

Total trade gains are decomposed into the roles of trade, geography (trade costs), and trade policy. Trade itself plays the main role in determining the gains from trade, and other factors also play some roles. Small European countries enjoy 10-15% higher welfare through their proximity to large productive countries. These large European countries (e.g., Germany, France, the UK themselves benefit by being near one another and experience higher welfare by approximately 10%. The negative impacts of geography are prevalent for Oceanian and countries in southern Africa, which suffer from 10–20% lower welfare due to their remoteness. The largest negative impact, 22%, is (not surprisingly) observed for New Zealand. Trade policies affect welfare, but less than trade cost does. Average tariff rates and free-trade agreements change income 5–10% for some developing countries. In general, trade policy has minor effects on developed countries; tariff rates are already close to zero, so a lower tariff, or removing tariffs through FTAs, does not drastically change welfare. However, the margin of welfare gains through tariff reduction is not small for some developing countries.

The paper is organized as follows. The rest of the introduction discusses how the paper draws from and contributes to the literature. The next section presents the model. Section 3 explains data, calibration strategy, and the results. The final section concludes.

1.1 Contributions to the literature

This paper combines two strands of literature and offers new insights on both of them: development accounting, and application of Ricardian models à la Eaton and Kortum (2002). Given the results of standard development accounting (Caselli, 2005; Hsieh and Klenow, 2010), researchers examine the sources of TFP differences. For example, misallocation within a country can be a source of a low aggregate TFP in poor countries (Restuccia and Rogerson, 2008; Hsieh and Klenow, 2009). Input-output chain amplifies a small difference in TFP in a sector to large aggregate TFP (Jones, 2011, 2013). Other than a few exceptions, these studies basically depend on closed-economy analysis. Jones (2013) includes inputs from other countries, but he does not explicitly construct a model of international trade. Gancia et al. (2013) consider the role of international technology adoption by including international trade of goods, but do not highlight the role of trade barriers. My paper complements studies of development accounting by examining the role of international trade and trade barriers in TFP measurement.

Compared with other applications of multi-country Ricardian models (Alvarez et al., 2013; Alvarez and Lucas, 2007a,b; Arkolakis and Ramanarayanan, 2009; Mutreja et al., 2014a,b; Waugh, 2010), my contribution is to bring the model into a relatively simple development accounting framework. As previously noted, my paper builds on Alvarez and Lucas (2007b), which is a direct extension of Alvarez and Lucas (2007a). Alvarez and Lucas (2007a) re-specify the model of Eaton and Kortum (2002) to be a full-fledged general equilibrium model in which labor is the only fundamental factor of production. They examine the impact of trade costs and tariff on income across countries, but do not consider the implication of measured productivity across countries. Alvarez and Lucas (2007b) further include capital as an additional production factor and analyze the transition dynamics of the model. However, they do not examine steady-state implications of trade costs and welfare.

Many international trade papers analyze the welfare gains from trade and/or gains from reducing trade costs/tariffs (see, e.g., Arkolakis et al., 2012), but not in terms of productivity. An exception is Arkolakis and Ramanarayanan (2009) who show a two-country version of TFP decomposition in the spirit of Hulten (1978): in a first order approximation, a change in the country ' s aggregate TFP depends on changes in productivities of two-countries. However, Arkolakis and Ramanarayanan (2009) focus on business cycle properties of the Eaton and Kortum (2002) model in a two-country framework. Alvarez et al. (2013) include diffusion of knowledge, but disregard the accounting. Arkolakis et al. (2012) provide a simple formula that can assess quantitative gains from trade in several trade models, including Eaton and Kortum's (2002).

Waugh (2010) and Mutreja et al. (2014a,b) use versions of Eaton and Kortum (2002) to quantitatively examine cross-country income differences. Waugh (2010) assumes that capital and labor are exogenously given, consumption and investment goods are produced by a single final good sector, and tariffs are not included. I assume that capital and labor are endogenously determined, consumption and investment goods productions are distinguished, and tariffs are included. Nevertheless, my model provides an extended decomposition of the aggregate output as seen in Waugh (2010). Waugh (2010) then parameterizes the model using observed trade, income and price data to quantitatively assess the impact of trade cost reduction on the welfare. He focuses on the role of asymmetric trade costs between rich and poor countries and analyzes the welfare effects of a hypothetical reduction in trade costs from current levels. His work serves to explicate implications of reducing trade costs. I instead use income data to calibrate productivity parameters, which is parallel to standard development accounting. Mutreja et al. (2014a,b) further extend the model of Waugh (2010) by incorporating capital goods trade, goods-direction-specific trade costs, two types of capital goods, and international productivity differences in various sectors. They calibrate the model using many observable values and successfully replicate various other macro-values.

Contrary to Waugh (2010) and Mutreja et al. (2014a,b), I keep my model simple and calibrate a minimal number of country specific parameters to highlight the mechanism underlying the cross-country income differences. Another benefit of using a simple calibration strategy is that I can include many countries, especially developing ones, in my quantitative analysis.[3] Including many developing countries gives richer insights into the role of trade barriers on welfare. Note also that Waugh (2010) and Mutreja et al. (2014a,b) do not examine the general equilibrium effects on welfare.

My paper complements Alvarez and Lucas (2007a,b), Waugh (2010) and Mutreja et al. (2014a,b) by examining the role of technology, international trade and trade barriers for welfare in a full-fledged general equilibrium model with capital and labor. I also show the quantitative significance of general equilibrium effects in welfare analysis, which is not necessarily highlighted by Alvarez and Lucas (2007a).

2 Model

The model is a discrete-time infinite horizon model ($t = 0, 1, ...$) with no aggregate uncertainty. The analysis will focus on the steady-state equilibrium, and variables without time subscripts stand for the steady-state values.

2.1 Setup

The world consists of n countries, and each country is indexed by $i, j = 1, ..., n$. Each country has N_i workers, which are exogenously given. In each country, a representative household supplies labor, and consumes the final consumption good c_i. Households cannot move across countries. A household in a country owns capital and lends it to firms in the country. I make two assumptions: international financial transactions are not possible, and trade is balanced.

In each country, there are an infinite number of firms that produce consumption goods, investment goods, or intermediate goods. A consumption (or investment) goods firm produces its goods using capital, labor and intermediate composite goods. The consumption and investment goods are country specific and non-tradeable. An intermediate good producer produces one of a continuum of intermediate goods using capital, labor and intermediate

[3] I include 140 countries in the quantitative analysis. Alvarez and Lucas (2007a) include 59 countries and an aggregate representing the rest of the world. Waugh (2010), Mutreja et al. (2014a), and Mutreja et al. (2014b) include 77, 84, and 88 countries, respectively.

composite goods. Each intermediate good differs in its cost of production and is distinguished by the cost parameter $\upsilon \in \mathbb{R}^n$. Intermediate goods are internationally tradeable. Intermediate goods are aggregated into the intermediate composite via a constant elasticity of substitution (CES) function. All the markets are perfectly competitive.

2.1.1 Intermediate composite

Let $f(\upsilon)$ be the density of each variety υ. An intermediate composite good comprises intermediate goods $c_{it}(\upsilon)$,

$$q_{it} = \left[\int c_{it}(\upsilon)^{\frac{\eta-1}{\eta}} f(\upsilon) \mathrm{d}\upsilon \right]^{\frac{\eta}{\eta-1}}. \tag{1}$$

Let p_{mit} and $p_{it}(\upsilon)$ denote the price of q_{it} and $c_{it}(\upsilon)$, respectively, and then the standard calculations of CES function implies

$$p_{mit} = \left(\int p_{it}(\upsilon)^{1-\eta} f(\upsilon) \mathrm{d}\upsilon \right)^{\frac{1}{1-\eta}}. \tag{2}$$

2.1.2 Consumption and investment goods

The consumption (or investment) good c_{it} (x_{it}) is produced from capital, labor and the intermediate composite goods. Let p_{cit} (p_{xit}) denote the price of the consumption (or investment) goods. Profit maximization problems are

$$\max p_{cit} \underbrace{\left(k_{cit}^{\alpha} l_{cit}^{1-\alpha}\right)^{\gamma_c} q_{cit}^{1-\gamma_c}}_{=c_{it}} - r_{it} k_{cit} - w_{it} l_{cit} - p_{mit} q_{cit}, \tag{3}$$

$$\max p_{xit} \underbrace{\left(k_{xit}^{\alpha} l_{xit}^{1-\alpha}\right)^{\gamma_x} q_{xit}^{1-\gamma_x}}_{=x_{it}} - r_{it} k_{xit} - w_{it} l_{xit} - p_{mit} q_{xit}. \tag{4}$$

2.1.3 Intermediate good

An intermediate good $y_{it}(\upsilon)$ is produced from capital, labor and the intermediate composite goods. Let $\tilde{p}_{it}(\upsilon)$ denote the selling price of the intermediate good $y_{it}(\upsilon)$. A profit maximization problem is

$$\tilde{p}_{it}(\upsilon) \underbrace{\upsilon_{it}^{-\theta} \left(k_{it}(\upsilon)^{\alpha} l_{it}(\upsilon)^{1-\alpha}\right)^{\gamma_m} q_{mit}(\upsilon)^{1-\gamma_m}}_{=y_{it}(\upsilon)} - r_{it} k_{it}(\upsilon) - w_{it} l_{it}(\upsilon) - p_{mit} q_{mit}(\upsilon), \tag{5}$$

and υ_{it} is drawn from an exponential distribution,

$$f(\upsilon) = \left(\prod_{i=1}^{n} \lambda_i \right) \exp\left(- \sum_{i=1}^{n} \lambda_i \upsilon_{it} \right). \tag{6}$$

As Eaton and Kortum (2002) explain, λ_i determines the average level of productivity in country i and thereby controls the absolute advantage, while θ determines the variation of productivity across variety in a country and thus controls the magnitude of comparative advantage.

2.1.4 Households

The households maximize the life-time utility

$$\sum_{t=0}^{\infty} \beta^t N_i \left(\psi \ln c_{it} + (1-\psi)\ln(1-l_{it})\right), \tag{7}$$

subject to budget constraints,

$$N_{it}\left(p_{cit}c_{it} + (1+\tau_{xi})p_{xit}x_{it}\right) = N_{it}\left(w_{it}l_{it} + r_{it}k_{it}\right) + \Pi_{it}, \tag{8}$$

where Π_{it} is lump-sum transfer of tariff revenue, and τ_{xi} is a country-specific investment wedge (as used by Hsieh and Klenow (2009)). The role of the investment wedge is explained below. Capital, $K_{it} = N_i k_{it}$, accumulates following the standard formula,

$$K_{it+1} = (1-\delta)K_{it} + N_i x_{it}. \tag{9}$$

2.1.5 Input markets clearing conditions

Capital, labor and intermediate composite are used for various productions,

$$N_i\left(k_{cit} + k_{xit} + \int k_{it}(v)f(v)\mathrm{d}v\right) = K_{it}, \tag{10}$$

$$N_{it}\left(l_{cit} + l_{xit} + \int l_{it}(v)f(v)\mathrm{d}v\right) = N_{it}l_{it}, \tag{11}$$

$$q_{cit} + q_{xit} + \int q_{mit}(v)f(v)\mathrm{d}v = q_{it}. \tag{12}$$

2.1.6 Steady state

In the steady-state, the intertemporal Euler equation implies that

$$\frac{r_i}{p_{xi}} = \left(\frac{1}{\beta} - 1 + \delta\right)(1+\tau_{xi}) \equiv R_i, \tag{13}$$

where R_i is a modified version of the user cost of capital.

The model has two fundamental factors of production: capital and labor. Nevertheless, the model is Ricardian, not Heckscher-Ohlin, following an insight of Baxter (1992): in a model with endogenous capital accumulation, intertemporal optimization, and neoclassical production function, the steady-state of a dynamic economy of two-country, two-good, and two-factor (capital and labor) international trade model is described as a Ricardian model. More specifically, in the presence of intertemporal optimization and capital accumulation, capital-labor ratio is determined by the user costs. Since the user costs depend only on parameters of the model (β, δ, and τ_{xi}), the model can be reduced to a one factor (labor) model as in a Ricardian model.

It then follows that capital-labor ratio in a country depends only on the parameters β, δ, and τ_{xi}. Given large difference in capital-labor ratio across countries, I include the investment wedge (τ_{xi}) to vary across countries. Admittedly, this assumption is not an ideal response to the Lucas puzzle (Lucas, 1990), but it is a simple way to have variation in the capital-labor (and hence capital-output) ratio in the steady-state. The question arises whether this assumption systematically alters the model ' s properties, especially differences in rich and poor countries. Given the fact that investment-output ratio measured in domestic prices is not systematically correlated with income per worker (c.f., Hsieh and Klenow, 2007), capital-output ratio measured domestically is not systematically correlated with income per worker (see Figure 1 below). Accordingly, the investment wedge does not play a critical role in the results.

Another potential problem of the investment wedge is its effect on the labor-leisure choice. As is true in standard RBC models, the steady-state labor depends on the user cost (see equation (19) below). A variation in τ_{xi} can lead to a large variation in labor, which in turn affects other properties of the model. The model's implications might greatly differ from those of an exogenous labor model (as common seen in the development accounting literature). I include labor-leisure decision to check the effects of τ_{xi} on labor and productivity measures.

2.2 Equilibrium expressions

A key parameter in the model is $\lambda_i > 0$. This λ_i controls the mean of the cost distribution of the intermediate goods. Under autarky, each country produces all the intermediate goods. Hence, the mean of the distribution, λ_i, is a key parameter to determine country's aggregate productivity. Under an open-economy equilibrium, each country produces some of the intermediate goods. The mean productivity determines the range of production. Moreover, if a country has high average productivity, the country can export more goods in exchange for additional imported intermediate goods. The country then produces even more because the imported intermediate goods are used to produce other intermediate goods through the input-output chain.

2.2.1 Autarky

Under autarky, the available variety is $\upsilon \in [0, \infty]$. All the intermediate inputs are domestically produced, and the price of intermediate good for a buyer ($p_i(\upsilon)$) equals the seller's price

$(\tilde{p}_i(\upsilon))$,

$$y_i(\upsilon) = c_i(\upsilon), \tag{14}$$

$$p_i(\upsilon) = \tilde{p}_i(\upsilon). \tag{15}$$

Following calculations (see Appendix B), p_{mi} can be expressed as a function of w_i. Other prices are also linear functions of w_i. Once prices are calculated, other variables are easily calculated.

2.2.2 N country model

International trade incurs iceberg trade cost. In particular, one unit of any tradeable good shipped from j to i results in $\kappa_{ij} \in (0, 1]$ units arriving in i. Similarly, a country can impose tariffs. If country j ships to country i, $\omega_{ij} \in (0, 1]$ fraction of each dollar arrives as payment to a seller in j. The tariff revenue is transferred to the household in i as a lump-sum. Intra-country shipment is subject neither to trade costs nor to tariffs, $\kappa_{ii} = \omega_{ii} = 1$.

With the possibility of trade, the price that an intermediate composite good producer in i faces is

$$p_i(\upsilon) = \min_j \left\{ \frac{\tilde{p}_i(\upsilon)}{\kappa_{ij}\omega_{ij}} \right\}, \tag{16}$$

and as shown by Eaton and Kortum (2002), the stochastic formulation of productivity helps calculate this minimum.[4]

Let D_{ij} denote the fraction of country i's spending for intermediate goods from country j to the total spending for the intermediate goods. This share, D_{ij}, depends on a vector of wages $\mathbf{w} = (w_1, .., w_n)$. The trade balance holds

$$\underbrace{\sum_{j \neq i} N_i p_{mi} q_i D_{ij} \omega_{ij}}_{\text{total value imported}} = \underbrace{\sum_{j \neq i} N_j p_{mj} q_j D_{ji} \omega_{ji}}_{\text{total value exported}}. \tag{17}$$

The equilibrium wage vector $\mathbf{w}$ solves a system of equations $(Z_1(\mathbf{w}), ..., Z_n(\mathbf{w})) = \mathbf{0}$ and

$$Z_i(\mathbf{w}) = \frac{1}{w_i} \sum_{j=1}^{n} \frac{N_j w_j D_{ji}(\mathbf{w}) \omega_{ji}}{\Psi_j - \Phi_j F_j(\mathbf{w})} - \frac{N_i F_i(\mathbf{w})}{\Psi_i - \Phi_i F_i(\mathbf{w})}, \tag{18}$$

where Ψ_i and Φ_i are terms depending only on parameters (see Appendix B), and $F_i = F_i(\mathbf{w}) = \sum_j D_{ij}\omega_{ij}$. This system of equations is completely parallel to an equation (3.18) of Alvarez and Lucas (2007a) and can be numerically solved.

[4] In a Ricardian trade model, a country imports goods from the country with the lowest prices. When υ follows the exponential distribution, a minimum of multiple random variables follows another exponential distribution. Using this stochastic formulation, the minimum price has a closed-form expression.

Once $\mathbf{w}$ is found, other variables are easily calculated. In particular, labor is

$$l_i = \left(1 + \frac{1-\psi}{\psi}\frac{1}{1-\alpha}\frac{1 - F_i + \gamma_m F_i - (\gamma_x(1-F_i) + \gamma_m F_i)\frac{\alpha\delta}{R_i}}{\gamma_c(1-F_i) + \gamma_m F_i}\right)^{-1}. \tag{19}$$

Labor depends on ω_{ij} and prices of intermediate goods from other countries through F_i, and also depends on τ_{xi} through R_i. Similarly, the capital-output ratio in domestic prices is

$$\frac{p_{xi}k_i}{p_{ci}c_i + p_{xi}x_i} = \frac{1}{\delta_i}\left(\frac{1 - F_i + \gamma_m F_i}{\gamma_c(1-F_i) + \gamma_m F_i}\frac{R_i}{\alpha\delta} + \frac{(\gamma_c - \gamma_x)(1-F_i)}{\gamma_c(1-F_i) + \gamma_m F_i}\right)^{-1}, \tag{20}$$

and GDP divided by price of the investment goods is

$$\frac{N_i(p_{ci}c_i + p_{xi}x_i)}{p_{xi}} = \text{constant} \times K_i^{\alpha}(l_i N_i)^{1-\alpha}\Omega_i\left(\frac{\lambda_i}{D_{ii}}\right)^{\frac{\theta(1-\gamma_x)}{\gamma_m}}, \tag{21}$$

where

$$\Omega_i = \frac{1 - F_i + \gamma_m F_i + \frac{\alpha\delta}{R_i}\left((\gamma_c - \gamma_x)(1-F_i)\right)}{\gamma_c(1-F_i) + \gamma_m F_i}. \tag{22}$$

In this equation, N_i and λ_i are exogenously given, while K_i, l_i, Ω_i and D_{ii} are endogenously determined. Still, this equation is useful because the aggregate production is expressed as a Cobb-Douglas production function.[5]

If labor-leisure choice is not considered, then l_i is constant and common across countries. When the tariff rate is zero for all the pairs ($\omega_{ij} = 1$), then $\Omega_i = 1$ (because $F_i = \sum_j D_{ij}\omega_{ij}$ and D_{ij} is share, $\sum_j D_{ij} = 1$). Finally, by assuming a perfect substitutability of consumption and investment goods, $p_c = p_x$. Under these three assumptions, the measured TFP depends on $(\lambda_i/D_{ii})^{\frac{\theta(1-\gamma_x)}{\gamma_m}}$, which is obtained by Waugh (2010).[6] Further, under autarky, $D_{ii} = 1$ and hence the TFP term depends only on λ_i. This means that development accounting correctly identifies the productivity parameter if the country is autarkic. Under the possibility of trade, the measured TFP includes additional terms: a term directly related to tariffs (Ω_i), and the other summarizing trade dependence (D_{ii}).

The question is how large λ_i is. Under autarky, the measured TFP has a one-to-one relationship to this parameter. However, with the possibility of trade (as in the real world), λ_i can be calculated only by solving the model.

[5] The expression is normalized by the investment good price rather than the purchasing-power-parity (PPP). By appropriately defining PPP in the model, I can obtain an alternative expression, but the expression is not as simple as (21).

[6] Mutreja et al. (2014b) also obtain an analogous expression. They have two types of capital goods, but they do not have labor-leisure choice and tariffs.

3 Data, calibration and results

I first explain the data source and calibration strategy, and then present the results.

3.1 Data and calibration

3.1.1 Data

National accounting data comes from Penn World Table 8.0 (Feenstra et al., 2015).[7] Throughout the paper, I use GDP per worker (employment) as a measure of the income. The observation year is 2005, but to minimize the effects of business cycles, the values are averages of 2004–2006 values. The number of countries included in my analysis is 140. Availability of variables limits the countries included.[8]

Figure 1 shows capital-output ratio against income per worker across countries. Income per worker is relative to the US, and the scale of the horizontal axis is the logarithm with base 2. First, as is well known, income per worker greatly differs across countries. Income in poor countries is less than 1/64th of the US income level. Second, capital-output ratio is not systematically correlated with income. Based on this fact, I use a simple method, varying the investment wedge τ_{xi}, to replicate observed capital-output ratio.

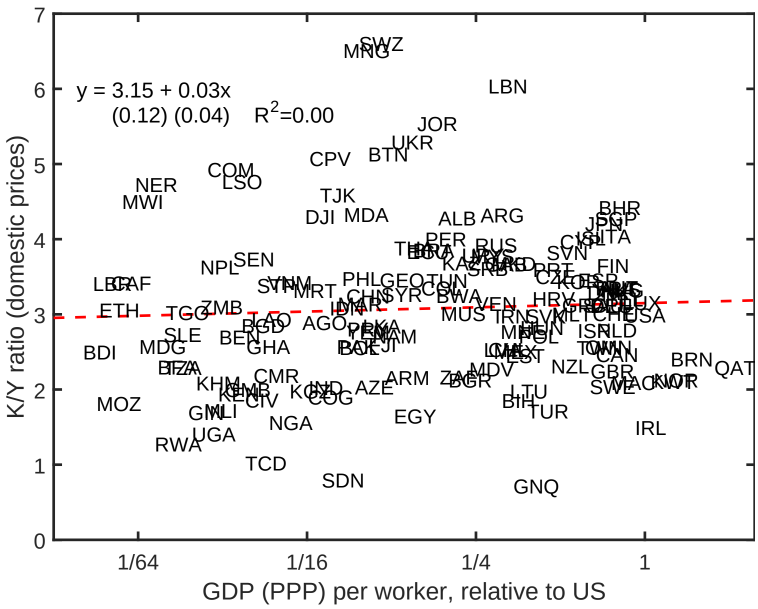

Figure 1: Capital-output ratio (in domestic prices), 2005

Given that capital-output ratio is not strongly correlated with income per worker, differences in TFP should play a significant role in explaining cross-country income differences.

[7] Data details are in Appendix A.

[8] Typically, employment, capital or tariff rates are missing. I also drop Guinea-Bissau, which shows an extremely high capital-output ratio. (It is likely explained by a large reduction in output, which is caused by a civil war in 2005.) Contrary to Alvarez and Lucas (2007a), I do not include the "rest of the world" as an additional country. The sum of the 140 countries I include accounts for more than 99% of the real GDP of all the countries included in PWT in 2005.

Figure 2 plots conventionally measured TFP using Cobb-Douglas production function with share parameter $\alpha = 0.4$ (which is used in my quantitative assessment).[9] If TFP perfectly explains the cross-country income differences, then the countries are on the 45-degree line (blue line). Obviously, TFP is strongly correlated with income. The slope (red-dashed line) is flatter than the 45-degree line, that is, TFP explains part of the income differences.

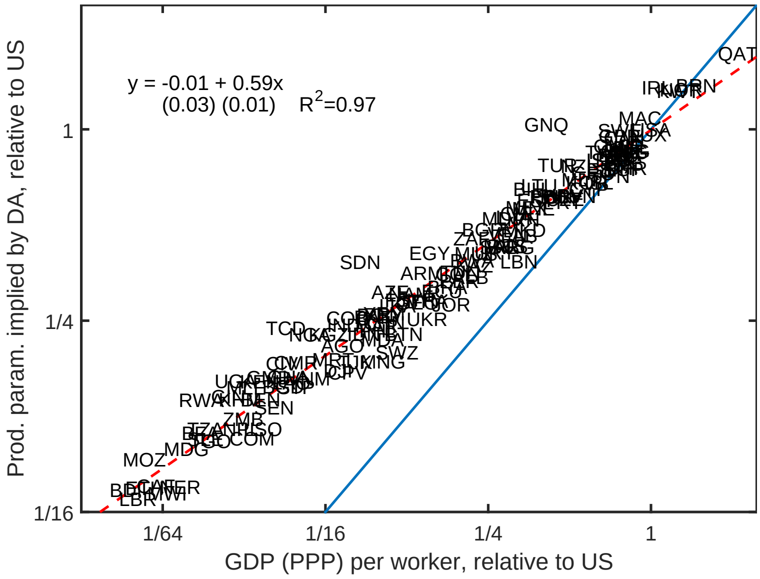

Figure 2: Measured TFP relative to the US, 2005

In the model, GDP is normalized by the price of the investment good, rather than PPP. Figure 3 examines whether GDP in PPP differs drastically from GDP in investment goods price. The countries are approximately on the 45-degree line. In this sense, using GDP in investment goods price does not greatly change the implication of development accounting.

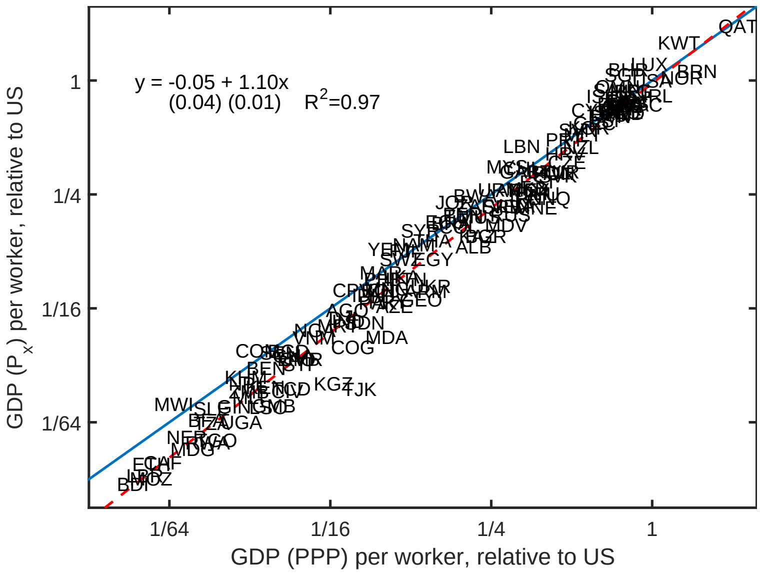

Figure 3: GDP per worker relative to the US (PPP vs investment goods price), 2005

[9] Precisely, $\text{TFP}_i = (\text{Real GDP per worker})^{1-\alpha}/(\text{capital-output ratio})^{\alpha}$

3.1.2 Calibration

Table 1 shows the parameter values common across countries. The parameter basically follows Alvarez and Lucas (2007a,b).

Table 1: Common parameters

Parameter	Value	Interpretation
α	0.4	Capital-share in value-added (VA)
γ_c	0.81	VA share in the consumption goods production
γ_x	0.5	VA share in the investment goods production
γ_m	0.5	VA share in the intermediate goods production
η	1.5	Substitution among varieties
θ	0.15	Technology variation
δ	0.07	Capital depreciation rate
β	1.07^{-1}	Subjective discounting factor
ψ	0.3	Consumption share in the utility
κ	0.75	Average iceberg trade cost

Alvarez and Lucas (2007a,b) set the share parameters (γ_c, γ_x, and γ_m) based on the value-added shares in gross output productions. Mutreja et al. (2014b) use slightly higher values for γ_c while they use lower values for γ_x and γ_m. I conduct sensitivity analysis by changing parameters.[10]

The number of workers equals employment in the PWT. In the calibration, this is N_i, not $N_i \times l_i$. Hence, my model suggests that development accounting includes the contribution of endogenous labor choice l_i, which I analyze later.

Iceberg trade cost relates to distance. The calibration follows the procedure used by Alvarez and Lucas (2007a) in their additional assessment. First, let dist_{ij} denote the great-circle distance between the largest cities of countries i and j, normalized so that the average distance (excluding dist_{ii}) is unity.[11] I then set $\kappa_{ij} = \kappa_0 \exp(-\kappa_1(\text{dist}_{ij} - 1))$. The elasticity of trade cost with respect to distance is $\kappa_1 = 0.3$. The scale parameter κ_0 is chosen so that the average trade cost, $\kappa \equiv \sum_{i=1}^{n} \sum_{j \neq i} \kappa_{ij}/n/(n-1)/2$, becomes 0.75. The value equals the baseline of Alvarez and Lucas (2007a) in which they chose κ and κ_1 based on Anderson and van Wincoop (2004).[12]

Tariff value is importer specific $\omega_{ij} = \omega_i$ for all $j \neq i$, and ω_i is one minus the most favored nation (MFN) tariff value, excluding a pair of countries with a free trade agreement (FTA). Tariff rate is zero for a country with an FTA (If i and j have an FTA, $\omega_{ij} = 1$. If not, $\omega_{ij} = \omega_i = 1 - \text{MFN tariff value}_i$).[13] I use the MFN values calculated by the World Bank. As

[10] In this type of model, the elasticity of substitution across industries η does not play any critical role (see Alvarez and Lucas, 2007a). The only technical restriction regarding η is $1 + \theta(1 - \eta) > 0$.

[11] The distances are derived from Mayer and Zignago (2011).

[12] Using this measure, the minimum trade cost occurs between Austria and Slovakia, while the maximum trade cost occurs between Paraguay and Taiwan.

[13] Appendix A lists the FTAs included in this paper.

shown in Figure 4, the tariff value is negatively correlated with income. The red-dashed line shows a regression line. The slope is negative and significantly different from zero.

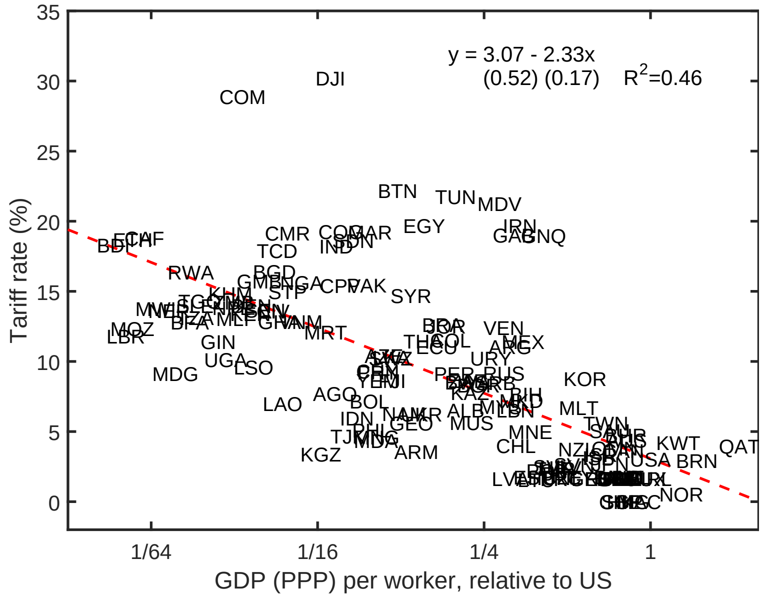

Figure 4: Tariff values, 2005

Two sets of parameters remain: the investment wedge τ_{xi} and the productivity parameter λ_i. They are calibrated to match capital-output ratio (20) and GDP divided by investment goods price (21). That is, given all the parameters and hypothetical values of $\{\lambda_i, \tau_{xi}\}_{i=1}^n$, the excess demand function (18) is solved. Next, I calculate variables in the equilibrium. The search ends when the model and data values of capital-output ratio and GDP/p_x match.

3.2 Implied productivity

Figure 5 compares the productivity parameter obtained from the development accounting and a comparable parameter obtained from the model under the open-economy equilibrium.

Productivity parameters are $\lambda_i^{\theta(1-\gamma_x)/\gamma_m}$, not λ_i. and relative to the US (that is, the US is normalized to unity). As shown by equation (21), this transformation makes this productivity parameter exactly comparable to the measured TFP from development accounting.

If international trade does not affect outcomes, then the countries are on the 45-degree line. Model values are positively correlated with the conventional measure of TFPs, but countries are not on the 45-degree line. The productivity parameters are smaller under the open-economy equilibrium.

A simple regression implies that the slope coefficient is 0.66, and the intercept is almost zero. This means that productivity parameters required for replicating observed cross-country income differences is about 70% of what is required in the simple development accounting. In other words, conventional TFP measures overestimate fundamental productivity differences by 30%.

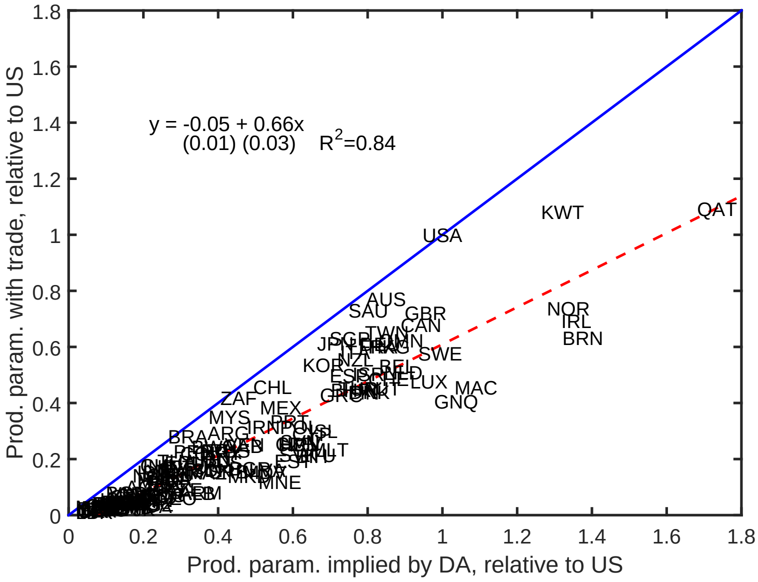

Figure 5: Productivity parameters by development accounting vs model with trade

A regression imposing no interception implies that the slope is 0.59 ("Regression 2" of row (1) of Table 2). In this case, the implied variation in the productivity is even smaller than 30%. An alternative measure of the productivity comparison is the ratio of the standard deviations: the standard deviation of the productivity measure (relative to the US) calculated from the model divided by that from the development accounting ("SD ratio"). This measure captures the difference in variation between two productivities. The ratio is 0.72. Again, the productivity parameter in the model with trade has smaller variation than what development accounting indicates. The ratio is also a measure of overestimation, and this measure implies 28% overestimation.

In summary, although the exact magnitude depends on the measurement ranging 28%–41%, TFP measures of development accounting overestimate fundamental productivity differences.

Table 2: Trade barrier variations

	Case	Regression 1	Regression 2	SD ratio
(1)	Baseline	$y = \underset{(0.01)}{-0.05} + \underset{(0.03)}{0.66}x$	$y = \underset{(0.02)}{0.59}x$	0.72
(2)	Autarky	$y = \underset{(0.01)}{-0.03} + \underset{(0.02)}{1.00}x$	$y = \underset{(0.01)}{0.96}x$	1.02
(3)	Low trade cost, $\kappa = 0.825$	$y = \underset{(0.01)}{-0.05} + \underset{(0.03)}{0.61}x$	$y = \underset{(0.02)}{0.54}x$	0.67
(4)	High trade cost, $\kappa = 0.675$	$y = \underset{(0.01)}{-0.06} + \underset{(0.03)}{0.72}x$	$y = \underset{(0.02)}{0.64}x$	0.78
(5)	No tariff	$y = \underset{(0.01)}{-0.06} + \underset{(0.03)}{0.65}x$	$y = \underset{(0.02)}{0.57}x$	0.71

3.2.1 Trade barriers and implied productivity

Table 2 shows the role of trade barriers for the productivity calculations. Row (1) is the baseline case.

Row (2) shows the case under autarky. There are slight differences in productivity parameters obtained by development accounting and by a model under autarky because each measures labor slightly differently. For development accounting, labor is measured as the total number of employed workers (N_i); for the model under autarky, labor is measured as the total number of employed workers times average hours worked ($N_i l_i$). As shown by Row (2), the productivity parameter difference is small. The contribution of leisure is small, and the variation in τ_{xi} does not have a systematic consequence in the accounting.

Rows (3) and (4) examine robustness of the implication with respect to the value of κ_{ij}. A 10% lower trade cost (which means high κ_{ij} by setting $\kappa = 0.75 \times 1.1$) implies a slightly larger impact of trade, and a 10% higher trade cost ($\kappa = 0.75 \times 0.9$) implies a slightly smaller impact. Nevertheless, the changes in the slope coefficients and SD ratio are not large.

For (5), the tariff is removed. This assumption is frequently used in the literature, in particular by Waugh (2010) and Mutreja et al. (2014a,b). The exclusion of tariff does not change the implications. The slope coefficients and SD ratio are close to the baseline values.

3.2.2 Parameter variations

Table 3 examines the sensitivity of the quantitative results to parameter changes. Again, Row (1) is the baseline case.

Rows (2) and (3) change a key parameter of the model, θ. The parameter θ translates λ_i to the country's productivity, and amplifies the effects of comparative advantage. Large θ implies a small difference in λ_i, which leads to a large difference in the aggregate productivity. In this case, even without large differences in the productivity, the model implies a large difference in income across countries. The direct effect of this transmission process is adjusted by comparing productivity with $\lambda_i^{\theta(1-\gamma_x)/\gamma_m}$. This adjustment, however, does not adjust any indirect effects that arise through input-output and international trade chain.

The literature does not perfectly agree on the value of θ. Eaton and Kortum (2002), Alvarez and Lucas (2007a), Waugh (2010), and Mutreja et al. (2014b), use 0.12, 0.15, 0.18, and 0.25, respectively. Row (2), $\theta = 0.1$, is a lower bound of these values, while (3), $\theta = 0.3$, is an upper bound. Changes in θ are quantitatively important. Under small θ, the implied slope coefficients and SD ratio are larger than the baseline. The international trade does little to explain cross-country TFP variations. On contrary, under large θ, the contribution of trade becomes large. The magnitude of overestimation is in a range of 10%–70%. Among the values, $\theta = 0.15$ gives fairly conservative numbers.

The remaining rows change the values of production share parameters (γ_c, γ_x, γ_m and α). As shown by Rows (4) and (5), a change in γ_c does not affect the implications. Under low

Table 3: Parameter variations

	Case	Regression 1	Regression 2	SD ratio
(1)	Baseline (BL)	$y = \underset{(0.01)}{-0.05} + \underset{(0.03)}{0.66}x$	$y = \underset{(0.02)}{0.59}x$	0.72
(2)	$\theta = 0.10$ (BL: 0.15)	$y = \underset{(0.01)}{-0.04} + \underset{(0.03)}{0.78}x$	$y = \underset{(0.02)}{0.72}x$	0.82
(3)	$\theta = 0.30$ (BL: 0.15)	$y = \underset{(0.01)}{-0.05} + \underset{(0.04)}{0.40}x$	$y = \underset{(0.02)}{0.32}x$	0.50
(4)	$\gamma_c = 0.70$ (BL: 0.81)	$y = \underset{(0.01)}{-0.05} + \underset{(0.03)}{0.66}x$	$y = \underset{(0.02)}{0.59}x$	0.72
(5)	$\gamma_c = 0.90$ (BL: 0.81)	$y = \underset{(0.01)}{-0.05} + \underset{(0.03)}{0.66}x$	$y = \underset{(0.02)}{0.59}x$	0.72
(6)	$\gamma_x = 0.45$ (BL: 0.5)	$y = \underset{(0.01)}{-0.05} + \underset{(0.03)}{0.63}x$	$y = \underset{(0.02)}{0.56}x$	0.69
(7)	$\gamma_x = 0.55$ (BL: 0.5)	$y = \underset{(0.01)}{-0.06} + \underset{(0.03)}{0.70}x$	$y = \underset{(0.02)}{0.62}x$	0.75
(8)	$\gamma_m = 0.45$ (BL: 0.5)	$y = \underset{(0.01)}{-0.05} + \underset{(0.03)}{0.63}x$	$y = \underset{(0.02)}{0.56}x$	0.70
(9)	$\gamma_m = 0.55$ (BL: 0.5)	$y = \underset{(0.01)}{-0.05} + \underset{(0.03)}{0.69}x$	$y = \underset{(0.02)}{0.61}x$	0.74
(10)	$\alpha = 0.35$ (BL: 0.4)	$y = \underset{(0.01)}{-0.07} + \underset{(0.03)}{0.67}x$	$y = \underset{(0.02)}{0.57}x$	0.73
(11)	$\alpha = 0.45$ (BL: 0.4)	$y = \underset{(0.01)}{-0.04} + \underset{(0.03)}{0.66}x$	$y = \underset{(0.02)}{0.60}x$	0.71

($\gamma_c = 0.7$) or high ($\gamma_c = 0.9$) share parameter, the regression lines are almost identical to baseline , and the ratio of the standard deviations are also very close to baseline.

The choice of γ_x (Rows (6) and (7)) mildly affects the implications. When γ_x is lower (higher), the slope is flatter (steeper) and the SD ratio is smaller (larger). The effects are, however, small in absolute value. Rows (8) and (9) show the effects of a change in γ_m. A higher γ_m implies a flatter slope, but the change is small. The last rows, (10) and (11), show the effects of α, and the effect of this parameter is also limited.

Overall, except for θ, variations in parameter values have limited impacts on the implications. The quantitative implication depends on θ. Even for small θ, the trade shows a significant role for productivity calculations. A large θ amplifies the role of trade. Compared to the literature, my baseline value yields a conservative result.

3.3 Trade barriers, productivity and income

The effect of trade barriers on income is a subject of long-standing research, and Table 4 presents results through the lens of my model. This table includes only a few selected countries to highlight the results. Complete tables are provided at the end of the paper (Table C1).

The calculations are as follows. First, I solve the equilibrium of the model under alternative (hypothetical) trade barrier assumptions while fixing baseline productivity parameters $\{\lambda_i, \tau_{xi}\}_{i=1}^n$. Second, I calculate hypothetical utility values for various scenarios. Finally, I compare the consumption-equivalent welfare changes of two alternative scenarios, and measure the effects of various trade barriers on the economic welfare of countries.

Table 4: Effects of trade barriers

	Country	Code	Total effect	Sym. TC	Distance	Avg. tariff	FTA	ACR	High TC	Low TC	No tariff
1	Sao Tome & Principe	STP	5.48	6.25	0.93	0.95	1.00	2.20	0.88	1.12	1.06
2	Liberia	LBR	5.06	5.55	0.95	0.96	1.00	2.17	0.88	1.12	1.05
3	Gambia, The	GMB	4.34	4.78	0.98	0.93	1.00	2.10	0.88	1.12	1.08
⋮											
57	Luxembourg	LUX	2.51	2.17	1.17	0.98	1.01	1.79	0.89	1.11	1.01
58	Paraguay	PRY	2.49	2.83	0.90	0.94	1.04	1.77	0.88	1.12	1.02
⋮											
127	Mexico	MEX	1.36	1.40	0.98	0.96	1.04	1.29	0.90	1.12	1.01
⋮											
130	New Zealand	NZL	1.34	1.74	0.78	0.97	1.02	1.27	0.90	1.11	1.01
⋮											
138	Japan	JPN	1.12	1.17	0.97	0.99	1.00	1.10	0.96	1.05	1.01
139	Australia	AUS	1.09	1.31	0.84	0.99	1.00	1.07	0.97	1.04	1.01
140	United States	USA	1.05	1.07	0.98	1.00	1.00	1.04	0.98	1.02	1.00
	Mean		2.40	2.51	1.01	0.96	1.00	1.66	0.89	1.11	1.04
	Std.		0.89	1.01	0.10	0.03	0.01	0.27	0.02	0.01	0.03
	Max		5.48	6.25	1.17	1.03	1.04	2.20	0.98	1.13	1.12
	Min		1.05	1.07	0.78	0.89	0.99	1.04	0.87	1.02	0.97

The countries are listed in descending order of the "Total effect." The total effect compares the consumption-equivalent welfare of the observed income and the consumption-equivalent welfare under autarky. The value means that for small countries (such as Gambia), the current consumption is more than four times of the (hypothetical) consumption under autarky. The value is smallest for the US, but even the US shows gains of 5%.

Arkolakis et al. (2012) provide an alternative formula to calculate gains from trade. They show that for many trade models, gains from trade can be computed using the import penetration rate and the trade elasticity parameter. In particular, for a model of Eaton and Kortum (2002), the import penetration rate is $1 - D_{ii}$, while the trade elasticity is θ.[14] Using the equilibrium values, the column "ACR" shows the total gains from trade calculated by the formula of Arkolakis et al. (2012). There are three important differences "Total effect" and "ACR." First, "ACR" does not include income change through tariff revenue. However, the experiment below shows that the quantitative effect of tariff revenue is small.

Second, and more important, the formula of Arkolakis et al. (2012) is based on the model of Eaton and Kortum (2002), not Alvarez and Lucas (2007a). The practical difference is that Eaton and Kortum (2002) include a nonmanufacturing sector to easily determine the

[14] The parameter θ in Alvarez and Lucas (2007a) is $1/\theta$ of Eaton and Kortum (2002) and Arkolakis et al. (2012). I follow the notation of Alvarez and Lucas (2007a).

wage, while Alvarez and Lucas (2007a) (and hence my model) solve the general equilibrium to determine the wage.

Third, "ACR" does not include leisure, and this assumption also leads to a simple determination of wage. The second and the third differences reveal that the central difference between "Total effect" and "ACR" is whether consideration is given to general equilibrium effects through wage change (for all countries).

A comparison between "Total effect" and "ACR" shows that the discrepancy is large, particularly for small countries; changes in the rest of the world dramatically affect wages in small countries. In contrast, changes in the rest of the world have a relatively smaller impact on wages in large countries. In any case, both "Total effect" and "ACR" show huge welfare gains from trade, especially for small developing countries. At the same time, general equilibrium effects have significant quantitative impacts on the gains from trade.

The remaining columns, "Sym. TC," "Distance," "Avg. tariff," and "FTA," decompose the total effects into the contribution of trade, geography, tariffs, and FTAs, respectively. Column "Sym TC" considers the following situation: tariff rates are zero for all the pairs, and trade costs are set to $\kappa_{ij} = 0.75$ for all $i \neq j$. I compare the (consumption-equivalent) welfare under this hypothetically "symmetric" world to the welfare under autarky. Basically, the values in this column focus on the effects of opening trade after eliminating all the heterogeneity in geography and trade policy. The values in "Sym TC" are descending, as seen in "Total effect." In this sense, simply opening trade is the main instigator of the welfare gains from trade. However, the discrepancy is large for some countries.

The next column in Table 4, "Distance," examines the effects of introducing distance-based trade costs. The column compares welfare under the symmetric world and welfare under a case with distance-based trade costs (as in the baseline) but without tariffs. The numerator of the ratio does not consider any geographical features (or tariffs), but the denominator explicitly include the effects of distance. Note that, in this model, a country located near many large, productive countries faces lower trade costs than countries more distant from these large producers. It follows that the proximate country can produce more than a country of equal productivity that lacks easy access to productive trade partners. An interpretation of "Distance" column is the contribution of geographical proximity to productive countries to income.

The values are large for small European countries such as Luxembourg. Other small European countries (e.g., Belgium, Czech Republic) enjoy similar benefits (see Table C1). These countries achieve high income partly from their proximity to large and productive other European countries (as Germany and France). Even for large European countries (e.g., Germany, France, the UK), being close to one another increases income by approximately 10%. The value for Canada (1.13) is positive, indicating benefit from proximity to the U.S. In contrast, geographically isolated countries show low values. Among developed countries, New Zealand (0.78) and Australia (0.84) face the largest limitations to trade with other productive countries. Other Oceanian and countries in south Africa (e.g., Fiji, South Africa, and Mozambique) suffer from location disadvantage (see Table C1).

The next column in Table 4, "Avg. tariff," shows the ratio of the welfare under the distance-based trade cost with no tariff assumption to the welfare under the distance-based trade cost with a country-specific uniform tariff assumption.[15] This column measures the effects of average tariff rate of a country on welfare. The values for developed countries are close to unity since average tariff rates are very low for developed countries. The effects are not large for developing countries, as well. Presumably, imposing a high tariff, makes difficult for a country to enjoy production gains by importing productive intermediate goods. However, many of the trade partners of developing countries are developed countries in which tariff rates are low. Even for a developing country that imposes high tariffs so that the import price is disturbed, exporting prices are not greatly disturbed. Moreover, tariffs directly contribute to income through tariff revenue. Consequently, a high tariff rate does not necessarily imply low welfare. In fact, the Comoros and Djibouti have two of the highest tariff rates in the model (see Figure 4), but the effect of tariff is 0.96 for the Comoros and 0.92 Djibouti(see Table C1). While these effects are larger than average, the largest effect is for 0.89 for Equatorial Guinea (see Table C1). In addition, imposing a tariff sometimes improves the welfare (1.03 for Swaziland). Nevertheless, the effect of tariff is, in general, negative (on average -4%), and the negative effects are prevalent for developing countries that impose high tariff rates.

The last column, "FTA," shows the ratio of the welfare under the distance-based trade cost with country-specific uniform tariff assumption (without FTAs) to the welfare under the distance-based trade cost with FTA-adjusted tariff assumption. A country with multiple FTA partners has easy access to the partners' inputs, resulting in high income.[16] This effect turns out to be small for most of the countries for the several reasons. First, developed countries already have a tariff rate close to zero, so that additional effects from FTAs are minimal. Second, developing countries usually lack FTA partners, thereby minimizing effects. Notable exceptions are Mexico and Paraguay. While the average tariff is relatively high (11.4) in Mexico, which is included among high-income countries, it also has many FTA partners. The negative effect of tariff for Mexico (0.96) is almost offset by the positive effect of FTAs (1.04). In Paraguay, where the tariff rate is 9.2, The FTAs (based on Mercosur) provide cheap access to imports from Brazil and Argentina and increase the welfare.

The last three columns in Table 4 provide additional examinations: increasing the trade costs by 10% ("High TC"), decreasing trade costs by 10% ("Low TC"), and removing all the tariffs ("No tariff"). For these columns, the denominator of the comparison is the baseline welfare. Changes in trade costs almost uniformly translate into changes in the welfare. The cross-country differences in the welfare gain are small. However, the US generally experiences

[15] Note, however, that this model treats tariff rates as exogenous parameters and does not include any endogenous determination of tariffs. The values in this column do not necessarily capture causal impacts of tariffs on income.

[16] Again, the causal impact may differ.

the smallest change.

The effects of tariff removal are not large in general. This small effect reflects the small impacts of trade policy. For some developing countries, however, the effects are more that 5%.

3.4 Other variables

In this section, I examine other implied values of the model.

3.4.1 Labor

In the standard development accounting, labor is just N_i, number of employed workers in a country. In my model, effective labor is $N_i l_i$, which augments the endogenous labor-leisure choice. As shown in (19), this li depends on τ_{xi} through R_i and other parameter values. A question is whether a high τ_{xi} increases (or decreases) l_i so as to change the productivity. Figure 6 examines whether endogenous labor is systematically correlated with income. Clearly, this is not the case. The endogenous part of labor forms a flat line, indicating that the productivity measure is not systematically contaminated with the endogenous component of labor.

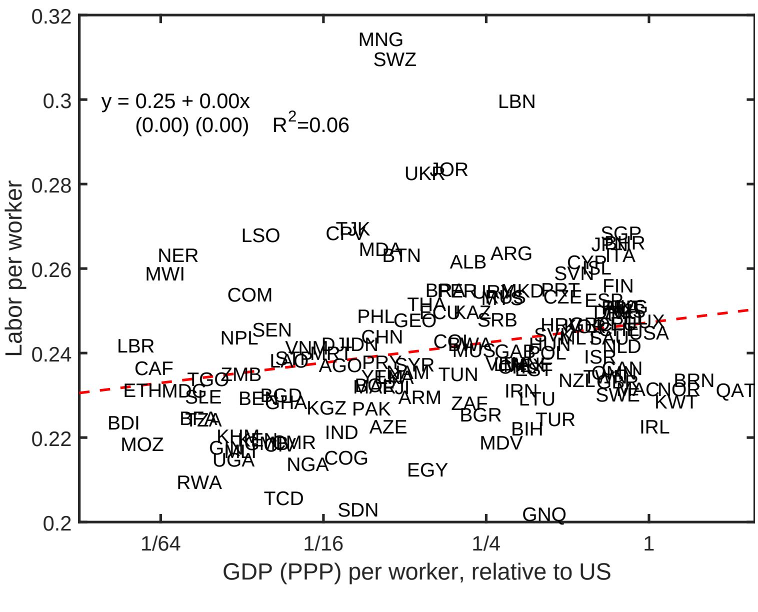

Figure 6: Equilibrium labor

3.4.2 Trade-GDP ratio

Figure 7 compares data and model values of imports to GDP ratio. When the model perfectly replicates the ratio, the countries are on the 45-degree line.

Admittedly, the model does not work perfectly. Since my calibration does not aim to mimic this import and GDP dimension at all, a perfect match is not expected. Moreover,

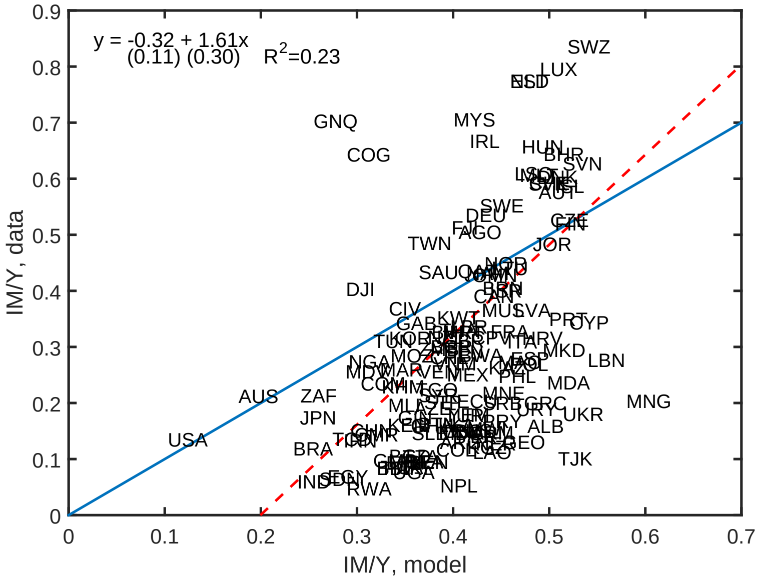

Figure 7: Import to GDP ratio, data and model

(The figure excludes three outliers: Belgium, Hong Kong, and Singapore. The data-based import-to-GDP ratios in these countries are approximately 1.2, 1.6, and 2.0, respectively, but the model ratios are approximately 0.4. However, these three countries are included in calculations for the regression line.)

in this simple framework, it is almost impossible to replicate trade-hub countries like Hong Kong and Singapore (which, at noted, are outliers and do not appear in Figure 7). However, the regression line, which is dotted line, has positive slope, so that the direction is correct.

3.4.3 Relative price

Hsieh and Klenow (2007) emphasize that cross-country differences in relative price between consumption and investment goods in domestic prices help explain cross-country differences in investment rate, and my model provides a simple explanation of the cross-country differences in the relative price. Researchers have long recognized the cross-country difference in the investment rate, but Hsieh and Klenow (2007) provide new perspectives: (1) investment rate is positively correlated with income when investment rate is measured in PPP prices but is not correlated when the rate is measured in national prices; (2) a high domestic relative price of investment (to GDP price) in poor countries is a key driver to explain this gap; and (3) low domestic consumption prices in poor countries explain the high price of investment goods in those same countries. Hsieh and Klenow (2007) then argue that the relative difference across sectors in total factor productivity of investment and consumption goods can account for the relative price differences.

In my model, the relative price is positively correlated with income driven by (1) the difference in the total factor productivity of intermediate goods producing sector, and (2) the difference in the share of the use of the intermediate goods in producing investment and consumption goods. In particular, under autarky

$$\frac{p_{ci}}{p_{xi}} = \text{Constant} \times \lambda_i^{\frac{\theta(\gamma_c - \gamma_x)}{\gamma_m}}. \tag{23}$$

Remember that in the baseline calibration, the production of consumption goods requires fewer intermediate goods than the production of investment goods does, meaning $\gamma_c > \gamma_x$. Since productivity λ_i is higher in richer countries, and the power term is positive, p_{ci}/p_{xi} is positively correlated with productivity, and hence income. Under open-economy equilibrium, this simple formula does not hold, but the analogous effect prevails.

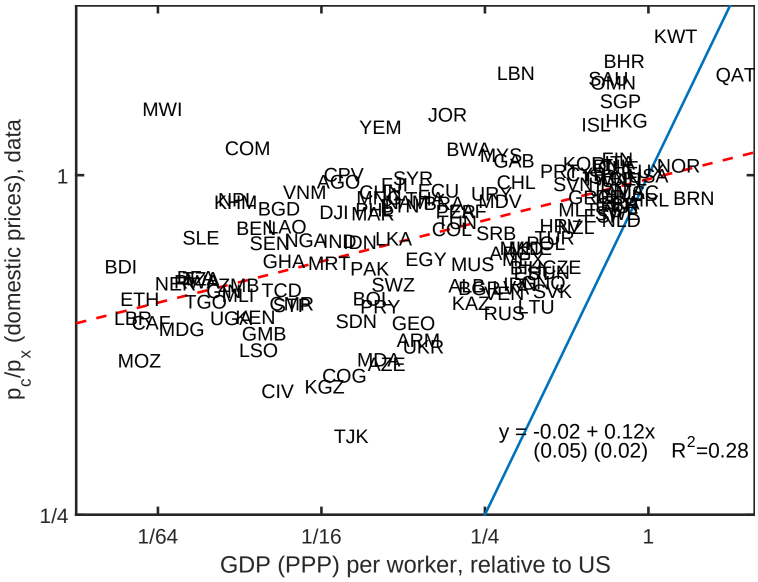

Figure 8: Relative prices of consumption and investment (data)

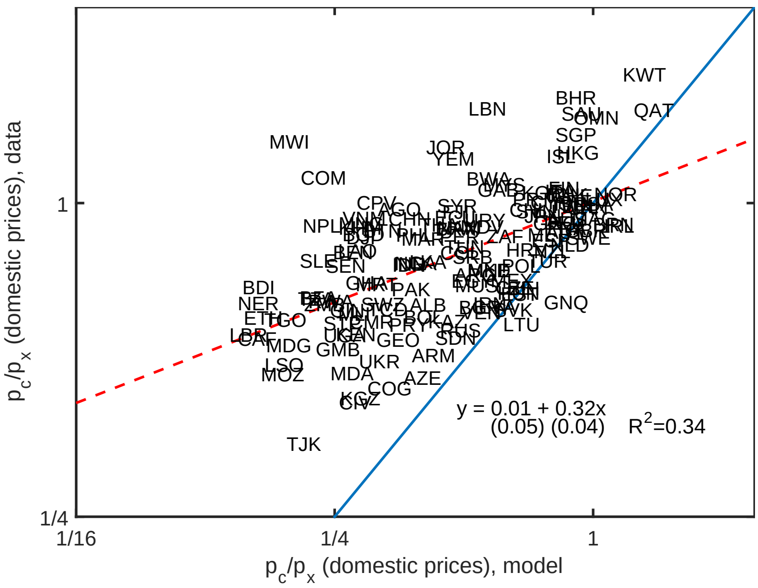

Figure 9: Relative prices of consumption and investment (model vs data)

Figure 8 shows the relative price of consumption and investment goods in PWT8.0 data.

As summarized by Hsieh and Klenow (2007), who used older data, the relative price is positively associated with income. Figure 9 shows the model values positively correlate with data values, thereby explain a part of the variations in data. In the model, the main driver of the relative price difference is λ_i, and hence the variations are small. More country-specific parameters might explain the variations around the upward sloping line. Actually, Mutreja et al. (2014b) almost perfectly replicate the relationship between the relative price and income, likely thanks to their more complex model structure and additional parameters. However, the main point illustrated by these figures is that TFP of intermediate production is an important determinant of the relative price of investment to consumption goods if the share of intermediate use differs across sectors.

4 Conclusion

This paper considers the role of international trade to explain cross-country differences in TFP. By introducing a multi-country Ricardian international trade structure in the standard development accounting model, I show that conventional TFP measures overestimate fundamental productivity differences by 30%.

I then show that trade plays important role for determining economic welfare. Small European countries enjoy 10–15% higher welfare through their proximity to large productive countries, while Oceanian and countries in southern Africa suffer from 10–20% lower welfare due to their remoteness. Moreover, average tariff rates and free-trade agreements change welfare up to 10% for some developing countries. By comparing trade gains with or without general equilibrium effects, the gains are in general larger for cases with general equilibrium effects.

My model is silent about the fundamental source of productivity difference in intermediate good producing sector. Yet, my result implies that adding this refinement to development accounting can help make the challenging task of explaining TFP differences less difficult. However, depending on the trade frictions and production structures, a source of TFP differences may or may not be amplified. I leave other trade-incorporated development accountings as a future task.

References

Alvarez, F., F. J. Buera, and R. E. Lucas, Jr. (2013): "Idea Flows, Economic Growth, and Trade," NBER working paper 19667.

Alvarez, F. and R. E. Lucas, Jr. (2007a): "General Equilibrium Analysis of the Eaton-Kortum Model of International Trade," *Journal of Monetary Economics*, 54, 1726–1768.

——— (2007b): "Capital Accumulation and International Trade," mimeo.

Anderson, J. E. and E. van Wincoop (2004): "Trade Costs," *Journal of Economic Literature*, 42, 691–751.

Arkolakis, C., A. Costinot, and A. Rodríguez-Clare (2012): "New Trade Models, Same Old Gains?" *American Economic Review*, 102, 94–130.

Arkolakis, C. and A. Ramanarayanan (2009): "Vertical Specialization and International Business Cycle Synchronization," *Scandinavian Journal of Economics*, 111, 655–680.

Baxter, M. (1992): "Fiscal Policy, Specialization, and Trade in the Two-Sector Model: The Return of Ricardo?" *Journal of Political Economy*, 100, 713–744.

Caselli, F. (2005): "Accounting for Cross-Country Income Differences," in *Handbook of Economic Growth*, ed. by P. Aghion and S. N. Durlauf, Amsterdam: North-Holland, vol. 1A of *Handbooks in Economics*, chap. 9, 679–741.

Eaton, J. and S. Kortum (2002): "Technology, Geography, and Trade," *Econometrica*, 70, 1741–1779.

Feenstra, R. C., R. Inklaar, and M. P. Timmer (2015): "The Next Generation of the Penn World Table," *American Economic Review*, forthcoming.

Gancia, G., A. Müller, and F. Zilibotti (2013): "Structural Development Accounting," in *Advances in Economics and Econometrics, Tenth World Congress of the Econometric Society*, ed. by D. Acemoglu, M. Arellano, and E. Dekel, New York: Cambridge University Press, vol. II: Applied Economics.

Hsieh, C.-T. and P. J. Klenow (2007): "Relative Prices and Relative Prosperity," *American Economic Review*, 97, 562–585.

——— (2009): "Misallocation and Manufacturing TFP in China and India," *Quarterly Journal of Economics*, 124, 1403–1448.

——— (2010): "Development Accounting," *American Economic Journal: Macroeconomics*, 2, 207–223.

Hulten, C. R. (1978): "Growth Accounting with Intermediate Inputs," *Review of Economic Studies*, 45, 511–518.

Jones, C. I. (2011): "Intermediate Goods and Weak Links in the Theory of Economic Development," *American Economic Journal: Macroeconomics*, 3, 1–28.

——— (2013): "Misallocation, Economic Growth, and Input-Output Economics," in *Advances in Economics and Econometrics, Tenth World Congress of the Econometric Society*, Cambridge University Press, vol. II.

Lucas, Jr., R. E. (1990): "Why Doesn't Capital Flow from Rich to Poor Countries?" *American Economic Review*, 80, 92–96.

Mayer, T. and S. Zignago (2011): "Notes on CEPII's Distances Measures : the GeoDist Database," CEPII Working Paper 2011-25.

Mutreja, P., B. Ravikumar, R. Riezman, and M. Sposi (2014a): "Price Equalization, Trade Flows, and Barriers to Trade," *European Economic Review*, 70, 383–398.

Mutreja, P., B. Ravikumar, and M. Sposi (2014b): "Capital Goods Trade and Economic Development," mimeo.

Restuccia, D. and R. Rogerson (2008): "Policy Distortions and Aggregate Productivity with Heterogeneous Plants," *Review of Economic Dynamics*, 11, 707–720.

Waugh, M. (2010): "International Trade and Income Differences," *American Economic Review*, 100, 2093–2124.

A Appendix A: Data

A.1 Data

A.1.1 Data sources

GDP, capital, employment and other basic variables are obtained from Penn World Table 8.0 (Feenstra et al., 2015).

The tariff data is obtained from the World Bank.[17] The data has many missing observations, and for maximizing the availability of data, the MFN values are averaged over the period 2003–2007. If the value is missing for some of the years, I use the average of the values of the remaining (observable) years.

FTA data is taken from World Trade Organization.[18] Among the FTAs effective by 2005, the FTAs covering both goods and services are chosen. The list includes EFTA (3 countries), EU (25 countries), Mercosur (4 countries), NAFTA (3 countries), and following bilateral (or one-to-an alliance) FTAs: Jordan–Singapore, India–Singapore, Thailand–New Zealand, Japan–Mexico, Thailand–Australia, US–Australia, Mexico–Uruguay, Republic of Korea–Chile, US–Chile, US–Singapore, China–Macao, Singapore–Australia, China–Hong Kong, Japan–Singapore, US–Jordan, New Zealand–Singapore, Chile–Mexico, Canada–Chile, Colombia–Mexico, Australia–New Zealand, EFTA–Chile, EFTA–Mexico, EFTA–Singapore, EU–Mexico, EU–Macedonia, EU–Chile

[17] http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/0,,contentMDK:21051044~pagePK:64214825~piPK:64214943~theSitePK:469382,00.html

[18] http://rtais.wto.org/UI/PublicAllRTAList.aspx

The distance data is basically taken from Mayer and Zignago (2011). I treat Serbia and Montenegro as different countries, but the dataset does not. For calculating the distance from Montenegro, I first obtain the GPS code of Podgorica and then calculate the great-circle distances to other countries using Havesine equation.

A.1.2 List of countries

Albania (ALB), Angola (AGO), Argentina (ARG), Armenia (ARM), Australia (AUS), Austria (AUT), Azerbaijan (AZE), Bahrain (BHR), Bangladesh (BGD), Belgium (BEL), Benin (BEN), Bhutan (BTN), Bolivia (BOL), Bosnia and Herzegovina (BIH), Botswana (BWA), Brazil (BRA), Brunei (BRN), Bulgaria (BGR), Burkina Faso (BFA), Burundi (BDI), Cambodia (KHM), Cameroon (CMR), Canada (CAN), Cape Verde (CPV), Central African Republic (CAF), Chad (TCD), Chile (CHL), China (CHN), Colombia (COL), Comoros (COM), Congo, Republic of (COG), Cote d'Ivoire (CIV), Croatia (HRV), Cyprus (CYP), Czech Republic (CZE), Denmark (DNK), Djibouti (DJI), Ecuador (ECU), Egypt (EGY), Equatorial Guinea (GNQ), Estonia (EST), Ethiopia (ETH), Fiji (FJI), Finland (FIN), France (FRA), Gabon (GAB), Gambia (GMB), Georgia (GEO), Germany (DEU), Ghana (GHA), Greece (GRC), Guinea (GIN), Hong Kong (HKG), Hungary (HUN), Iceland (ISL), India (IND), Indonesia (IDN), Iran (IRN), Ireland (IRL), Israel (ISR), Italy (ITA), Japan (JPN), Jordan (JOR), Kazakhstan (KAZ), Kenya (KEN), Korea, Republic of (KOR), Kuwait (KWT), Kyrgyzstan (KGZ), Laos (LAO), Latvia (LVA), Lebanon (LBN), Lesotho (LSO), Liberia (LBR), Lithuania (LTU), Luxembourg (LUX), Macao (MAC), Macedonia (MKD), Madagascar (MDG), Malawi (MWI), Malaysia (MYS), Maldives (MDV), Mali (MLI), Malta (MLT), Mauritania (MRT), Mauritius (MUS), Mexico (MEX), Moldova (MDA), Mongolia (MNG), Montenegro (MNE), Morocco (MAR), Mozambique (MOZ), Namibia (NAM), Nepal (NPL), Netherlands (NLD), New Zealand (NZL), Niger (NER), Nigeria (NGA), Norway (NOR), Oman (OMN), Pakistan (PAK), Paraguay (PRY), Peru (PER), Philippines (PHL), Poland (POL), Portugal (PRT), Qatar (QAT), Russia (RUS), Rwanda (RWA), Sao Tome and Principe (STP), Saudi Arabia (SAU), Senegal (SEN), Serbia (SRB), Sierra Leone (SLE), Singapore (SGP), Slovak Republic (SVK), Slovenia (SVN), South Africa (ZAF), Spain (ESP), Sri Lanka (LKA), Sudan (SDN), Swaziland (SWZ), Sweden (SWE), Switzerland (CHE), Syria (SYR), Taiwan (TWN), Tajikistan (TJK), Tanzania (TZA), Thailand (THA), Togo (TGO), Tunisia (TUN), Turkey (TUR), Uganda (UGA), Ukraine (UKR), United Kingdom (GBR), United States (USA), Uruguay (URY), Venezuela (VEN), Vietnam (VNM), Yemen (YEM), Zambia (ZMB).

B Appendix B: Computation

See separate appendix.

C Appendix C: Effects of trade barriers (full table)

Table C1: Effects of trade barriers (full table)

	Country	Code	Total effect	Sym. TC	Dist-ance	Avg. tariff	FTA	ACR	High TC	Low TC	No tariff
1	Sao Tome & Principe	STP	5.48	6.25	0.93	0.95	1.00	2.20	0.88	1.12	1.06
2	Liberia	LBR	5.06	5.55	0.95	0.96	1.00	2.17	0.88	1.12	1.05
3	Gambia, The	GMB	4.34	4.78	0.98	0.93	1.00	2.10	0.88	1.12	1.08
4	Moldova	MDA	4.33	3.93	1.12	0.98	1.00	2.11	0.89	1.11	1.02
5	Central African Rep.	CAF	4.26	4.81	0.95	0.94	1.00	2.07	0.88	1.11	1.07
6	Tajikistan	TJK	4.18	4.13	1.04	0.97	1.00	2.09	0.88	1.11	1.03
7	Cape Verde	CPV	4.14	4.22	0.99	1.00	1.00	2.03	0.88	1.12	1.01
8	Niger	NER	3.96	4.07	0.99	0.99	1.00	2.02	0.88	1.12	1.02
9	Kyrgyzstan	KGZ	3.90	3.92	1.04	0.96	1.00	2.06	0.88	1.11	1.04
10	Togo	TGO	3.89	4.32	0.95	0.95	1.00	2.03	0.88	1.12	1.06
11	Montenegro	MNE	3.87	3.52	1.13	0.97	1.00	2.05	0.89	1.11	1.03
12	Bhutan	BTN	3.84	3.86	1.01	0.98	1.00	1.96	0.88	1.12	1.02
13	Comoros	COM	3.79	4.54	0.87	0.96	1.00	1.93	0.88	1.11	1.04
14	Burundi	BDI	3.76	4.51	0.91	0.92	1.00	2.01	0.89	1.11	1.09
15	Djibouti	DJI	3.75	4.15	0.98	0.92	1.00	1.94	0.89	1.11	1.08
16	Sierra Leone	SLE	3.68	4.08	0.96	0.94	1.00	2.00	0.88	1.12	1.06
17	Lesotho	LSO	3.63	4.50	0.83	0.98	1.00	1.99	0.88	1.12	1.03
18	Mongolia	MNG	3.60	3.46	1.04	1.00	1.00	1.99	0.88	1.12	1.00
19	Mauritania	MRT	3.53	3.68	1.00	0.96	1.00	1.98	0.88	1.12	1.04
20	Armenia	ARM	3.46	3.32	1.08	0.97	1.00	1.99	0.89	1.11	1.04
21	Albania	ALB	3.45	3.11	1.13	0.99	1.00	1.97	0.89	1.11	1.02
22	Georgia	GEO	3.40	3.24	1.08	0.97	1.00	1.97	0.89	1.11	1.03
23	Laos	LAO	3.31	3.45	1.00	0.96	1.00	1.96	0.88	1.12	1.05
24	Guinea	GIN	3.29	3.64	0.97	0.94	1.00	1.95	0.88	1.12	1.07
25	Burkina Faso	BFA	3.25	3.52	0.98	0.94	1.00	1.93	0.88	1.12	1.06
26	Macedonia	MKD	3.23	2.91	1.13	0.98	1.01	1.95	0.89	1.11	1.02
27	Mali	MLI	3.20	3.50	0.98	0.93	1.00	1.93	0.88	1.12	1.07
28	Malta	MLT	3.16	2.90	1.11	0.97	1.01	1.94	0.89	1.11	1.02
29	Rwanda	RWA	3.11	3.74	0.92	0.91	1.00	1.91	0.89	1.11	1.10
30	Benin	BEN	3.01	3.36	0.96	0.94	1.00	1.88	0.88	1.12	1.06
31	Latvia	LVA	2.99	2.68	1.13	0.98	1.01	1.91	0.89	1.11	1.01
32	Estonia	EST	2.99	2.70	1.12	0.98	1.01	1.91	0.89	1.11	1.01
33	Senegal	SEN	2.96	3.12	0.99	0.96	1.00	1.85	0.88	1.12	1.04
34	Maldives	MDV	2.94	3.52	0.93	0.90	1.00	1.85	0.88	1.11	1.12
35	Chad	TCD	2.92	3.30	0.98	0.90	1.00	1.87	0.89	1.11	1.11
36	Bosnia & Herzegovina	BIH	2.90	2.66	1.14	0.96	1.00	1.87	0.89	1.11	1.04
37	Swaziland	SWZ	2.88	3.36	0.83	1.03	1.00	1.80	0.88	1.12	0.97
38	Nepal	NPL	2.87	2.99	1.01	0.95	1.00	1.83	0.88	1.11	1.06
39	Malawi	MWI	2.82	3.35	0.87	0.97	1.00	1.81	0.88	1.11	1.03
40	Madagascar	MDG	2.80	3.51	0.84	0.95	1.00	1.84	0.88	1.11	1.06
41	Iceland	ISL	2.80	2.58	1.11	0.98	1.00	1.86	0.88	1.12	1.02
42	Azerbaijan	AZE	2.79	2.77	1.07	0.94	1.00	1.84	0.89	1.11	1.06

Table C1: Effects of trade barriers (full table)

	Country	Code	Total effect	Sym. TC	Dist-ance	Avg. tariff	FTA	ACR	High TC	Low TC	No tariff
43	Mozambique	MOZ	2.78	3.61	0.83	0.93	1.00	1.83	0.88	1.12	1.08
44	Cote d'Ivoire	CIV	2.76	3.13	0.95	0.93	1.00	1.83	0.88	1.12	1.08
45	Congo, Rep. of	COG	2.76	3.36	0.91	0.90	1.00	1.81	0.88	1.11	1.11
46	Ethiopia	ETH	2.75	3.07	0.97	0.93	1.00	1.80	0.89	1.11	1.08
47	Lithuania	LTU	2.73	2.45	1.13	0.98	1.01	1.85	0.89	1.11	1.01
48	Cambodia	KHM	2.73	3.00	0.99	0.92	1.00	1.81	0.88	1.12	1.08
49	Uganda	UGA	2.70	3.11	0.93	0.94	1.00	1.82	0.89	1.11	1.07
50	Jordan	JOR	2.67	2.49	1.07	1.01	0.99	1.77	0.89	1.11	1.00
51	Zambia	ZMB	2.63	3.24	0.86	0.94	1.00	1.78	0.88	1.11	1.06
52	Cyprus	CYP	2.61	2.44	1.09	0.98	1.00	1.82	0.89	1.11	1.02
53	Serbia	SRB	2.58	2.33	1.14	0.98	1.00	1.78	0.89	1.11	1.03
54	Slovenia	SVN	2.53	2.23	1.15	0.98	1.01	1.80	0.89	1.11	1.01
55	Bulgaria	BGR	2.53	2.35	1.13	0.96	1.00	1.78	0.89	1.11	1.04
56	Slovak Rep.	SVK	2.53	2.23	1.15	0.98	1.01	1.80	0.89	1.11	1.01
57	Luxembourg	LUX	2.51	2.17	1.17	0.98	1.01	1.79	0.89	1.11	1.01
58	Paraguay	PRY	2.49	2.83	0.90	0.94	1.04	1.77	0.88	1.12	1.02
59	Croatia	HRV	2.44	2.18	1.15	0.98	1.00	1.77	0.89	1.11	1.02
60	Ghana	GHA	2.42	2.70	0.95	0.94	1.00	1.73	0.88	1.12	1.06
61	Tanzania	TZA	2.41	2.89	0.89	0.93	1.00	1.73	0.89	1.11	1.07
62	Ukraine	UKR	2.40	2.16	1.12	1.00	1.00	1.72	0.89	1.11	1.00
63	Macao	MAC	2.39	2.37	1.03	0.97	1.01	1.76	0.88	1.12	1.02
64	Cameroon	CMR	2.38	2.77	0.94	0.91	1.00	1.70	0.89	1.11	1.10
65	Fiji	FJI	2.37	3.14	0.79	0.95	1.00	1.72	0.87	1.13	1.05
66	Lebanon	LBN	2.34	2.16	1.08	1.01	1.00	1.69	0.89	1.11	0.99
67	Kenya	KEN	2.33	2.74	0.92	0.93	1.00	1.70	0.89	1.11	1.08
68	Tunisia	TUN	2.28	2.19	1.12	0.94	1.00	1.64	0.89	1.11	1.07
69	Namibia	NAM	2.24	2.77	0.85	0.96	1.00	1.69	0.88	1.12	1.05
70	Hungary	HUN	2.23	1.98	1.14	0.98	1.01	1.71	0.89	1.11	1.01
71	Equatorial Guinea	GNQ	2.21	2.63	0.94	0.89	1.00	1.66	0.89	1.11	1.12
72	Morocco	MAR	2.20	2.16	1.09	0.94	1.00	1.63	0.88	1.12	1.07
73	Bolivia	BOL	2.20	2.58	0.90	0.95	1.00	1.67	0.88	1.13	1.06
74	Syria	SYR	2.19	2.15	1.08	0.95	1.00	1.64	0.89	1.11	1.05
75	Czech Republic	CZE	2.16	1.89	1.15	0.98	1.01	1.68	0.89	1.11	1.01
76	Bahrain	BHR	2.15	2.12	1.04	0.98	1.00	1.65	0.89	1.11	1.03
77	Mauritius	MUS	2.15	2.68	0.83	0.96	1.00	1.66	0.89	1.11	1.04
78	Sudan	SDN	2.13	2.39	1.00	0.90	1.00	1.64	0.89	1.11	1.12
79	Gabon	GAB	2.11	2.41	0.93	0.94	1.00	1.58	0.89	1.11	1.06
80	Yemen	YEM	2.10	2.21	1.00	0.96	1.00	1.63	0.89	1.11	1.05
81	Kazakhstan	KAZ	2.09	2.09	1.03	0.96	1.00	1.62	0.89	1.11	1.04
82	Brunei	BRN	2.05	2.21	0.96	0.97	1.00	1.63	0.88	1.12	1.04
83	Angola	AGO	2.05	2.41	0.89	0.96	1.00	1.61	0.89	1.11	1.05
84	Vietnam	VNM	2.02	2.10	1.01	0.95	1.00	1.58	0.88	1.11	1.05
85	Sri Lanka	LKA	2.01	2.25	0.94	0.95	1.00	1.59	0.89	1.11	1.06
86	Bangladesh	BGD	1.97	2.12	1.00	0.93	1.00	1.55	0.89	1.11	1.08
87	Denmark	DNK	1.96	1.73	1.14	0.98	1.01	1.60	0.89	1.11	1.01

Table C1: Effects of trade barriers (full table)

	Country	Code	Total effect	Sym. TC	Dist- ance	Avg. tariff	FTA	ACR	High TC	Low TC	No tariff
88	Uruguay	URY	1.96	2.27	0.87	0.95	1.04	1.58	0.88	1.12	1.01
89	Ireland	IRL	1.94	1.72	1.14	0.98	1.01	1.60	0.89	1.11	1.01
90	Finland	FIN	1.91	1.74	1.12	0.98	1.01	1.58	0.89	1.11	1.01
91	Portugal	PRT	1.89	1.73	1.10	0.98	1.01	1.58	0.89	1.11	1.01
92	Austria	AUT	1.87	1.65	1.14	0.98	1.01	1.57	0.89	1.11	1.01
93	Botswana	BWA	1.86	2.32	0.84	0.96	1.00	1.53	0.89	1.11	1.05
94	Switzerland	CHE	1.84	1.63	1.15	0.99	1.00	1.55	0.89	1.11	1.02
95	Poland	POL	1.84	1.64	1.13	0.98	1.01	1.55	0.89	1.11	1.01
96	Ecuador	ECU	1.83	2.02	0.95	0.96	1.00	1.50	0.88	1.13	1.04
97	Philippines	PHL	1.81	1.88	0.99	0.97	1.00	1.52	0.89	1.12	1.03
98	Belgium	BEL	1.80	1.57	1.16	0.98	1.01	1.53	0.89	1.11	1.01
99	Greece	GRC	1.80	1.65	1.10	0.98	1.01	1.53	0.89	1.11	1.01
100	Oman	OMN	1.80	1.84	1.01	0.96	1.00	1.52	0.89	1.11	1.04
101	Sweden	SWE	1.79	1.61	1.12	0.98	1.01	1.53	0.89	1.11	1.01
102	Pakistan	PAK	1.77	1.86	1.03	0.93	1.00	1.47	0.89	1.11	1.08
103	Israel	ISR	1.77	1.70	1.07	0.97	1.00	1.51	0.89	1.11	1.03
104	Norway	NOR	1.77	1.60	1.13	0.98	1.00	1.52	0.89	1.11	1.02
105	Netherlands	NLD	1.72	1.51	1.15	0.98	1.01	1.50	0.89	1.11	1.01
106	Egypt	EGY	1.71	1.77	1.06	0.91	1.00	1.44	0.89	1.11	1.10
107	Venezuela	VEN	1.70	1.79	1.00	0.95	1.00	1.44	0.88	1.13	1.05
108	Nigeria	NGA	1.69	1.93	0.95	0.92	1.00	1.44	0.89	1.11	1.09
109	Qatar	QAT	1.68	1.69	1.03	0.97	1.00	1.46	0.89	1.11	1.04
110	Colombia	COL	1.60	1.73	0.97	0.96	1.00	1.39	0.88	1.12	1.04
111	Turkey	TUR	1.60	1.51	1.10	0.98	1.00	1.43	0.90	1.11	1.03
112	Kuwait	KWT	1.56	1.55	1.04	0.97	1.00	1.40	0.90	1.10	1.04
113	Peru	PER	1.55	1.79	0.90	0.97	1.00	1.36	0.89	1.12	1.04
114	Hong Kong	HKG	1.55	1.56	1.01	0.97	1.01	1.41	0.89	1.11	1.02
115	Russia	RUS	1.54	1.45	1.08	0.98	1.00	1.35	0.90	1.10	1.02
116	Thailand	THA	1.53	1.62	0.98	0.97	1.00	1.35	0.90	1.11	1.04
117	Canada	CAN	1.49	1.33	1.13	0.97	1.02	1.37	0.88	1.13	1.00
118	Iran	IRN	1.49	1.52	1.05	0.93	1.00	1.30	0.90	1.10	1.07
119	Spain	ESP	1.48	1.37	1.10	0.98	1.01	1.37	0.90	1.10	1.01
120	Malaysia	MYS	1.45	1.57	0.95	0.97	1.00	1.32	0.90	1.10	1.03
121	Singapore	SGP	1.45	1.55	0.94	0.97	1.02	1.35	0.90	1.10	1.01
122	Indonesia	IDN	1.43	1.61	0.92	0.97	1.00	1.31	0.91	1.10	1.03
123	France	FRA	1.41	1.28	1.11	0.99	1.01	1.32	0.91	1.10	1.01
124	United Kingdom	GBR	1.38	1.26	1.11	0.98	1.01	1.30	0.91	1.10	1.01
125	Taiwan	TWN	1.37	1.40	1.02	0.97	1.00	1.28	0.91	1.10	1.03
126	Italy	ITA	1.37	1.27	1.09	0.99	1.00	1.29	0.91	1.10	1.01
127	Mexico	MEX	1.36	1.40	0.98	0.96	1.04	1.29	0.90	1.12	1.01
128	Germany	DEU	1.35	1.24	1.10	0.99	1.01	1.28	0.92	1.09	1.01
129	Argentina	ARG	1.35	1.57	0.86	0.97	1.02	1.25	0.91	1.10	1.01
130	New Zealand	NZL	1.34	1.74	0.78	0.97	1.02	1.27	0.90	1.11	1.01
131	Saudi Arabia	SAU	1.34	1.36	1.01	0.97	1.00	1.25	0.92	1.09	1.03
132	Chile	CHL	1.33	1.61	0.85	0.96	1.01	1.27	0.91	1.10	1.03

Table C1: Effects of trade barriers (full table)

	Country	Code	Total effect	Sym. TC	Dist-ance	Avg. tariff	FTA	ACR	High TC	Low TC	No tariff
133	Korea, Republic of	KOR	1.32	1.32	1.03	0.97	1.00	1.23	0.91	1.10	1.03
134	India	IND	1.29	1.39	1.00	0.93	1.00	1.20	0.92	1.09	1.07
135	China	CHN	1.25	1.26	1.01	0.97	1.00	1.18	0.93	1.09	1.03
136	South Africa	ZAF	1.20	1.52	0.82	0.97	1.00	1.15	0.94	1.07	1.04
137	Brazil	BRA	1.17	1.34	0.89	0.98	1.00	1.12	0.94	1.07	1.02
138	Japan	JPN	1.12	1.17	0.97	0.99	1.00	1.10	0.96	1.05	1.01
139	Australia	AUS	1.09	1.31	0.84	0.99	1.00	1.07	0.97	1.04	1.01
140	United States	USA	1.05	1.07	0.98	1.00	1.00	1.04	0.98	1.02	1.00
	Mean		2.40	2.51	1.01	0.96	1.00	1.66	0.89	1.11	1.04
	Median		2.22	2.26	1.00	0.97	1.00	1.68	0.89	1.11	1.03
	Std.		0.89	1.01	0.10	0.03	0.01	0.27	0.02	0.01	0.03
	Max		5.48	6.25	1.17	1.03	1.04	2.20	0.98	1.13	1.12
	Min		1.05	1.07	0.78	0.89	0.99	1.04	0.87	1.02	0.97