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Essays On Globalization And Economic Growth

Abstract

Globalization, characterized as enhanced trade integration among countries, has make nations vulnerable to forces emanating from their borders. The following essays contribute to the understanding of how forces of globalization interact with national economies.

The first two chapters focus on a specific feature of globalization: the fragmentation of the production process across borders. The first chapter finds a novel way of solving a multistage version of Eaton and Kortum (2002)'s trade model, which contradicts previous findings that trade barriers have a larger impact when, not only final goods are traded, but also inputs along the production chain. Previous findings where based on unrealistic assumptions, that in this chapter are not made.

The second chapter, estimates a multi-country version of the previous model, and evaluates the impact on the distribution of welfare among countries of eliminating trade barriers. The chapter concludes that when there is multistage production, eliminating trade barriers carries an increase in welfare inequality, while a classical one-stage production/trade model predicts a decrease in inequality.

The final chapter of this dissertation focus on the relationship between human capital and the decision of whether to imitate foreign technologies or to innovate, in order to increase productivity. The papers suggests that differences on human capital endowments, makes technologies developed in advanced countries less productive in the developing world, and therefore, the optimal decision for firms in less developed countries, is to create their own technologies.

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Constanza Isabel Vergara Delgadillo

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ESSAYS ON GLOBALIZATION AND ECONOMIC GROWTH

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To my son Arben

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ABSTRACT

ESSAYS ON GLOBALIZATION AND ECONOMIC GROWTH

Constanza Isabel Vergara Delgadillo

Jesús Fernández-Villaverde

Globalization, characterized as enhanced trade integration among countries, has made nations vulnerable to forces emanating from their borders. The following essays contribute to the understanding of how forces of globalization interact with national economies.

The first two chapters focus on a specific feature of globalization: the fragmentation of the production process across borders. The first chapter finds a novel way of solving a multistage version of Eaton and Kortum (2002)'s trade model, which contradicts previous findings that trade barriers have a larger impact when, not only final goods are traded, but also inputs along the production chain. Previous findings were based on unrealistic assumptions, that in this chapter are not made.

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TABLE OF CONTENTS

ACKNOWLEDGEMENT	iv
ABSTRACT	v
LIST OF TABLES	viii
LIST OF ILLUSTRATIONS	x
CHAPTER 1 : ARE TRADE COSTS AMPLIFIED IN A STANDARD TRADE MODEL WITH MULTISTAGE PRODUCTION?	1
1.1 Introduction	1
1.2 Model	2
1.3 Share of Upstream Varieties Traded	5
1.4 Share of Downstream Varieties	8
1.5 Yi (2010)'s Results and Assumptions	9
1.6 Endogenous solution of the Model	11
1.7 A numerical example	13
1.8 Conclusion	14
CHAPTER 2 : WELFARE, INCOME DISTRIBUTION, AND PATTERNS OF VERTICAL SPECIALIZATION IN A WORLD WITH FRAGMENTED PRODUCTION PROCESS.	17
2.1 Introduction	17
2.2 Stage Specialization	19
2.3 Model	22
2.4 Estimation	25
2.5 Patterns of Vertical Specialization	30

2.6	Zero-Gravity World	34
2.7	Conclusion	39
CHAPTER 3 : INNOVATION AND TECHNOLOGY DIFFUSION IN DEVELOPING COUNTRIES.		40
3.1	Introduction	40
3.2	Related Literature	41
3.3	Expansion Strategies and Human Capital in Latin American Countries	44
3.4	Expansion Strategies and Human Capital: Worldwide Comparison	49
3.5	Model	55
3.6	Calibration	62
3.7	Conclusion	67
APPENDIX		69
BIBLIOGRAPHY		76

LIST OF TABLES

TABLE 1 :	Countries included in the analysis.	19
TABLE 2 :	Linear regression of Vertical Specialization and GDP	21
TABLE 3 :	Linear Regression of Ratio of Final Goods Exported and GDP	22
TABLE 4 :	Summary of Parameters	28
TABLE 5 :	States of Technology	29
TABLE 6 :	Geographic Barriers	29
TABLE 7 :	Summary Statistics Changes in Welfare in Zero Gravity World - Immobile Labor One Stage Model	35
TABLE 8 :	Summary Statistics Changes in Welfare in Zero Gravity World - Immobile Labor Multistage Model	36
TABLE 9 :	Correlation between expansion strategies and human capital indicators	47
TABLE 10 :	Productivity Differences by year	49
TABLE 11 :	Random Effects regression on the fraction of patents developed in the country over total patents registered.	52
TABLE 12 :	Random Effects regression on Total Factor Productivity.	53
TABLE 13 :	Random Effects regression on patent applications from foreigners.	54
TABLE 14 :	Calibration Parameters	62
TABLE 15 :	Estimated and Actual proportion of firms using local innovations	66
TABLE 16 :	Enterprise Surveys Database	74
TABLE 17 :	Proportions of firms following Expansion Strategies	75
TABLE 18 :	Data used for calibration	76
TABLE 19 :	Observations for the regression	77

LIST OF ILLUSTRATIONS

FIGURE 1 :	Production Model with 2-Stages	3
FIGURE 2 :	Shares of Final goods bought at home: One-stage, and Two-stages model with endogenous source of upstream inputs.	14
FIGURE 3 :	Shares of Final goods bought at home: One-stage model, and Two- stages model with endogenous and exogenous source of upstream inputs.	15
FIGURE 4 :	Shares of Final goods bought at home: One-stage model, two-stages model with endogenous and exogenous source of upstream inputs, and two-stages model with exogenous source of upstream inputs a modified production function.	15
FIGURE 5 :	Relationship between vertical specialization and GDP, 2008	20
FIGURE 6 :	Relationship between Ratio of Final Exported and GDP, 2008 . .	21
FIGURE 7 :	Contribution of vertical specialization to ratio of exports to GDP between 1995 and 2008	23
FIGURE 8 :	Correlation between actual an estimated vertical specialization. . .	30
FIGURE 9 :	Correlation between actual an estimated ratio of downstream vari- eties exported.	31
FIGURE 10 :	Correlation between actual an estimated exports to GDP ratio . .	31
FIGURE 11 :	Relationship between vertical specialization and income.	32
FIGURE 12 :	Relationship between ratio of downstream varieties exported over total exports, and ratio of technology.	33
FIGURE 13 :	Comparison of changes in welfare when moving to Zero Gravity in Eaton and Kortum (2002) and this paper	36
FIGURE 14 :	Relationship between changes in wages and wages in base scenario - one stage model	37

FIGURE 15 : Relationship between changes in wages and wages in base scenario.	38
FIGURE 16 : Relationship between ratio of second stage goods exported and income.	38
FIGURE 17 : Relationship between vertical specialization and income.	39
FIGURE 18 : Proportions of firms by Expansion Strategies	46
FIGURE 19 : Productivity Distribution of Firms by Expansion Strategy No Growth Strategy	49
FIGURE 20 : Productivity Distribution of Firms by Expansion Strategy Local Innovation	50
FIGURE 21 : Productivity Distribution of Firms by Expansion Strategy Imitation	50
FIGURE 22 : Simulated TFP South TFP with and without Technology Diffusion	63
FIGURE 23 : Simulated TFP North and South TFP with Technology Diffusion	64
FIGURE 24 : Technology diffusion without mismatch of skills	66
FIGURE 25 : Estimated and Actual TFP	67

CHAPTER 1 : ARE TRADE COSTS AMPLIFIED IN A STANDARD TRADE MODEL WITH MULTISTAGE PRODUCTION?

1.1. Introduction

A large body of research has found that there is “too little international trade” to be rationalized by standard trade models. As an example, Anderson and Van Wincoop (2003) finds that trade patterns between the United States and Canada can only be rationalized by international trade costs of 91 percent, which is presumed to be excessive for the current tariff levels and transport costs between the two countries. This phenomena has been called “home bias puzzle”, and Yi (2010) attempts to explain this puzzle, using a multistage production model. The intuition is that, when different stages are produced in different countries, trade costs are incurred multiple times, as goods cross national borders while they are in process. Then, the actual cost incurred in trading is a multiple of any existing transport cost and or tariffs, and the optimal share of goods bought at home is larger than the one implied by a one-stage model.

This paper shows that Yi (2010) makes assumptions that are not innocuous but rather critical to the results. It concludes that a multistage production model does not result in lower trade levels, but the opposite.

To reach this conclusion, a similar exercise than the one found in Yi (2010) is performed: a second production stage is added to Eaton and Kortum (2002)’s model, and it is solved for two symmetric countries, obtaining shares of traded varieties for each stage and for each level of trade costs. These shares are compared with the shares that result in a one-stage model.

The main difference between this paper and Yi (2010)’s, is the way in which the model is solved. When adding stages, the model becomes more complex, and closed form, estimable equations, like the ones derived in Eaton and Kortum (2002), do not arise. Yi (2010) reduces

the complexity of the problem by assuming that the first stage is produced in the country that ultimately consumes the second (and final) stage. This assumption is not realistic, and imposes double border crossing of goods whenever there are comparative advantages to exploit. In this paper, Nadarajah (2005)'s findings are employed to reduce the complexities of a multistage problem with two countries.

Additionally, when setting up the problem, Yi (2010) implicitly assumes that the parameter that governs the heterogeneity of the draws in the first stage is a fraction of the equivalent parameter in the second stage, which entails that the second stage has less variance than the first one. This assumption is not embedded in the setup of this paper.

As a result of eliminating these two assumptions, this paper concludes that the “home bias puzzle” is not solved by a multistage production model, but aggravated. A two stages production process depends on two random variables, which introduces extra sources of comparative advantage. As a result, a two-stages model predicts even lower shares of goods bought at home than a one-stage model.

1.2. Model

The model used for the analysis is a multistage version of Eaton and Kortum (2002), more specifically, a second stage is added to the production process. There are a continuum of varieties indexed by $z \in [0, 1]$. Each variety requires two stages of production: upstream ($k = 1$) and downstream ($k = 2$). The model determines the share of varieties traded at each stage of production.

Before presenting the equations that define the model, Figure 1 shows a diagram that represents the production flow. An upstream variety z_n is produced using labor and an aggregate intermediate M . Then, the upstream variety z_n along with labor, are used to produce the downstream variety z_n . Households consume only the downstream varieties, and the aggregate intermediate is produced by compounding all upstream varieties.

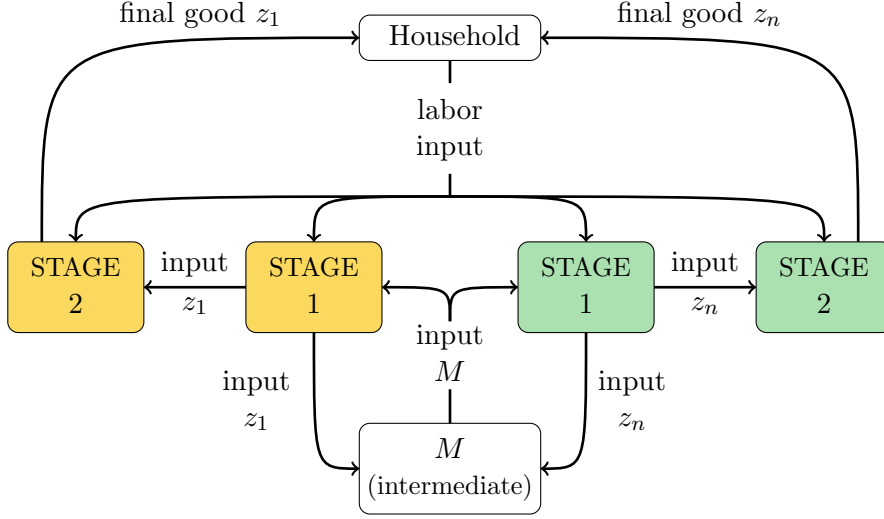


Figure 1: Production Model with 2-Stages

1.2.1. Household

The representative household in region i maximizes

$$U_i = \exp \left[\int_0^1 \log(x_{h2,i}(z)) dz \right] \quad (1.1)$$

subject to the budget constraint

$$\int_0^1 c_{2,i}(z) x_{h2,i}(z) dz = Y_i,$$

where $x_{h2,i}(z)$ is consumption of the downstream variety z in country i , $c_{2,i}(z)$ is the price, inclusive of transport and border costs, that the household pays for a downstream variety z , and Y_i is income available for consumption.

1.2.2. Technology

The production function for the upstream variety in country i is

$$y_{1,i}(z) = A_{1,i}(z) l_{1,i}(z)^{1-\theta_1} M_i(z)^{\theta_1} \quad z \in [0, 1], \quad (1.2)$$

and output of the downstream variety is

$$y_{2,i}(z) = A_{2,i}(z)l_{2,i}(z)^{1-\theta_2}x_{21,i}(z)^{\theta_2} \quad z \in [0, 1], \quad (1.3)$$

where $A_{k,i}(z)$ is productivity making the k th stage of variety z in country i , θ_k is the intermediate share in stage k , $l_{k,i}$ is the labor input into the k th stage of variety z in country i , $M_i(z)$ is the input of the composite intermediate into the upstream variety z in country i , where

$$M_i = \exp \left[\int_0^1 \log(x_{M1,i}(z)) dz \right], \quad (1.4)$$

$x_{21,i}(z)$ is the input of the upstream of variety into downstream production of variety z , and $x_{M1,i}(z)$ is the input of upstream variety z into country i 's composite intermediate. Total use of upstream variety z by country i is:

$$x_{1,i}(z) = x_{21,i}(z) + x_{M1,i}(z),$$

the sum of what is used in its downstream conjugate and what is used in creating country i 's composite intermediate.

The $A_{k,i}(z)$'s are realization of Fréchet random variables drawn from the distributions

$$F_{k,i}(a_{k,i}) = \Pr[A_{k,i}(z) \leq a_{k,i}] = \exp \left(-T_{k,i}a_{k,i}^{-n_k} \right),$$

where $T_{k,i} > 0$ is the scale parameter, and $n_k > 1$ is the shape parameter. The mean of $A_{k,i}$ is increasing in $T_{k,i}$, and n_k governs the heterogeneity of the draws from the productivity distribution. The larger n_k is, the lower the heterogeneity or variance of $A_{k,i}$.

1.2.3. Equilibrium

All factor and goods markets are characterized by perfect competition. The following market clearing conditions hold for each region.

Market equilibrium condition for the upstream variety z implies

$$y_1(z) \equiv \sum_{i=1}^I y_{1,i}(z) = \sum_{i=1}^I d_{1,i}(z)x_{1,i}(z), \quad (1.5)$$

where $d_{k,i}(z)$ is the total trade cost incurred by shipping stage k variety from its cheapest production location to region i . A similar set of conditions applies to the downstream variety:

$$y_2(z) \equiv \sum_{i=1}^I y_{2,i}(z) = \sum_{i=1}^I d_{2,i}(z)x_{h2,i}(z). \quad (1.6)$$

In each region, aggregate intermediate must be completely used,

$$M_i = \int_0^1 M_i(z) dz. \quad (1.7)$$

and labor market clears:

$$L_i = \int_0^1 l_{1,i}(z) + l_{2,i}(z) dz, \quad (1.8)$$

where L_i is labor force in country i .

An equilibrium is a sequence of varieties, factor prices, and quantities, such that the first-order conditions to the households' maximization problem in equation (1.1) and firms' maximization problem, associated with technologies (1.2), (1.3), and (1.4), as well as the market clearing conditions (1.5), (1.6), (1.7), and (1.8) are satisfied.

1.3. Share of Upstream Varieties Traded

All stages of production are subject to perfect competition, which implies that the price that a firm pays for the upstream variety is equal to its cost in the final destination. Geographic

barriers are assumed to be of the iceberg type, which means that delivering a stage k variety from country i to country j , requires producing $d_{k,ij}$ units in i .

Cost minimization for the firm associated with technology (1.2), implies that the unit cost of an upstream variety z , if produced in country i and delivered to country j , is given by

$$c_{1,ji}(z) = \frac{d_{1,ji}c_{1,i}}{A_{1,i}(z)}, \quad (1.9)$$

where $c_{1,i}$ is the input cost of producing the upstream varieties in country i , given by

$$c_{1,i} = \psi_1(w_i)^{1-\theta_1}(P_i)^{\theta_1}, \quad (1.10)$$

where w_i is the wage in country i , P_i is the cost of the composite intermediate there, and $\psi_k = \theta_k^{-\theta_k}(1-\theta_k)^{-(1-\theta_k)}$. Hence, the distribution of costs for upstream varieties that i can deliver to destination j is

$$\begin{aligned} \Pr [C_{1,ji} \leq c] &= \Pr \left[A_{1,i}(z) \geq \frac{d_{1,ji}c_{1,i}}{c} \right], \\ &= 1 - \exp \left[-T_{1,i} (d_{1,ji}c_{1,i})^{-n_1} c^{n_1} \right], \\ &= 1 - \exp \left[-\Phi_{1,ji} c^{n_1} \right], \end{aligned} \quad (1.11)$$

where $\Phi_{1,ji} = T_{1,i} (d_{1,ji}c_{1,i})^{-n_1}$. The expression $T_{1,i} (d_{1,ji}c_{1,i})^{-n_1}$ represents the technology available in j from i , discounted by input costs and geographic barriers.

Destination j will use the lowest cost version of upstream variety z , which means that the cost of the upstream variety in country j is equal to

$$c_{1,j}(z) = \min_i \{c_{1,ji}(z)\}. \quad (1.12)$$

The distribution of $c_{1,j}(z)$ is given by

$$\begin{aligned}
G_{1,j}(c) &= \Pr [C_{1,j} \leq c], \\
&= 1 - \prod_{i=1}^I \Pr [C_{1,ji} \geq c], \\
&= 1 - \exp(-\Phi_{1,j}c^{n_1}),
\end{aligned}$$

where

$$\Phi_j = \sum_{i=1}^I \Phi_{1,ji}. \quad (1.13)$$

The parameter Φ_j summarizes how states of technology and input costs around the world, along with geographic barriers, govern the cost of upstream inputs in country j .

The probability that country i is the lowest cost source for j is

$$\begin{aligned}
\pi_{1,ji} &= \Pr [C_{1,ji} \leq \min_s \{c_{1,js}(z); s \neq j\}] \\
&= \int_0^\infty \prod_{s \neq i} (1 - \Pr [C_{1,js} \leq c]) \times \Pr [C_{1,ji} = c] dc \\
&= \Phi_{1,ji} n_1 \int_0^\infty \prod_{s=1}^I \exp[-\Phi_{1,js}c^{n_1}] \times c^{n_1-1} dc \\
&= \Phi_{1,ji} n_1 \int_0^\infty c^{n_1-1} \exp \left[-c^{n_1} \sum_{s=1}^I \Phi_{1,js} \right] dc \\
&= \frac{\Phi_{1,ji}}{\Phi_{1,j}}
\end{aligned} \quad (1.14)$$

Since there is a continuum of varieties, (1.14) is also the fraction of upstream varieties that country j buys from i .

In order to compare with Yi (2010)'s results, consider an economy with two symmetric countries: home (H) and foreign (F). The iceberg transport cost between the two countries are assumed to be symmetric ($d_k = d_{k,HF} = d_{k, FH}$), and are assumed to be non-existent within the country ($d_{k,HH} = d_{k,FF} = 1$). Countries are assumed to have symmetric technology levels ($T_k = T_{k,H} = T_{k,F}$) and input costs of producing the upstream variety (i.e.

$c_1 = c_{1,H} = c_{1,F}$), so that $\Phi_1 = \Phi_{1,H} = \Phi_{1,H}$. For this particular case, the share of upstream varieties bought by the Home country at Home is given by

$$\pi_{1,HH} = 1 - \frac{1}{d_1^{n_1} + 1}. \quad (1.15)$$

Up to this point, the model behaves just like Eaton and Kortum (2002), which means that equation (1.15) also describes the share of goods bought at home in a one-stage model (π_{HH}) with symmetric countries, iceberg transport costs d_1 , and shape parameter n_1 :

$$\pi_{HH} = \pi_{1,HH}. \quad (1.16)$$

1.4. Share of Downstream Varieties

Zero profit condition for the downstream variety implies that, the price that a consumer pays for a stage 2 variety is equal to its cost in the final destination. The unit cost of downstream variety z if produced in country i and delivered to destination j (with iceberg transport cost $d_{2,ij}$) is

$$c_{2,ji}(z) = \frac{\psi_2 d_{2,ji} w_i^{1-\theta_2} c_{1,i}^{\theta_2}}{A_{2,i}(z)}. \quad (1.17)$$

Considering the two-country symmetric case, the probability that the downstream variety z is bought at home, for a given set of costs for the upstream variety ($c_{1,H}(z), c_{1,F}(z)$), is the probability that

$$\begin{aligned} \pi_{2,HH}(z|c_{1,H}(z), c_{1,F}(z)) &= \Pr [C_{2,HH}(z) \leq C_{2,FH}(z) | c_{1,H}(z), c_{1,F}(z)], \\ &= \Pr \left[\frac{\psi_2 d_2 w^{1-\theta_2} c_{1,H}^{\theta_2}(z)}{A_{2,H}(z)} \leq \frac{\psi_2 w^{1-\theta_2} c_{1,F}^{\theta_2}(z)}{A_{2,F}(z)} \mid c_{1,H}(z), c_{1,F}(z) \right], \\ &= 1 - \Pr \left[\frac{A_{2,H}(z)}{A_{2,F}(z)} \leq \frac{1}{d_2} \left(\frac{c_{1,H}(z)}{c_{1,F}(z)} \right)^{\theta_2} \mid c_{1,H}(z), c_{1,F}(z) \right], \\ &= 1 - \Pr \left[\frac{A_{2,H}(z)}{A_{2,F}(z)} \leq D(z) \mid c_{1,H}(z), c_{1,F}(z) \right], \end{aligned}$$

where $D(z) = \frac{1}{d_2} \left(\frac{c_{1,H}(z)}{c_{1,F}(z)} \right)^{\theta_2}$. Notice that symmetry does not imply that the upstream input cost for variety z bought in each country is the same, that is $c_{1,H}(z) \neq c_{1,F}(z)$. The cost of labor and the aggregate intermediate is the same, but for each variety z the firm is going to choose where is cheapest to buy the upstream input.

Solving for the ratio of the productivities gives,

$$\begin{aligned} \Pr \left[\frac{A_{2,H}}{A_{2,F}} \leq D(z) \right] &= \int_0^\infty \Pr [A_{2,H} \leq D(z)a_{2,F}|a_{2,F}] dF(a_{2,F}), \\ &= T_2 n_2 \int_0^\infty \exp \left(-T_2 a_{2,F}^{-n_2} (D(z)^{-n_2} + 1) \right) a_{2,F}^{-n_2-1} da_{2,F}, \\ &= \frac{1}{D(z)^{-n_2} + 1}, \\ &= \frac{1}{d_2^{n_2} \left(\frac{c_{1,H}(z)}{c_{1,F}(z)} \right)^{-n_2 \theta_2} + 1}. \end{aligned}$$

Hence, the conditional probability that the downstream variety z is bought at home is given by

$$\pi_{2,HH}(z|c_{1,H}(z), c_{1,F}(z)) = 1 - \frac{1}{d_2^{n_2} \left(\frac{c_{1,H}(z)}{c_{1,F}(z)} \right)^{-n_2 \theta_2} + 1} \quad (1.18)$$

1.5. Yi (2010)'s Results and Assumptions

At this point of the model the derivation differs from Yi (2010)'s. Before presenting the unconditional share of varieties bought at home in a two-stages model, the results and assumptions from Yi (2010) are presented, in order to make a clear exposition of the differences.

Consider the case where the productivities of both stages have the same dispersion ($n = n_1 = n_2$), and iceberg transport costs are the same for both stages ($d = d_1 = d_2$). In order to solve equation (1.18), Yi (2010) assumes that the first stage is produced in the country that ultimately consumes the final good. This assumption is making the decision of where to buy the upstream input, exogenous.

By making this assumption he finds that the fraction of downstream varieties bought at home¹ is given by

$$\pi_{2,HH}^{Yi} = 1 - \frac{1}{d^{n\frac{1+\theta_2}{1-\theta_2}} + 1},$$

which is larger than the equivalent fraction in the one-stage model, defined in (1.16),

$$\pi_{HH} = 1 - \frac{1}{d^n + 1},$$

since $\frac{1+\theta_2}{1-\theta_2} > 1$ ². As a result, he concludes that in a two-stages production model, the optimal fraction of goods bought at home is larger than in a standard one-stage model, and therefore, the “Home bias puzzle” can be solved by correctly specifying the model.

To get this result, Yi (2010) also specifies a different productivity function for the downstream variety. In equation (2) of Yi (2010), the production function of the downstream variety is defined as

$$y_{2,i}^{Yi} = [A_{2,i}(z)l_{2,i}(z)]^{1-\theta_2}x_{21,i}(z)^{\theta_2} \quad z \in [0, 1], \quad (1.19)$$

and the cumulative distribution of the productivities as

$$F_{k,i}(a_{k,i}) = \Pr [A_{k,i}(z) \leq a_{k,i}] = \exp\left(-T_{k,i}a_{k,i}^{-n}\right) \quad k = 1, 2.$$

The shape parameter that governs the heterogeneity of the draws is the same for A_1 and A_2 , but the productivity of the downstream variety is equal to $A_{2,i}(z)^{1-\theta_2}$, and therefore has a cumulative distribution of

$$F_{2,i}\left(a_{2,i}^{1-\theta_2}\right) = \exp\left(-T_{k,i}a_{2,i}^{-\frac{n}{1-\theta_2}}\right).$$

This is a Fréchet distribution, with shape parameter equal to $\frac{n}{1-\theta_2} > n$. This condition

¹This expression is shown in equation (23) of Yi (2010).

²Recall that $\theta_2 \in (0, 1)$ is the share of intermediates in the production function of the downstream variety.

implies that the second stage has lower heterogeneity than the first stage, which means that there is a weaker force for trade in the downstream variety. In other words, when there is less variability, there are less incentives to buy across borders, and trade costs exert larger resistance against commerce.

When the production function of the downstream function is specified with the same shape parameter as the upstream production function, the share of downstream varieties bought at home, when the source of the upstream input is exogenous, is equal to

$$1 - \frac{1}{d^{n(1+\theta_2)} + 1},$$

which is still larger than π_{HH} . By eliminating the assumption that the second stage has lower dispersion than the first stage, the fraction of goods bought at home in a two stages model is still larger than in a one-stage model, but the difference is smaller.

1.6. Endogenous solution of the Model

Recall equation (1.18), that defines the probability that the downstream variety z is bought at home, conditional on upstream input costs used for production:

$$\pi_{2,HH}(z|c_{1,H}(z), c_{1,F}(z)) = 1 - \frac{1}{d^n \left(\frac{c_{1,H}(z)}{c_{1,F}(z)} \right)^{-n\theta_2} + 1}.$$

Appendix A.1 shows that the function $\nu(z) \equiv \left(\frac{c_{1,H}(z)}{c_{1,F}(z)} \right)^{-n\theta_2}$ is the result of the product of a Fréchet and a Weibull distributions. The properties of the distribution of this product are described in Nadarajah (2005), and when applied to solve equation (1.18), the decision of where to buy the upstream input can be made endogenous. Then, the fraction of downstream varieties bought at home is given by

$$\begin{aligned}
\pi_{2,HH} &= \int_0^\infty \Pr [C_{2,HH} \leq C_{2,FH} | \nu] dF(\nu), \\
&= 1 - \frac{1}{\theta_2} \int_0^\infty \frac{1}{d^n \nu + 1} \frac{(\nu)^{\frac{1}{\theta_2} - 1}}{\left[1 + (\nu)^{\frac{1}{\theta_2}}\right]^2} d\nu.
\end{aligned} \tag{1.20}$$

Proposition 1 *The share of downstream varieties bought at home, as defined in (1.20), is smaller or equal to the share of upstream varieties bought at home, as defined in (1.15), i.e.*

$$1 - \frac{1}{\theta_2} \int_0^\infty \frac{1}{d^n \nu + 1} \frac{(\nu)^{\frac{1}{\theta_2} - 1}}{\left[1 + (\nu)^{\frac{1}{\theta_2}}\right]^2} d\nu \leq 1 - \frac{1}{d^n + 1}.$$

Proof: The proof follows from Theorem 1.14 in Dharmadhikari and Joag-Dev (1988): *Let X be a unimodal random variable. If $\max\{X - m, 0\}$ is stochastically larger than $-\min\{X - m, 0\}$, then X has a mode M satisfying $M \leq m \leq \mu$, where m is defined as the median of X , and μ is the mean of X .*

Defining $Z \equiv \frac{1}{d^n \nu + 1}$, appendix A.2 proves that Z is a unimodal random variable with median $m = \frac{1}{d^n + 1}$ and mean $\mu = \frac{1}{\theta_2} \int_0^\infty \frac{1}{d^n \nu + 1} \frac{(\nu)^{\frac{1}{\theta_2} - 1}}{\left[1 + (\nu)^{\frac{1}{\theta_2}}\right]^2} d\nu$. Additionally, appendix A.2 proves that the $\max\{Z - m, 0\}$ is stochastically larger than the $-\min\{Z - m, 0\}$, which implies that $\mu \geq m$ and $1 - \mu \leq 1 - m$.

Corollary 1 *A two-stages model would predict lower or equal shares of goods bought at home than a one-stage model, for every $d > 1$. Hence, the “home bias” would be exacerbated in a two-stages model.*

Proof: By construction, the total share of goods bought at home in the one-stage model is equal to the share of upstream varieties bought at home in the two-stages model (i.e. $\pi_{HH} = \pi_{1,HH}$). In a two-stages model the total share of goods bought at home is a weighted average of $\pi_{1,HH}$ and $\pi_{2,HH}$, which together with Proposition 1, implies that the total share

of goods bought at home in the two-stages model will be in the range $(\pi_{2,HH}, \pi_{1,HH})$. This condition means that a one-stage model would predict shares of goods bought at home larger than the ones predicted by a two-stages model.

As a result from Corollary 1, the “home bias puzzle” is not explained by a multistage production model, but exacerbated: To explain the share of goods bought at home in a two-stages model, it would be needed to have even larger trade costs than the ones implied by a one-stage model. The random productivity of the second stage, adds heterogeneity to the production process, increasing the source of comparative advantage, and making trade more attractive.

1.7. A numerical example

To close the argument, Figure 2, 3, and 4 compare the relationship between trade costs and the share of final goods bought a home in a one-stage model, relatively to the equivalent share that results in a two-stages model, for different assumptions. Shape parameters are assumed to be $n = 3.6$, and input shares of the second stage equal to $\theta_2 = 0.7$ ³.

In Figure 2, the source of the upstream input for the production of the second stage is let to be endogenous. The Figure shows that for any level of trade costs, a two stages model predicts lower shares of final goods bought at home. Equivalently, for an observed share of final goods bought at home of 90%, a one-stage model would predict a trade costs of 80%⁴, while a two-stages model would predict trade costs of 110%.

Figure 3 adds a third line to Figure 2, showing the prediction of a two-stages model when the source of the upstream input is exogenous, and determined by the location where the final good is consumed. To simplify the exposition, the exogeneity assumption is defined as “AY1”. In this case, for any trade cost, the share of final goods bought at home is larger than in the one-stage model, and for an observed share of final goods bought at home of

³These values are in the range of the numbers used in the literature. See for example Eaton and Kortum (2002). An input share of 0.7 is equivalent to a labor share of 0.3.

⁴Zero trade costs is equivalently of $d = 1$. Therefore, $d' = 1.8$ can be interpreted as a trade cost of 80%.

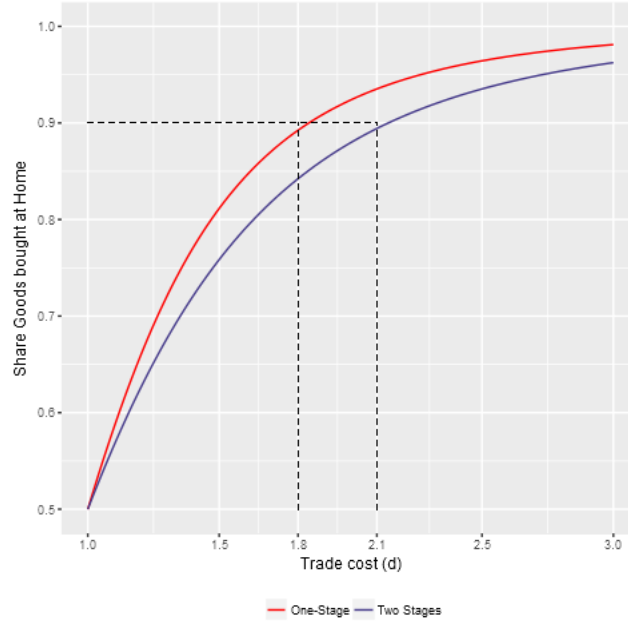


Figure 2: Shares of Final goods bought at home: One-stage, and Two-stages model with endogenous source of upstream inputs.

90% a two-stages model would predict trade costs of 40%. In this example, it is clear that multistage production does not explain the home bias, but the specific assumption that Yi (2010) makes about where to buy the upstream input.

Finally, Figure 4 adds a fourth line that shows a two-stages model that assumes an exogenous source of upstream input, and a modified production function as in equation (1.19). The modified production function assumption, is defined as “AY2”. The share of final goods bought at home is even larger than in the previous figure, because heterogeneity has been reduced, and with that, the sources of comparative advantage.

1.8. Conclusion

This paper has shown that a multistage production model does not explain the “home bias puzzle”, but moreover, exacerbates it. When the production chain has multiple stages, with different productivity shocks, the sources of comparative advantage increase, making trade more attractive than in standard one-stage trade model. Therefore, shares of goods bought

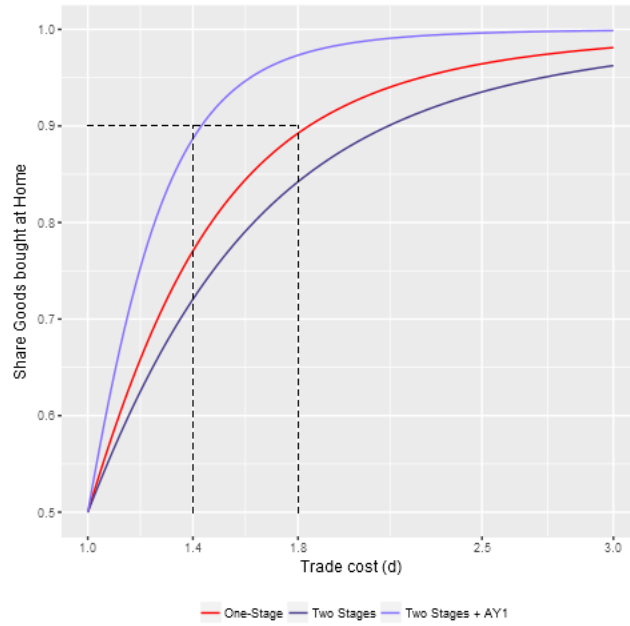


Figure 3: Shares of Final goods bought at home: One-stage model, and Two-stages model with endogenous and exogenous source of upstream inputs.

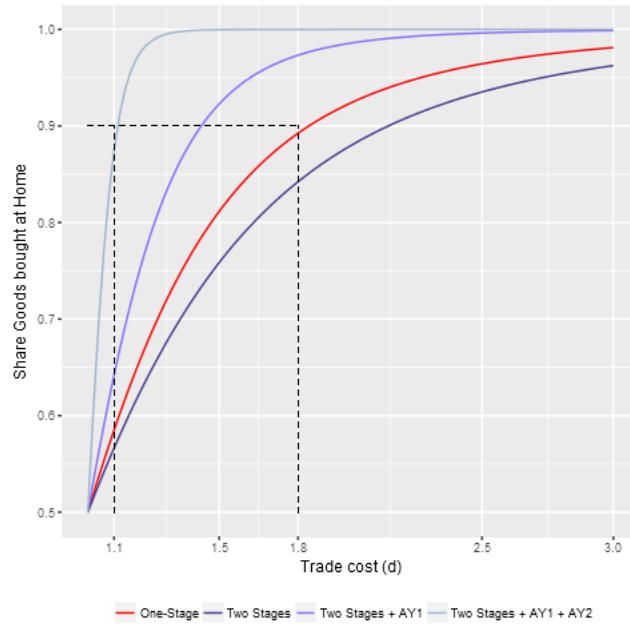


Figure 4: Shares of Final goods bought at home: One-stage model, two-stages model with endogenous and exogenous source of upstream inputs, and two-stages model with exogenous source of upstream inputs a modified production function.

at home in a multistage model would be smaller than the ones implied by a one-stage model, and even larger trade costs would be necessary to rationalize the current levels observed.

Additionally, by applying the findings of Nadarajah (2005), this paper finds estimable equations for the trade shares of a two-stages model. Further exploration of this model, would allow to expand the understanding of the implications of multistage production on trade flows, and on the impact of globalization on welfare across nations.

CHAPTER 2 : WELFARE, INCOME DISTRIBUTION, AND PATTERNS OF VERTICAL SPECIALIZATION IN A WORLD WITH FRAGMENTED PRODUCTION PROCESS.

2.1. Introduction

A significant feature of the increased level of globalization is the fragmentation of the production process across borders, allowing different countries to specialize in making particular stages of a good. Hummels, Ishii, and Yi (2001) calls this phenomena *vertical specialization*, and measures it as the proportion of imported goods that are used as inputs, to produce a country's export goods. Using this measure of vertical specialization, and the Input-Output database produced by the OECD, the first section of this paper shows that a country's vertical specialization decreases when income increases. Moreover, the ratio of final goods exported over the sum of final and intermediate goods exported, decreases when income increases. Therefore, there is evidence that relatively high-income countries tend to specialize in early stages of production, while relatively low-income countries specialize in later stages of production. This observation is consistent with the cases studied in Hummels, Rapoport, and Yi (1998), in which relatively low-wage countries engage in final assembly, and relatively high-wage countries engage in parts and components production. In this paper, the consequences over the distribution of welfare among countries of this fragmentation of production and specialization in stages, are studied.

The interest on welfare distribution among countries over other aspects that are affected by trade, comes from the perception that some countries are on "the winning side" of trade while others are on the "losing side". This belief has fueled the current backlash against international trade. Understanding not only welfare consequences, but the distribution of the gains of the trade, can help policy makers in designing deals that can be sustain over time.

To study how eliminating trade barriers affects welfare distribution in the context of multi-

stage production, the theoretical model that adds a second stage of production to the Eaton and Kortum (2002)'s trade model outlined in Chapter 1, is extended for the multi-country case, and is estimated. With the calibrated parameters in hand, this paper compares the impact on welfare distribution when trade barriers are eliminated, in a two-stages model versus an equivalent one-stage model.

First of all, it is important to notice that welfare gains are larger in a two-stages model. In a two-stages model there are two sources of heterogeneity, coming from the productivity process of each stage. This increased heterogeneity, increases the sources of comparative advantage, and trade brings larger welfare gains.

Focusing on the analysis of welfare distribution, reducing trade barriers has the potential to increase income inequality among participant countries in a multistage production model, while in a one-stage model inequality decreases. The potential of increasing inequality in the two-stages model depends on labor mobility. If full labor mobility is assumed, wages do not change, and zero gravity brings price equality across nations. This equalization tends to favor countries that had high production costs, which also tend to be the least productive and poorest countries, which in turns leads to a decrease in inequality among nations in both models (one-stage and two-stages). However, if labor is assumed to be immobile, changes in the demand for goods would have heterogeneous impacts on wages. In the two-stages model, the demand for inputs increases more than the demand for final goods, and therefore input producers' wages experiment larger increases. Since input producers tend to be high-income countries, these are the countries that benefit the most from the increase in demand. When labor is assumed to be immobile, this effect dominates over the price equalization effect, leading to an increment on income inequality on the two stages model. In the one-stage model, changes in wages are smaller and the price equalization effect dominates.

Region	Country	Region	Country	Region	Country
Australia and New Zealand	Australia	Northern Europe	Estonia	South America	Colombia
Australia and New Zealand	New Zealand	Northern Europe	Finland	Southern Africa	So. African Customs Union
Central America	Costa Rica	Northern Europe	Iceland	Southern Asia	India
Central America	Mexico	Northern Europe	Ireland	Southern Europe	Croatia
Eastern Asia	Taiwan	Northern Europe	Latvia	Southern Europe	Greece
Eastern Asia	China	Northern Europe	Lithuania	Southern Europe	Italy
Eastern Asia	China Hong Kong SAR	Northern Europe	Norway	Southern Europe	Malta
Eastern Asia	Japan	Northern Europe	Sweden	Southern Europe	Portugal
Eastern Asia	Rep. of Korea	Northern Europe	United Kingdom	Southern Europe	Slovenia
Eastern Europe	Bulgaria	South-Eastern Asia	Brunei Darussalam	Southern Europe	Spain
Eastern Europe	Czech Rep.	South-Eastern Asia	Cambodia	Western Asia	Cyprus
Eastern Europe	Hungary	South-Eastern Asia	Indonesia	Western Asia	Israel
Eastern Europe	Poland	South-Eastern Asia	Malaysia	Western Asia	Saudi Arabia
Eastern Europe	Romania	South-Eastern Asia	Philippines	Western Asia	Turkey
Eastern Europe	Russian Federation	South-Eastern Asia	Singapore	Western Europe	Austria
Eastern Europe	Slovakia	South-Eastern Asia	Viet Nam	Western Europe	Belgium-Luxembourg
Northern Africa	Tunisia	South-Eastern Asia	Thailand	Western Europe	France
Northern America	Canada	South America	Argentina	Western Europe	Germany
Northern America	USA	South America	Brazil	Western Europe	Netherlands
Northern Europe	Denmark	South America	Chile	Western Europe	Switzerland

Table 1: Countries included in the analysis.

2.2. Stage Specialization

Vertical Specialization (VS) is defined as the phenomenon of disintegration of production, with each country specializing in particular stages of a good’s production sequence. A common measure of vertical specialization is the one defined in Hummels, Ishii, and Yi (2001), and expanded in Johnson and Noguera (2012), which is the value of imported goods used as inputs to produce a country’s export goods, i.e. the foreign value added embodied in exports. This measure emphasizes the multiple border crossing in the production of a good. For country i and sector k , vertical specialization (VS) is defined as

$$VS_{ik} \equiv \frac{\text{imported intermediates}_{ik}}{\text{gross output}_{ik}} \text{exports}_{ik},$$

and for country i is defined as

$$VS_i = \frac{\sum_k VS_{ik}}{\sum_k \text{exports}_{ik}}.$$

The data used in this paper comes from the Inter-Country Input-Output tables produced by the OECD (OECD, 2008). Table 2.2 shows the countries for which information is available, and the region they belong to.

Figure 5 plots the relationship between vertical specialization and nominal GDP in 2008,

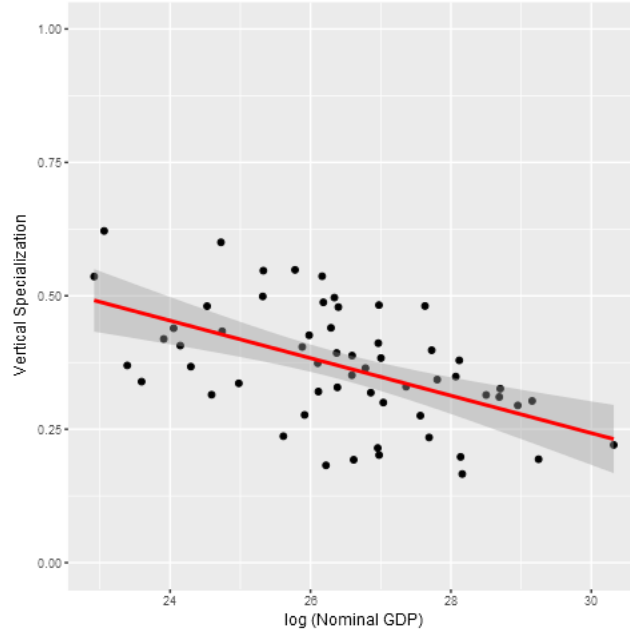


Figure 5: Relationship between vertical specialization and GDP, 2008

and table 2 shows the results of running a linear regression between vertical specialization and the logarithmic of GDP, for the same year. As can be seen, an increase in GDP of one percent is associated with a decrease in vertical specialization of 3.5 percentage points. That means that wealthier countries use relatively more domestic inputs to produce their exports.

The vertical specialization measure is a common way to describe the specialization in stages, and integration in production of countries. However, this paper also uses the ratio final goods exported over total goods exported, and figure 6 shows the relationship between this ratio and the logarithmic of GDP, while table 3 shows the result of running a linear regression between the two variables. The pattern of stage specialization persists in this additional measure, and an increase in GDP of 1% is associated with a decrease in the ratio of final goods exported of 1 percentage point.

Finally, and as a way to emphasize the importance of vertical specialization in trade, figure 7 shows the contribution of vertical specialization to the growth of exports to GDP ratio.

<i>Dependent variable:</i>	
Vertical Specialization	
log(GDP)	-3.511*** (0.755)
Constant	129.625*** (19.994)
Observations	58
R ²	0.279
Adjusted R ²	0.266

Note: *p<0.1; **p<0.05; ***p<0.01

Table 2: Linear regression of Vertical Specialization and GDP

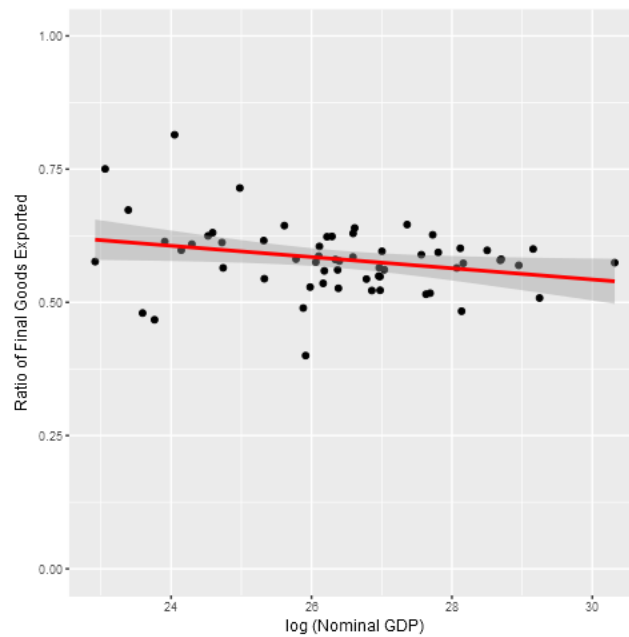


Figure 6: Relationship between Ratio of Final Exported and GDP, 2008

<i>Dependent variable:</i>	
Ratio of Final Goods Exported	
log(GDP)	-1.055** (0.494)
Constant	85.932*** (13.056)
Observations	60
R ²	0.073
Adjusted R ²	0.057
<i>Note:</i> *p<0.1; **p<0.05; ***p<0.01	

Table 3: Linear Regression of Ratio of Final Goods Exported and GDP

Exports to GDP ratio is decomposed according to the following expression

$$\Delta \frac{\text{exports}_k}{\text{output}_k} = \Delta \frac{VS_k}{\text{output}_k} + \Delta \frac{\text{exports}_k - VS_k}{\text{output}_k}.$$

Vertical Specialization accounts for 84% of the growth of manufacturing exports between 1995 and 2008, with percentages ranging from 33% to 102%. Moreover, in the same period, vertical specialization accounts for 59%-102% of trade growth in European regions, and for 74% in Eastern Asian countries (China, Taiwan, Hong-Kong and Japan). These numbers provide evidence that vertical links are relevant in explaining trade growth, and that a model with stages could be more appropriate.

2.3. Model

The model used for the analysis is the two-stages version of Eaton and Kortum (2002), outlined in Chapter 1. There are a continuum of varieties indexed by $z \in [0, 1]$. Each variety requires two stages of production: upstream ($k = 1$) and downstream ($k = 2$). The model determines the share of varieties traded at each stage of production.

The household maximization problem is defined in section 1.2.1, and the production technology is defined in section 1.2.2.

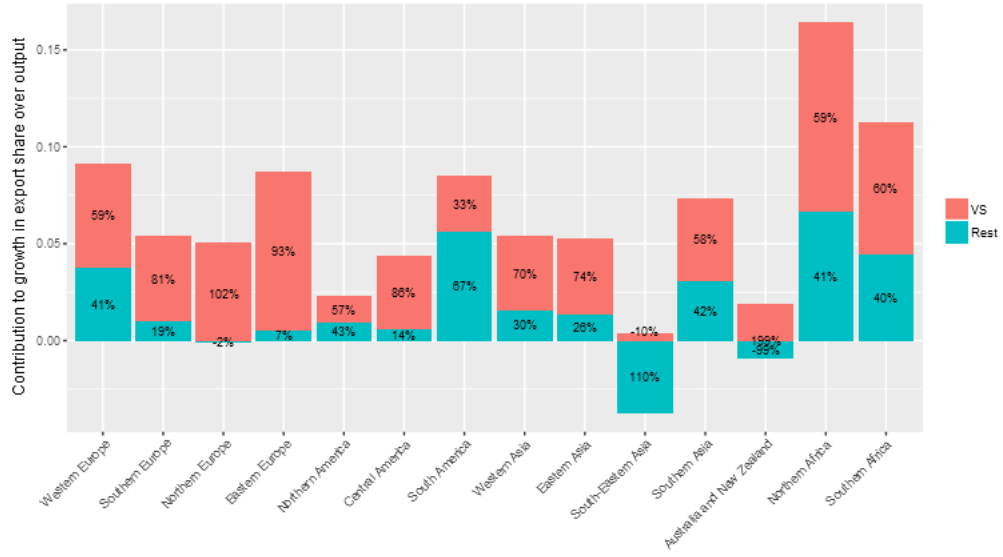


Figure 7: Contribution of vertical specialization to ratio of exports to GDP between 1995 and 2008

An equilibrium is a sequence of varieties, factor prices, and quantities, such that the first-order conditions to the households' maximization problem in equation (1.1) and firms' maximization problem, associated with technologies (1.2), (1.3), and (1.4), as well as the market clearing conditions (1.5), (1.6), (1.7), and (1.8) are satisfied.

2.3.1. Share of Upstream Varieties Traded

As shown in section 1.3, country i is the lowest cost source of upstream varieties for j with probability

$$\begin{aligned} \pi_{1,ji} &= \Pr \left[c_{1,ji} \leq \min_s \{c_{1,js}(z)\} \right], \\ &= \frac{T_{1,i} (d_{1,ji} c_{1,i})^{-n_1}}{\sum_{s=1}^I T_{1,s} (d_{1,js} c_{1,s})^{-n_1}}, \end{aligned}$$

where $c_{1,ji}$ is the unit cost that i can deliver to j , $d_{1,ji}$ is the iceberg transport cost, and $c_{1,i}$ is the upstream input cost produced in i , composed of wages and the price of M_i . The expression $T_{1,i} (d_{1,ji} c_{1,i})^{-n_1}$ represents the technology available in j from i , discounted by

input costs and geographic barriers. Since there is a continuum of varieties $\pi_{1,ji}$ is also the fraction of upstream varieties that country j buys from i .

The price index for the composite intermediate defined in equation 1.4 is

$$P_j = \Phi_{1,j}^{-\frac{1}{n_1}} \exp(\gamma/n_1) \quad (2.1)$$

where $\Phi_{1,j} = \sum_{s=1}^I T_{1,s} (d_{1,js} c_{1,s})^{-n_1}$ and γ is the Euler's constant.

2.3.2. Share of Downstream Varieties Traded

Cost minimization for the firm associated with technology 1.3, implies that the unit cost of a downstream variety z , if produced in country i and delivered to country j , with iceberg transport cost $d_{2,ij}$, is given by

$$c_{2,ji}(z) = \frac{\psi_2 d_{2,ji} w_i^{1-\theta_2} c_{1,i}^{\theta_2}}{A_{2,i}(z)}, \quad (2.2)$$

and its' distribution is

$$\begin{aligned} \Pr [C_{2,ji} \leq c_2] &= \int_0^\infty \Pr \left[A_{2,i}(z) \geq \frac{\psi_2 d_{2,ji} w_i^{1-\theta_2} c_1^{\theta_2}}{c_2} \middle| c_1 \right] dG_{1,i}(c_1), \\ &= 1 - \Phi_{1,j} n_1 \int_0^\infty \exp \left[-T_{2,i} \left(\psi_2 d_{2,ji} w_i^{1-\theta_2} c_1^{\theta_2} \right)^{-n_2} c_2^{n_2} - \Phi_{1,i} c_1^{n_1} \right] c_1^{n_1-1} dc_1. \end{aligned} \quad (2.3)$$

The probability that country j imports the downstream variety z from country i is the probability that

$$\pi_{2,ij}(z) = \int_0^\infty \prod_{s \neq i} (1 - \Pr [C_{2,si} \leq c_2]) d\Pr [C_{2,ji} \leq c_2], \quad (2.4)$$

where $\Pr [C_{2,ji} \leq c_2]$ is defined in (2.3). This equation will be computed numerically.

2.3.3. Equilibrium

The empirical implementation is to production and trade in manufactures. Manufacturing labor income in country i is labor' share of country i 's manufacturing production. Thus

$$w_i L_i = (1 - \theta_1) \sum_{j=1}^I \pi_{1,ji} X_{1,j} + (1 - \theta_2) \pi_{2,ji} X_{2,j} \quad (2.5)$$

where L_i is manufacturing workers, and $X_{1,j}$ and $X_{2,j}$ is total spending on upstream and downstream varieties, respectively. Denote aggregate final expenditure as Y_i with α the fraction spent on manufactures. Total expenditure on downstream varieties is given by

$$X_{2,i} = \alpha Y_i, \quad (2.6)$$

and total expenditure on upstream varieties by

$$X_{1,i} = \theta_2 \sum_{j=1}^I \pi_{2,ij} X_{2,j} + \theta_1 \sum_{j=1}^I \pi_{1,ij} X_{1,j}. \quad (2.7)$$

Final expenditure Y_i consists of value-added in manufacture $w_i L_i$ plus income generated in nonmanufacturing $Y_{0,i}$.

2.4. Estimation

2.4.1. Parameters

Trade costs of upstream varieties are assumed to be equal to trade costs of downstream varieties, that is $d_{ji} = d_{1,ji} = d_{2,ji} \forall i, j$, and following Eaton and Kortum (2002), are specified as

$$d_{ji} = \exp(\Gamma x_{ij}) M_j U_{ij}, \quad (2.8)$$

where x_{ij} is a vector of observables, that includes distance, dummy for contiguity, and dummy for common language; M_j is an importer fixed effect, and Γ is a vector of coefficients

on the bilateral variables x_{ij} . The error term consists of two components, one of them is a country-pair specific component that affect two-way trade. Trade costs within the country are assumed to be non-existent, i.e. $d_{jj} = 1$.

Additionally, the technology parameter of the upstream varieties is assumed to be the same as the technology parameter of the downstream variety. That is, $T_i = T_{1,i} = T_{2,i}$. Since there is a continuum of varieties, the probability that country i is the lowest cost source of an upstream variety for country j , which is given in equation (1.14), is also the fraction of upstream varieties that country j buys from country i . That is,

$$\pi_{1,ij} = \frac{X_{1,ji}}{X_{1,j}} = \frac{T_i (d_{ji}\psi_1(w_i)^{1-\theta_1}(P_i)^{\theta_1})^{-n_1}}{\Phi_{1,j}}, \quad (2.9)$$

where $X_{k,j}$ is country j 's total spending on stage k , of which $X_{k,ji}$ is spent on varieties from i . Dividing this expression by the analogous expression for the share of upstream varieties that country j buys from itself, and applying logarithms, gives

$$\begin{aligned} \frac{X_{1,ji}/X_{1,j}}{X_{1,jj}/X_{1,j}} &= \frac{T_i (d_{ji}\psi_1(w_i)^{1-\theta_1}(P_i)^{\theta_1})^{-n_1}}{\Phi_{1,j}} \frac{\Phi_{1,j}}{T_j (d_{jj}\psi_1(w_j)^{1-\theta_1}(P_j)^{\theta_1})^{-n_1}} \\ \frac{X_{1,ji}}{X_{1,jj}} &= \frac{T_i}{T_j} \left(\frac{w_i}{w_j}\right)^{-n_1(1-\theta_1)} \left(\frac{P_i}{P_j}\right)^{-n_1\theta_1} d_{ji}^{-n_1}, \\ \log\left(\frac{X_{1,ji}}{X_{1,jj}}\right) &= \log\left(\frac{T_i}{T_j}\right) - n_1(1-\theta_1)\log\left(\frac{w_i}{w_j}\right) - n_1\theta_1\log\left(\frac{P_i}{P_j}\right) - n_1\log(d_{ji}), \\ \log\left(\frac{X_{1,ji}}{X_{1,jj}}\right) &= \log\left(\frac{T_i}{T_j}\right) - n_1(1-\theta_1)\log\left(\frac{w_i}{w_j}\right) - n_1\theta_1\log\left(\frac{P_i}{P_j}\right) - n_1\Gamma x_{ji} - n_1\log(M_j) - n_1\log(U_{ij}). \end{aligned}$$

Rearranging the terms, the previous expression gets reduced to

$$\log\left(\frac{X_{1,ji}}{X_{1,jj}}\right) = S_i - (S_j + n_1M_j) - n_1\Gamma x_{ji} + u_{ji},$$

where $S_i = \log(T_i) - n_1(1-\theta_1)\log(w_i) - n_1\theta_1\log(P_i)$. The previous equation is estimated by generalized least squares. The share of imported intermediates over domestic intermediates (X_1^{ji}/X_1^{jj}), is obtained from the OECD Input-Output database (OECD, 2008) and

geographic characteristics (x_{ji}) are obtained from CEPII (Head, Mayer, and Ries, 2010) ¹.

Parameters can be retrieved by estimating

$$\hat{S}_i = \log(T_i) - n_1(1 - \theta_1) \log(w_i) - n_1\theta_1 \log(P_i).$$

A country’s technology (T_i) is approximated with domestic R&D capital stocks, estimated by Coe, Helpman, and Hoffmaister (2009) using the perpetual inventory method to add up real R&D investment ². Since wage costs (w_i) are correlated with the level of technology, total workforce and population density are used as instruments, in the following way

$$\log(\text{ulc} \times e^{-\text{hc}}) = \log(\text{lf} \times e^{-\text{hc}}) + \log(\text{lf}/\text{area}),$$

where “ulc” are unit labor costs in nominal terms obtained from the OECD databases (OECD, 2019); “hc” is an index of human capital per person, based on years of schooling and returns to education, obtained from Penn World Database (Feenstra et al., 2015); “lf” is the labor force obtained from the World Bank database (Bank, 2008), and the area of the country is obtained from the CEPII Gravity Database (OECD, 2019). The price level (P_i), is also correlated with the level of technology, so is instrumented using area, population, and technology level of the country. The dependent variables GDP price index, and the population were obtained from the Penn World Database (Feenstra et al., 2015).

The share of intermediate varieties used to produce the final goods (θ_2), can be retrieved from the data, and is equal to

$$\hat{\theta}_2 = \frac{1}{I} \sum_{j=1}^I \left(\frac{\sum_{i=1}^I X_{1,ji}}{\sum_{i=1}^I X_{2,ij}} \right).$$

Up to the previous step, the only parameter left to calibrate is the heterogeneity of the

¹Formulation includes distance, dummy for contiguity, and dummy for common language

²Only available for 24 of the 60 countries

Parameters	Definition	Value	Source
n_1	Comparative advantage stage 1	5.65	Section 2.4.1
n_2	Comparative advantage stage 2	5.08	Section 2.4.1
θ_1	Intermediates share stage 1	0.75	Section 2.4.1
θ_2	Intermediates share stage 2	0.68	Section 2.4.1
α	Manufacturing share	0.17	Input-Output database
T_i	States of technology	Table 5	Section 2.4.1
d_{ji}	Geographic barriers	Table 6	Section 2.4.1

Table 4: Summary of Parameters

second stage, given by n_2 . Equation (2.3), with calibrated parameters looks like

$$\Pr [C_{2,ji} \leq c_2] = 1 - \Phi_{1,j}^{\hat{n}_1} \int_0^\infty \exp \left[-\hat{T}_i \left(\hat{\psi}_2 \hat{d}_{ji} \hat{w}_i^{1-\hat{\theta}_2} c_1^{\hat{\theta}_2} \right)^{-n_2} c_2^{n_2} - \Phi_{1,i}^{\hat{n}_1} c_1^{\hat{n}_1} \right] c_1^{\hat{n}_1-1} dc_1,$$

and this expression can be plugged into equation (2.4). The parameter n_2 is estimated in order to minimize the difference between the actual and estimated share of imported downstream varieties defined in (2.4).

Table 4 shows the calibrated and estimated parameters, that will be used in the following sections.

2.4.2. Fitness of the model

For the model described in this paper, vertical specialization can be summarized by

$$VS_i = (1 - \pi_{1,ii}) [\theta_2 XR_i + \theta_1 (1 - XR_i)]$$

where $XR_i = \frac{\sum_{j \neq i} X_{2,ij}}{\sum_{j \neq i} X_{1,ij} + X_{2,ij}}$, is the ratio of downstream varieties exported, over total manufacturing exports. The correlation between actual and estimated vertical specialization is 81%, and is plotted in figure 8.

The correlation between actual and estimated ratio of downstream varieties exported is 46%

Country	Value	Country	Value	Country	Value
Argentina	117.68	France	1130.99	Netherlands	485.91
Australia	391.67	United Kingdom	1115.60	Norway	243.53
Austria	317.88	Greece	90.83	New Zealand	95.33
Belgium	401.35	Hong Kong	120.79	Philippines	8.51
Bulgaria	2.69	Croatia	0.41	Poland	27.24
Brazil	1146.04	Hungary	19.89	Portugal	99.70
Brunei Darussalam	44.75	Indonesia	32.18	Romania	8.84
Canada	637.84	India	43.01	Russian Federation	3356.63
Switzerland	486.05	Ireland	153.98	Saudi Arabia	4941.69
Chile	1003.29	Iceland	41.46	Singapore	716.43
China	2012.26	Israel	351.68	Slovakia	9.95
Colombia	38.20	Italy	671.06	Slovenia	2.02
Costa Rica	6.11	Japan	2099.64	Sweden	536.64
Cyprus	5.88	Cambodia	0.23	Thailand	148.94
Czech Republic	35.66	Korea (Republic of)	729.27	Tunisia	3.59
Germany	1467.56	Lithuania	1.83	Turkey	46.36
Denmark	276.96	Latvia	2.53	Taiwan, Province of China	530.13
Spain	394.69	Mexico	130.14	United States of America	3675.72
Estonia	3.84	Malta	0.95	Viet Nam	11.84
Finland	305.10	Malaysia	191.46	South Africa	193.79

Table 5: States of Technology

Source of Barrier	Value	Source of Barrier	Value	Source of Barrier	Value
log(distance)	-1.00				
Contiguity	0.34				
Common language	0.21				
Destination country:					
Argentina	0.60	France	0.50	Netherlands	0.61
Australia	0.43	United Kingdom	0.45	Norway	0.57
Austria	0.66	Greece	0.69	New Zealand	0.59
Belgium	0.53	Hong Kong	0.63	Philippines	0.63
Bulgaria	0.84	Croatia	1.21	Poland	0.65
Brazil	0.48	Hungary	0.69	Portugal	0.68
Brunei Darussalam	0.84	Indonesia	0.53	Romania	0.83
Canada	0.46	India	0.49	Russian Federation	0.44
Switzerland	0.61	Ireland	0.52	Saudi Arabia	0.45
Chile	0.50	Iceland	0.98	Singapore	0.45
China	0.37	Israel	0.63	Slovakia	0.76
Colombia	0.69	Italy	0.49	Slovenia	0.89
Costa Rica	0.82	Japan	0.40	Sweden	0.53
Cyprus	0.96	Cambodia	0.90	Thailand	0.46
Czech Republic	0.66	Korea (Republic of)	0.38	Tunisia	0.88
Germany	0.42	Lithuania	1.08	Turkey	0.65
Denmark	0.61	Latvia	1.03	Taiwan, Province of China	0.43
Spain	0.49	Mexico	0.51	United States of America	0.33
Estonia	0.99	Malta	0.94	Viet Nam	0.57
Finland	0.60	Malaysia	0.46	South Africa	0.53

Table 6: Geographic Barriers

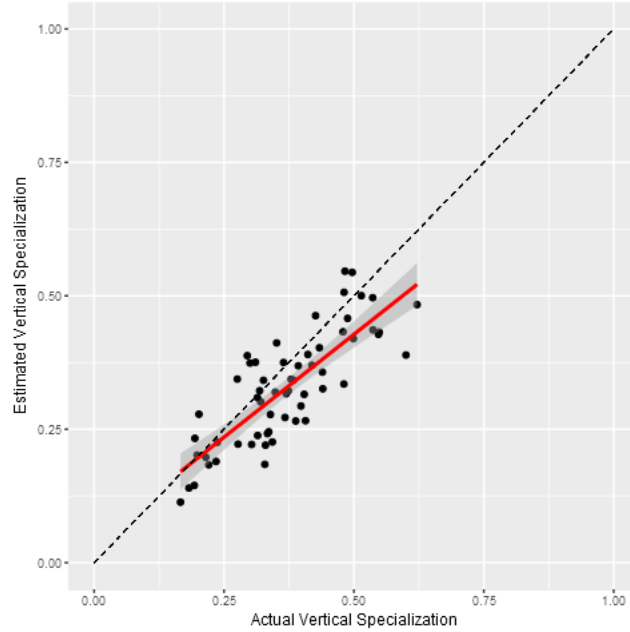


Figure 8: Correlation between actual and estimated vertical specialization.

and is plotted in figure 9.

Finally, figure 10 shows the relationship between actual and estimated exports to GDP ratio. In this case the correlation is weaker, of only 23%, and the model tends to overestimate the ratio.

2.5. Patterns of Vertical Specialization

Figure 5 in section 2.2, showed that countries with higher income tend to have lower levels of vertical specialization. This pattern of vertical specialization along with the relation between the ratio of downstream varieties exported and GDP plotted in figure 6, suggests that technologically advanced countries -and therefore, countries with higher income- produce relatively more inputs than final goods. This pattern of specialization will be important in explaining the impact of reducing trade barriers over income distribution, in a world of multi-stage production. Therefore, this section explores this pattern of vertical specialization in a two stages model.

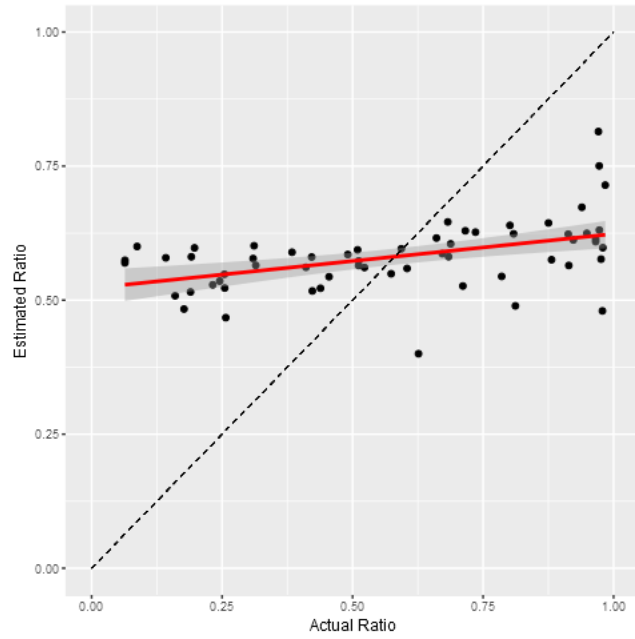


Figure 9: Correlation between actual an estimated ratio of downstream varieties exported.

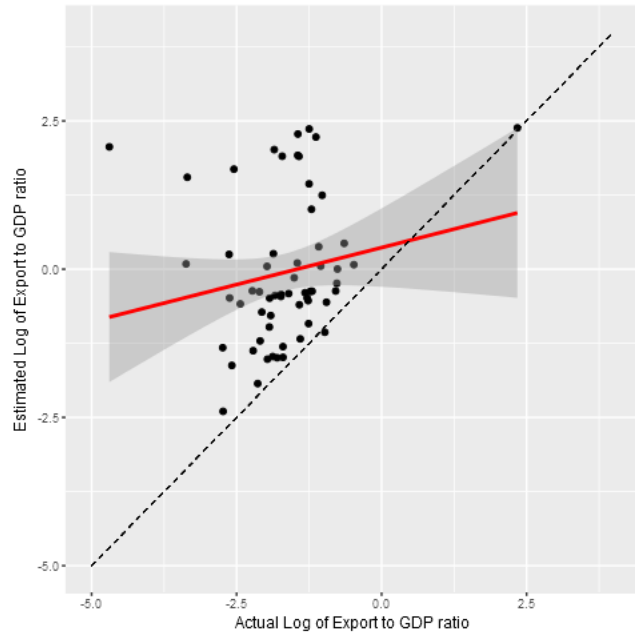


Figure 10: Correlation between actual an estimated exports to GDP ratio

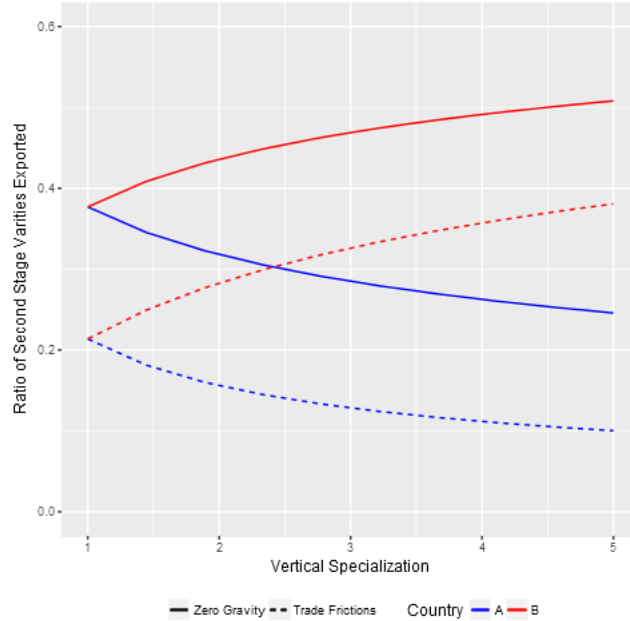


Figure 11: Relationship between vertical specialization and income.

Figure 11 compares vertical specialization of two initially identical countries, when country A experiments an increase in its technology, while country B stays the same. To simplify the exposition, and only for this section, the heterogeneity parameter and the share of intermediate goods of the second stage are assumed to be equal to the parameters of the first stage (i.e. $n_1 = n_2 = 5.09$, and $\theta_1 = \theta_2 = 0.75$). As represented by the solid lines in figure 11, when there are no trade frictions, and both countries have the same technology (i.e. the ratio of technology is 1), both countries have the same vertical specialization ratio. When country A experiments an increase in technology, its vertical specialization decreases, which means it is using relatively more domestic inputs for the production of its exports. This pattern of specialization occurs even when there are no trade costs, nor differences in the production process. This suggests that this pattern of vertical specialization is a result of the marginal value of saving costs at the input level being larger than the marginal value of saving costs at the final goods level.

The dashed lines in the same figure, compares vertical specialization of the same two countries, when country A experiments an increase in its technology, but this time, there are

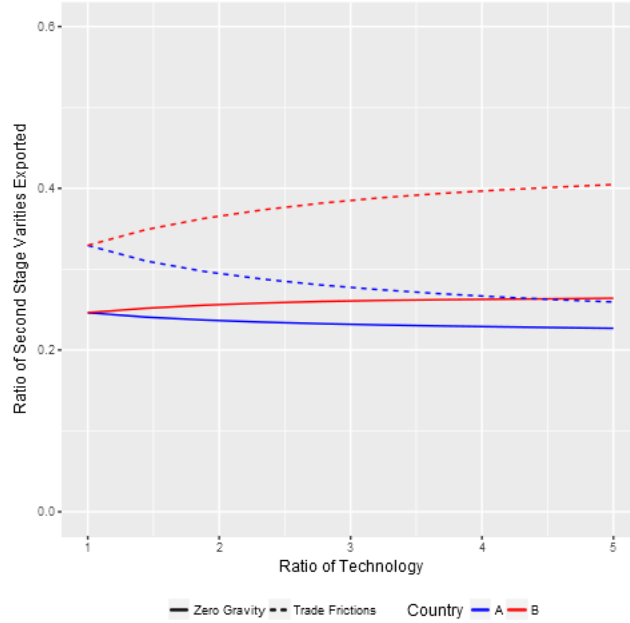


Figure 12: Relationship between ratio of downstream varieties exported over total exports, and ratio of technology.

trade frictions. It can be seen that pattern of vertical specialization persists, but the levels are lower.

It can be argued that vertical specialization it is heavily influenced by the share of upstream inputs shared between the countries, and that like in any gravity equation, trade is positively correlated with the income level of the partner country. In order to eliminate doubts on the mechanism, the ratio of downstream varieties exported over total exports (defined as XR_i in the previous section), is analyzed. Figure 12, follows the same exercise as figure 11, and compares XR for different technology ratios between two initially identical countries. When country A's technology increases relatively to country B's, country B exports relatively more downstream varieties while country A specializes in upstream varieties. When trade frictions are introduced, this pattern of specialization becomes even more accentuated.

2.6. Zero-Gravity World

In this section the impact of eliminating trade barriers (i.e. setting $d_{ji} = 0$ for all j and i) on welfare, and inequality is analyzed. This exercise is similar to the one performed in Eaton and Kortum (2002), and the results will be compared in order to prove consistency. Additionally, the impact on welfare and inequality in a two-stages model will be compared to the impact in a one-stage model, in order to understand the implications of a multistage production process over welfare and its distribution.

Welfare is measured as real GDP $W_i = Y_i/P_{2,i}^\alpha$, and inequality is described using Gini Index. The Gini coefficient measures the inequality among values of a frequency distribution, and is given by

$$G = \frac{\sum_{i=1}^I \sum_{j=1}^I |W_i - W_j|}{2I \sum_{i=1}^I W_i}$$

where W_i is the welfare an average person in country i . A Gini coefficient of zero expresses perfect equality, where all values are the same (for example, where everyone has the same welfare). A Gini coefficient of 100% expresses maximal inequality among values (e.g., for a large number of people, where only one person has all the income or consumption, and all others have none, the Gini coefficient will be very nearly one).

For simplicity, tariff revenues that geographic barriers might generate are ignored.

The impact on welfare of eliminating trade barriers depends on the assumptions over labor mobility. If labor is assumed to be mobile between manufacturing and non-manufacturing, the wage will be fixed and determined by the productivity in the non-manufacturing sector. Moreover total nominal income is exogenous. When trade barriers are eliminated, prices are equalized across nations, which particularly favors those countries with initially high prices. Therefore, welfare increases for all countries and inequality decreases.

A more interesting case is the other extreme assumption that labor is immobile. In this case, the number of manufacturing workers in each country is fixed, and non-manufacturing

Statistic	N	Mean	St. Dev.	Min	Max
Δ Wage	60	-21.987	15.437	-72.295	6.517
Δ Price	60	-300.670	27.819	-353.131	-248.797
Δ Welfare	60	29.459	18.510	-28.178	56.972

Table 7: Summary Statistics Changes in Welfare in Zero Gravity World - Immobile Labor One Stage Model

income is exogenous. When labor is immobile there are two forces at work, the price reduction described in the previous paragraph, and an impact on wages that will depend on comparative advantages. In this exercise, manufacturing employment is set to its actual level, and non manufacturing GDP to actual GDP less the baseline value for labor income in manufacturing (actual employment times the baseline wage).

Table 7 shows the changes in wages, prices, and welfare in the one-stage model. This is a similar exercise than the one made by Eaton and Kortum (2002), and the changes in welfare follow the same trend, as shown in figure 13.

The first thing to notice is that in a one-stage model wages and welfare can either decrease or increase. On the one hand, wages can decrease when the substitution effect dominates. That is, the price of intermediates has gone down when trade barriers are eliminated, and since labor and intermediates are substitutes in production, the price reduction pushes wages down. On the other hand, the decrease in prices pushes the demand for final goods up, which pushes the demand for intermediates up. This increase in demand, pushes wages (and prices) up.

Table 8 shows the changes in wages, prices, and welfare from eliminating trade barriers, but when the production process has two tradable stages. Labor is also assumed to be immobile, and results are compared with the one-stage case described in table 7. Notice that in the two-stages model, welfare changes are larger than in the one-stage model. The reason is that in the two-stages model, wages always go up, and the income effect that pushes demand up dominates over the substitution effect. In the multistage, there is more

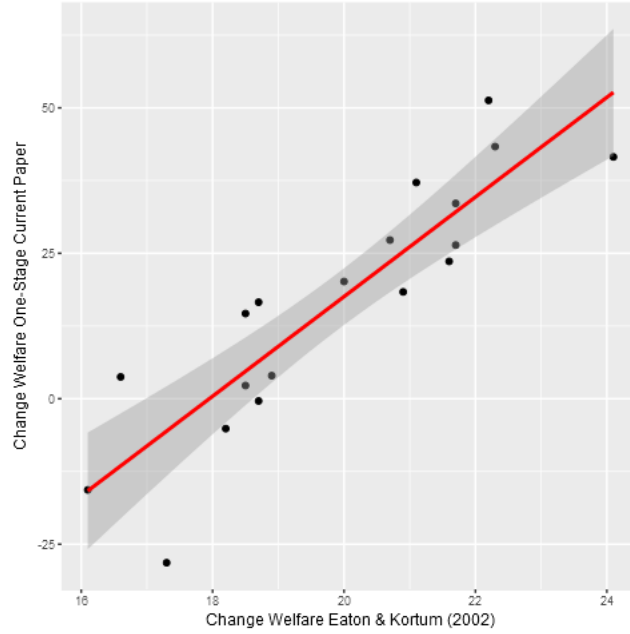


Figure 13: Comparison of changes in welfare when moving to Zero Gravity in Eaton and Kortum (2002) and this paper

Statistic	N	Mean	St. Dev.	Min	Max
Δ Wage	60	41.084	9.754	11.393	60.601
Δ Price	60	-177.446	7.992	-200.294	-161.767
Δ Welfare	60	71.446	9.491	41.131	90.522

Table 8: Summary Statistics Changes in Welfare in Zero Gravity World - Immobile Labor Multistage Model

demand for varieties.

Figure 14 compares the changes in welfare with welfare in the base scenario -with trade barriers- in the one-stage model. As can be seen in the figure, there is a decreasing relation between the two variables, meaning that low income countries are the ones that experiment larger increases in welfare, driven by lower reductions in wages. As a result, in the new equilibrium inequality goes down, from 82.2 to 78.6

The comparison between changes in welfare and welfare in the base scenario is shown in figure 15. In this case, the relation follows an inverted u-shape, and the larger increases in

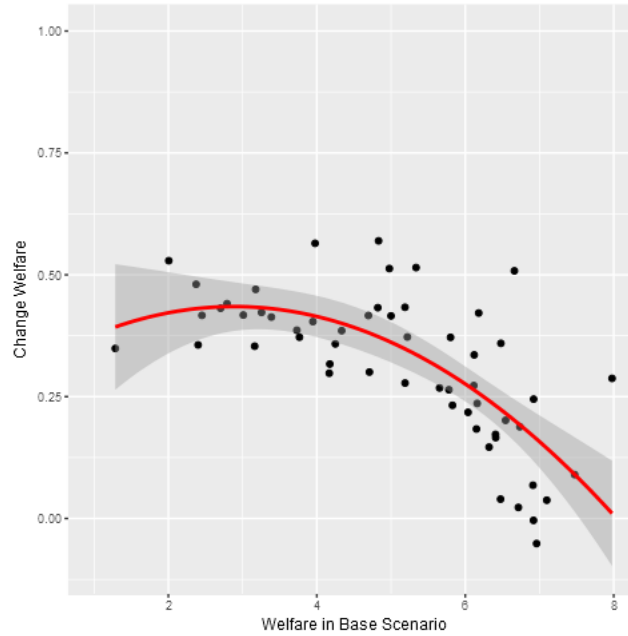


Figure 14: Relationship between changes in wages and wages in base scenario - one stage model

welfare favor middle-high income countries. As a result, overall inequality increases from 74.8 to 75.1.

To better understand the impact on welfare distribution, figure 16 compares the relationship between income and the ratio of downstream varieties over total exports, for the base scenario estimated in section 2.4, and for the zero gravity case, with a two-stages production process. When trade barriers are eliminated (red dots), all countries tend to receive relatively more income from the production of inputs rather than from final goods. Since high-income countries tend to have a comparative advantage on upstream varieties, will be more favored by this policy.

For completion, figure 17 compares the levels of vertical specialization before and after the trade liberalization. In the zero gravity case, all countries end up with relatively similar levels of vertical specialization. This conclusion differs from the results of the two-country case shown in figure 11, because in the multi-country case all countries are able find suppliers with comparative advantages on inputs.

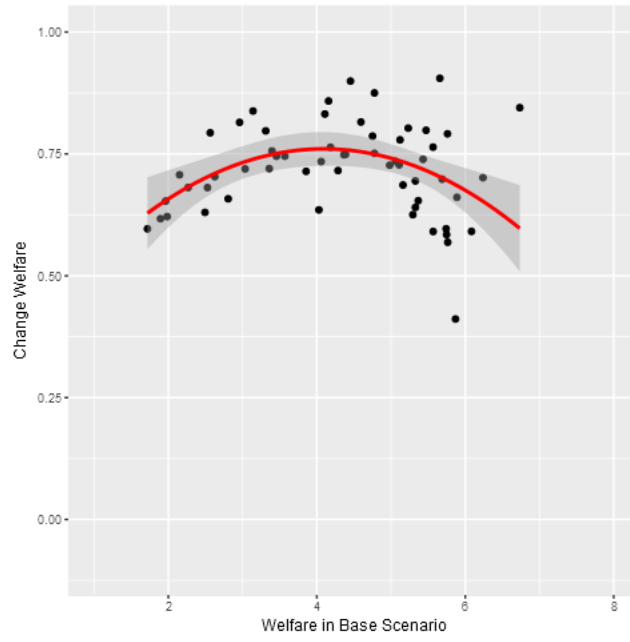


Figure 15: Relationship between changes in wages and wages in base scenario.

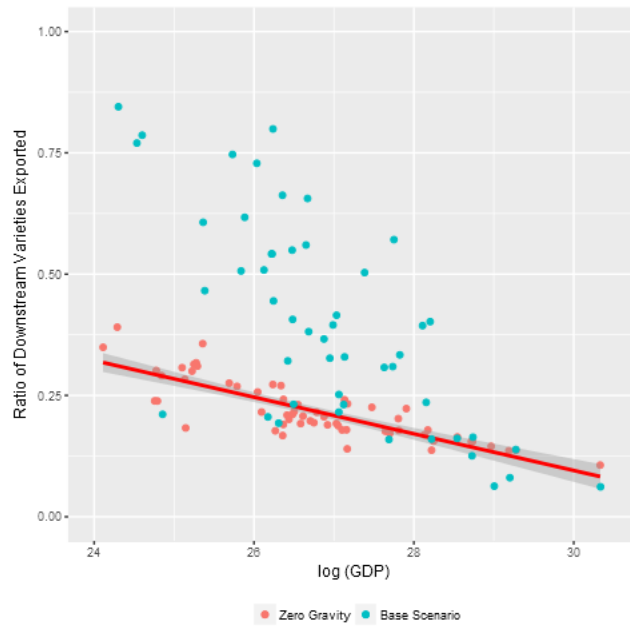


Figure 16: Relationship between ratio of second stage goods exported and income.

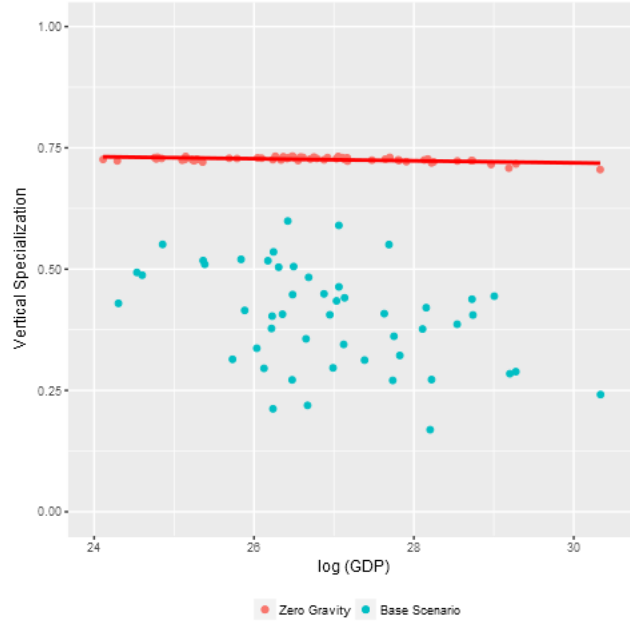


Figure 17: Relationship between vertical specialization and income.

2.7. Conclusion

This study develops a model to quantify the welfare and income distribution effect of fragmentation. As a first note, the model shows that technologically advanced countries will tend to specialize in earlier stages of production, even when productivity shocks of both stages follow the same distribution. The reason is that the marginal value of savings costs at the input level is larger than the marginal value of savings costs at the final goods level.

The main takeaway of this paper is the different impacts of reducing trade barriers in a world with fragmented production. As expected, when production is fragmented, welfare gains of eliminating trade barriers are larger. But, income distribution consequences are different in a model with one stage versus a two stages model. In the first one, eliminating trade barriers reduces inequality, while in the later one, inequality rises.

CHAPTER 3 : INNOVATION AND TECHNOLOGY DIFFUSION IN DEVELOPING COUNTRIES.

3.1. Introduction

Recent literature emphasizes the importance of technological progress in explaining productivity differences across firms and countries. One source of technological progress comes from creating new products or processes; another source of technological progress is adaption of technologies developed elsewhere. This last strategy is considered easier to implement and, therefore, a source of high growth at a relatively low cost. However, many developing countries fail to use technologies that would significantly increase their productivity and the reasons for this failure are not clear. One plausible explanation is that firms in developing countries do not have the required absorptive capacity to recognize the value of a new technology, assimilate it and apply it to commercial ends Cohen and Levinthal (1990).

The importance of absorptive capacity in adopting frontier technologies is illustrated in the research done by Bloom et al. (2011) in India. They introduced modern management practices in a sample of firms in India, and evaluated the results. Bloom et al. (2011) found that the implementation of these practices significantly increased the productivity of these firms, and therefore wondered why these practices were not implemented earlier. They conclude that financial constraints are not the main reason for why modern management techniques are not practiced, but that the lack of information about their existence, and the lack of knowledge about how these practices, if applied, could be profitable are the real issues.

Moreover, Cohen and Levinthal (1990) shows that low levels of absorptive capacity can drive the “non-invented-here” syndrome, in which firms resist accepting innovative ideas from the environment. If the ideas are too distant from the firm’s existing knowledge base, the firm will not adopt them because it does not appreciate them or it can not access to them.

In this paper, I explore the relationship between human capital and the decision of whether to innovate or to imitate technologies developed elsewhere, in order to increase productivity. Innovation is usually considered a difficult strategy, that requires highly qualified personnel to be successful. But human capital can also affect the absorptive capacity of a firm. For example, high-skilled workers might be better informed about frontier technologies and about how those technologies could be useful for their purposes, which is the first step for adopting a new technology. Also, new technologies might simply require high-skilled workers to be successfully implemented. Bloom et al. (2011) also conclude that new management practices are skilled-biased technologies, which implies that implementing them would require increasing the number of skilled workers. If developing countries have a shortage of high-skilled workers, it would more difficult for firms to adopt frontier technologies. In addition, if the frontier technology is too advanced compared to the current technological level of the firm, the cost of imitating it becomes even higher Hall and Khan (2003).

This paper starts from the puzzling fact that firms in developing countries are more likely to follow an innovation strategy rather than an imitation strategy, even though frontier technologies seem to be more productive, and firms would have more to gain from acquiring them. I also present some facts that suggest that innovation strategies could be even more frequent in developing countries than in advanced economies. The hypothesis behind these facts is that, differences on human capital endowments between advanced and laggard economies, makes the technologies developed in advanced countries not suitable or less productive in the developing world, and therefore, the optimal decision for firms in less developed countries, is to create their own technologies. A similar idea is presented Acemoglu and Zilibotti (1999), therefore I derive an extension of their model to rationalize the described findings.

3.2. Related Literature

There exists abundant literature on both, technology diffusion, and innovation; but only recently economists have attempted to study the decision of a firm to either innovate or

imitate, rather than focusing on only one of those growth strategy. In addition, technology diffusion in developing countries it is a major topic of research, but research on innovation in these countries is more scarce.

On the technology diffusion side, Eaton and Kortum (1996), conclude that imitation explains most of the economic growth of all OECD countries, but the United States, that instead it is leading the innovation process. Moreover, for all but the five leading research economies (United States, Japan, Germany, France and the United Kingdom) the 90% of the growth rates is explained by imitation of technology. Eaton and Kortum (1996) conclude that diffusion of technology results in all countries growing at the same rate, with countries that can absorb more innovations having higher relative productivity. In particular, they show that a country's level of education significantly facilitates its ability to adopt technology. Furthermore, Comin and Hobbijn (2006) conclude that adoption lags - defined as the length of time between the invention and adoption of a technology- accounts for at least a quarter of per capita income disparities in their sample of countries.

Also related to technology diffusion, Acemoglu and Zilibotti (1999) find that, even when there are no barriers to adoption of technologies, difference in productivity might never be reduced. The explanation is that frontier technologies are skilled bias in response to a relatively abundance of skilled workers, which makes them less productive when complemented with unskilled workers. Since in developing countries skilled workers are scarce, frontier technologies are less productive than in the country where they were produced, and lagged economies will never reach the productivity levels of the frontier.

A subset of the technology diffusion literature focuses on Foreign Direct Investment (FDI). FDI has long been considered an important channel for technology diffusion and there are several models that show how multinational enterprises might generate learning externalities for domestic firms, through labor training or through the provision of high-quality intermediate inputs. However the evidence on FDI spillovers it is not conclusive Keller (2004). Most studies find no effect and even negative effect of FDI in the productivity

of the host country. Studies that find positive effect of FDI use data from the United States and the United Kingdom, which implies that the results do not necessarily apply to developing countries. According to Xu (2000), rich countries benefit from hosting U.S. multinational subsidiaries while poorer countries do not as much, because some threshold level of human capital is needed to successfully adopt foreign technology.

Finally, recent literature has looked into the endogenous decision between imitation and innovation, and how this affects economic growth (Jovanovic and MacDonald (1993), Acemoglu et al. (2006), Benhabib et al. (2014), König et al. (2012), Luttmer (2012)). Usually in these models, it is assumed that laggard economies are more intensive in imitation activities, while advanced economies are focused in innovation. In Acemoglu et al. (2006), the benefit of developing economies of following an imitation strategy is large, but rigid arrangements are assumed at early stages of development, resulting in economies switching out of the imitation strategy too soon or too late. In Jovanovic and MacDonald (1993), both innovation and imitation are costly activities. The cost of imitation is represented in the form of informational barriers, that depend on the firm's current know-how and the know-how of other firms. Jovanovic and MacDonald (1993) use their model to explain firm size variances. In Benhabib et al. (2014) the productivity of the imitation strategy depends on investments that facilitate technology diffusion and on how easily is to adopt existing superior technologies. The ease of adopting technologies is measured by the distance to frontier. Benhabib et al. (2014) develop a model in which the initial productivity distribution affects the balanced growth path at which an economy converges, and where the efficiency of technology diffusion determines whether agents will ultimately catch up to the frontier, fall-back and continue to grow through technology diffusion or conduct autarkic innovation. In König et al. (2012)'s model, it is also assumed that there is a relative advantage of imitation over innovation for laggard firms, but the model can also generate "convergence clubs" when including limited capacity to absorb knowledge through imitation. Luttmer (2012) develop a model of noisy innovation and imitation that generates a balanced growth path along which, aggregate productivity grows faster than the average rate at which indi-

vidual producers are able to innovate. In Luttmer (2012)'s model there is an indirected search process, that delays the productivity of imitation, and gives rise to a thick tailed distribution of firm size.

Li (2011) studies innovation and imitation in the context of a developing country, more specifically on high-tech Chinese industries. The author studies the effect of technology diffusion on in-house R&D of firms, and concludes that technology imports alone do not contribute to the rate of patenting and that absorptive capacity is crucial for assimilating foreign technology. On the other hand, Li (2011) finds that absorptive capacity is not required for taking advantage of domestic knowledge (i.e. technology diffusion within the country) and that its presence facilitates firm's innovation. Li (2011) suggests that the argument for absorptive capacity is contingent upon the source of knowledge.

3.3. Expansion Strategies and Human Capital in Latin American Countries

In this section I present three facts. First, for a selected group of Latin American countries, the innovation strategy is more frequent than the imitation strategy, that is, there are more firms spending resources on creating technologies than firms bringing technologies from the frontier. Second, firms that imitate technology tend to have higher levels of human capital than firms innovating. Lastly, foreign technologies seem to have a higher impact on increasing productivity.

Using data collected by The World Bank (2010) - described in the appendix-, I propose a mechanism to distinguish firms that adopt technology from firms that create technology. I also distinguish innovations that are locally novel from the ones that represent an innovation at the frontier. Then, I compare several human capital indicators among firms that follow different expansion strategies.

Consider the following expansion strategies:

1. **Imitation Strategy.** Firms are classified as frontier adopters or imitators if they

answered “yes” to the following question: *Does this establishment at present use technology licensed from a foreign-owned company, excluding office software?*

2. **Local Innovation.** Firms are classified as innovators, but only locally, if they answered “yes” to the following question: *Does this establishment have any patents registered in (insert name of country)?*

3. **Frontier Innovation.** Firms are classified as frontier innovators if they answered “yes” to the following question: *Does this establishment have any patents registered abroad?*

These measures do not fully take into account all the firms following each strategy, because they exclude firms that adopt some non-licensed technology or firms that create technology but do not patent it. Patent information does not include all important technological innovations nor reflect the importance of different innovations Li (2011). However, the fact that the technology is protected by some intellectual property instrument assures that the innovation is novel, at least to the country, and that has a positive value. Moreover, the procedures to fill patents are homogeneous across industries, a feature that other innovation measures like new product sales, do not fulfill Li (2011).

3.3.1. Frequency of Innovation and of Imitation

The following figure classifies Latin-American firms according to their expansion strategies. More detailed statistics can be found in table 17 of the Appendix.

According to the diagram, only half of the firms have followed an expansion strategy; and, among the firms that have followed an expansion strategy, most of them are local innovators. This result is puzzling: in developing countries, we should expect a higher proportion of firms following an imitation strategy rather than an innovation one. However, the data suggests that firms prefer to create technologies that are locally novel rather than adopting a probably more advanced technology developed elsewhere.

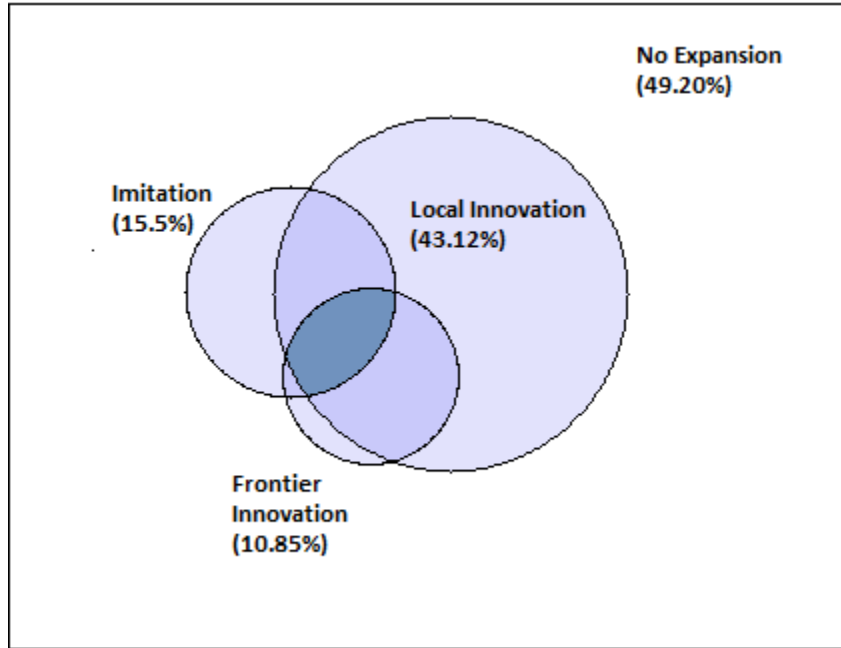


Figure 18: Proportions of firms by Expansion Strategies

3.3.2. Human Capital of Innovators and Imitators

The hypothesis of this paper is that this preference for local innovations can be explained by a lack of human capital endowment in the country or, in another words, a mismatch of skill endowments with respect to the frontier countries. When human capital is low, understanding and adopting frontier technologies could be more difficult than creating a technology that, even though is not as advanced as the one already developed somewhere else, represents an upgrade to their current level.

To support this hypothesis, the following table provides the estimated coefficients of three regressions. In the first regression, the dependent variable is the percentage of the workforce that has a bachelor degree. After controlling for foreign ownership, country of residence, and the industry on which the firm is classified, the table shows that the proportion of workers with a bachelor degree, in firms that follow a local innovation strategy, is only 1.46 percentage points higher than the proportion of workers with a bachelor degree in firms not following any expansion strategy. On the other hand, the proportion of workers with

Independent Variables	Proportion of workforce with Bachelor Degree	Probability Training	Log Wages
Only Local Innovation	1.46** (0.56)	1.45** (0.11)	0.34** (0.07)
Imitation	4.94** (0.71)	3.17** (0.35)	0.76** (0.08)
Frontier Innovation	5.99** (0.81)	3.60** (0.48)	1.02** (0.09)
Foreign Ownership	Yes	Yes	Yes
Country Dummies	Yes	Yes	Yes
Industry Dummies	Yes	Yes	Yes
% Bachelor	No	No	Yes
% Secondary	No	No	Yes
R^2	0.19	0.12	0.26
Observations	4,836	4,898	3,255

Table 9: Correlation between expansion strategies and human capital indicators
* means statistical significance at 90% level, and ** means statistical significance at 95% level.

a bachelor degree is almost five percentage points higher in firms following an imitation strategy and almost six percentage points higher in firms following a frontier innovation strategy. This result is consistent with the idea that the technology adopted from the frontier requires a higher level of human capital than the technology developed locally.

The third column of the table shows the results of running a logistic regression on whether a firm provides or not training for its workers. Using the same control variables as in the previous regression, the table shows that the odds of a local innovator providing training are 45% higher than of a firm that does not follow any innovation strategy. However, the odds of a firm that imitates foreign technology to provide training are 217% higher, and 260% higher for a frontier innovator.

Finally, the fourth column shows the results of running an OLS regression on the logarithmic of the average wage, controlling for foreign ownership, country of residence, industry, the proportion of the workforce that has a bachelor degree, and the proportion of the workforce that has a secondary degree. Local innovators pay an average wage 34% higher than firms that do not follow any expansion strategy, while imitators pay an average wage 76% higher, and frontier innovators pay an average wage 102% higher. Higher wages are associated with higher productivity, and therefore are also associated with non-observable human capital

variables.

From the results of the table, it can be concluded that imitators have higher levels of human capital than local innovators, but lower levels of human capital than frontier innovators. This conclusion is consistent with the hypothesis that frontier technologies require human capital capabilities that are not abundant in developing countries.

3.3.3. Impact on Productivity of Innovation and Imitation

In this subsection I compare the impact on productivity of local technologies versus frontier technologies. In order to do that, I estimate a total factor productivity (TFP) per firm, and compare TFP's distribution between 2006 and 2010 for three different groups: (1) firms that responded not having any expansion strategy in 2010, (2) firms that have only local innovations, and (3) firms that have acquired foreign technology ¹. For this part, I only use the panel version of the survey, i.e. only the firms that were surveyed in both, 2006 and 2010.

TFP per firm is estimated following König et al. (2012), that is, assuming a Cobb-Douglas technology of the form

$$Y_{it} = A_{it}K_{it}^aL_{it}^bM_{it}^c,$$

where Y_{it} denotes total sales of firm i at time t , A_{it} is total factor productivity, K_{it} its physical capital, and M_{it} its costs of materials.

The following figure compares the distribution of TFP among the three groups over time, and table 10 presents a T-test statistic for the difference on average productivity and a Kolmogorov-Smirnov test. From the figure and the tests, it can be concluded that firms that have followed only a local innovation strategy, did not have any increase in productivity between 2006 and 2010. On the other hand, for imitators, it can be concluded with 95%

¹There are not not enough observations for frontier innovators to make the analysis

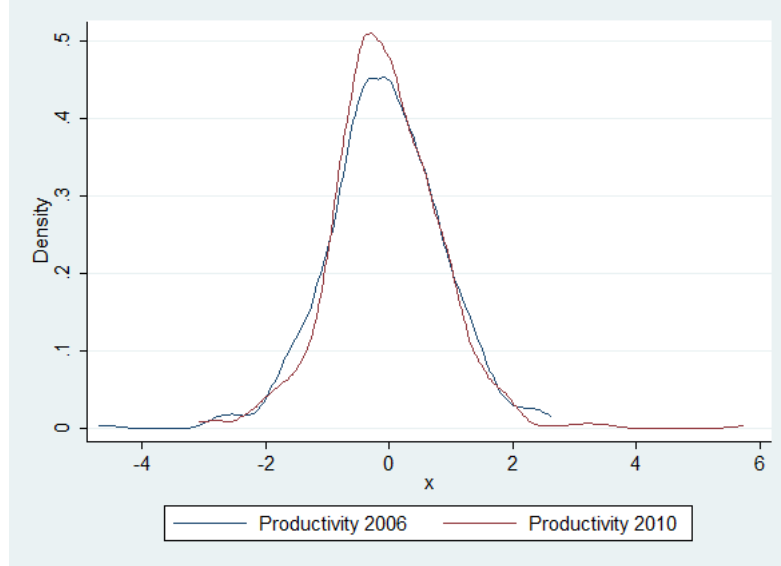


Figure 19: Productivity Distribution of Firms by Expansion Strategy No Growth Strategy

Group	Obs.	T-Test Average Productivity			Kolmogorov-Smirnov test	
		Difference Mean ($A_{2006} - A_{2010}$)	Std. Err.	Pr(diff<0)	Largest Difference ($A_{2006} - A_{2010}$)	P-value
No Growth Strategy	857	-0.02	0.06	0.38	-0.042	0.48
Local Innovation	569	-0.05	0.07	0.25	-0.049	0.51
Imitation	284	-0.18	0.11	0.05	-0.13	0.09

Table 10: Productivity Differences by year

confidence, that the average productivity in 2010 is higher than in 2006, and with 90% confidence that the distribution for 2010 switched to the right when compared with the distribution in 2006. These observations suggest that foreign technology has a larger impact on productivity relatively to local innovations, and rise the question of why is not imitation a more frequent strategy among firms.

3.4. Expansion Strategies and Human Capital: Worldwide Comparison

The previous analysis concluded that, in Latin American firms, the innovation strategy is more frequent than the imitation strategy, and that firms with large levels of human capital are the ones adopting foreign technologies, while firms with low levels of human capital are “creating” technologies. In this section, I would like to compare expansion strategies between developing countries and advanced economies and derive a similar set of facts,

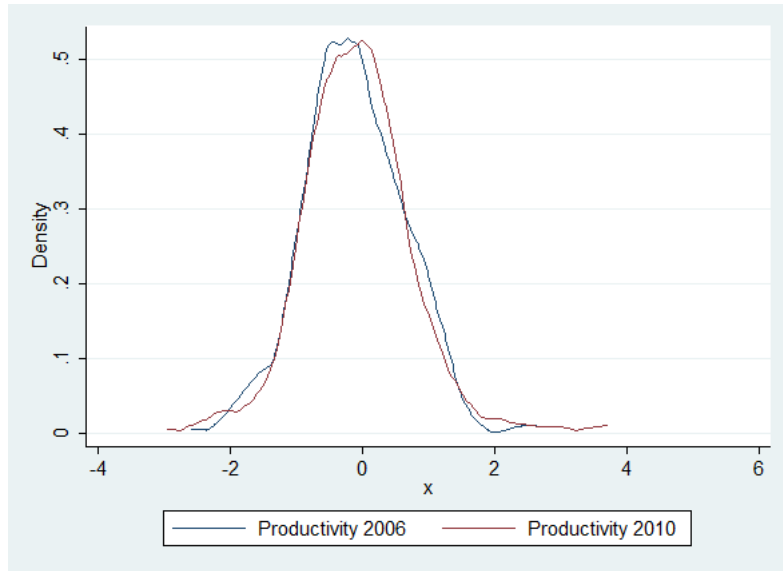


Figure 20: Productivity Distribution of Firms by Expansion Strategy Local Innovation

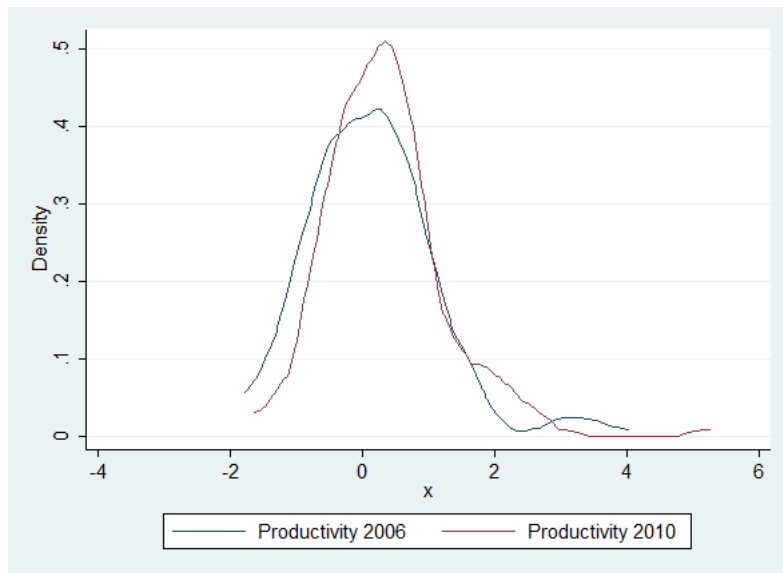


Figure 21: Productivity Distribution of Firms by Expansion Strategy Imitation

using the *WIPO Statistics Database*. The description of the variables used in the analysis can be found in section A.4, in the Appendix.

3.4.1. Frequency of Innovation and Imitation

First, I compare the proportion of patents that were developed and registered in the country relatively to the total number of inventions patented in the country². The following table shows the results of running a random effects regression on the proportion of patents developed in the country, controlling for human capital and for the total number of patents registered in the country. Human capital is measured using the human capital index constructed by Feenstra et al. (2013), that combines average years of schooling and assumed rates of return. The table indicates that the fraction of domestic patents is a convex function of the level of human capital. That is, for less educated countries, the fraction of domestic innovations decreases with the level of human capital, but for educated countries, the fraction of domestic innovations increases with human capital. This observation is in line with the one found in the previous section, that is, countries with low levels of human capital have a higher propensity to innovate, when compared with countries with intermediate levels of human capital. However, once the country is at the top of the educational distribution, it becomes an innovator.

3.4.2. Productivity, Innovation, and Imitation

In the analysis, it has been assumed that, in developing countries, local innovations have lower quality than the technologies developed abroad. To support this assumption, the following table summarizes the results of running a regression on Total Factor Productivity³ over the fraction of domestic patents, controlling for human capital and the total number of patents registered in the country. The table shows that a higher fraction of patents created in the country, is correlated with lower levels of TFP. However, when interacted with human capital, the relationship becomes positive. This results supports the hypothesis

²Including patents developed abroad and registered in the country

³Data obtained from Feenstra et al. (2013).

	Log (National Patents/Total Patents)	
(log Human Capital)	-12.99***	(3.465)
(log Human Capital) ²	8.801***	(1.833)
(log Total Patents)	-1.267***	(0.272)
(log Total Patents) ²	0.0418**	(0.0162)
Constant	8.211***	(1.923)
Observations	903	
R-sq Overall	0.2121	

Standard errors in brackets

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 11: Random Effects regression on the fraction of patents developed in the country over total patents registered.

that the imitation strategy, that is, bringing technologies from abroad has a higher impact on TFP.

3.4.3. Technology Diffusion and Human Capital Gaps

Finally, I follow Eaton and Kortum (1996)'s procedure in order to explore the relationship between human capital gaps and technology diffusion among countries. In their model, the number of patent applications from country i for protection in country n depends mainly on three factors: (1) the number of researchers in country i , (2) the fraction of patents developed in country i that are applicable in country n , and (3) the probability that an inventor from country i chooses to seek protection in country n . The number of patents granted in country n that were developed in country i , P_{nit} can be specified as

$$\log \frac{P_{nit}}{L_{it}} = \ln \alpha + \log \epsilon_{nit} + \beta \log \frac{R_{it}}{L_{it}} + \omega \log \frac{y_{it}}{y_{nt}} + u_{nit}. \quad (3.1)$$

The factor ϵ_{ni} is the marginal probability that an invention that occurred in country i is applicable in country n , measuring international technology diffusion. R_{it} and L_{it} are, respectively, the number of researchers and the total workforce in country i at period t . In Eaton and Kortum (1996) the probability that an inventor chooses to patent depends also

	Log TFP	
Log (National Patents/Total Patents)	-0.266***	(0.0545)
Log Human Capital	1.124***	(0.216)
Log Human Capital \times Log (National Patents/Total Patents)	0.232***	(0.0501)
Log Total Patents	0.0922***	(0.00774)
Constant	-2.551***	(0.214)
Observations	890	
R-sq Overall	0.3076	

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 12: Random Effects regression on Total Factor Productivity.

on how large the step is with respect to the current technology level. The step size of a patent is approximated with the relative levels of productivity.

Also, based on Eaton and Kortum (1996) the technology diffusion is approximated as

$$\begin{aligned} \log \epsilon_{nit} = & \epsilon_1 \mathbb{1}\{HK_{it} > HK_{nt}\} \log \left(\frac{HK_{it}}{HK_{nt}} \right) + \epsilon_2 \mathbb{1}\{HK_{it} \leq HK_{nt}\} \log \left(\frac{HK_{it}}{HK_{nt}} \right) \\ & + \epsilon_3 KM_{ni} + \epsilon_4 KM_{ni}^2 + \epsilon_5 \log IM_{nit}. \end{aligned}$$

The variable HK measures the level of human capital, and is used to test how the human capital gap affects the availability of the home country to adopt the foreign technology. The effect of the technological gap is separated in two groups: if the origin country has lower or greater level of human capital. The reason is that, when the technology gap increases the first variable also increases, but the second variable decreases.

The factor KM corresponds to the distance in kilometers from n to i , and KM^2 is the square of the distance, capturing geographical impediments to technology diffusion. Finally IM is n 's imports from i relative to n 's GDP, which examines whether imported goods are vehicle for the diffusion of technology.

	Log P_{nit}/L_{it}	
$\mathbb{1}\{HK_{it} > HK_{nt}\} \times \text{Log Ratio Human Capital}$	-1.539***	(0.155)
$\mathbb{1}\{HK_{it} \leq HK_{nt}\} \times \text{Log Ratio Human Capital}$	4.280***	(0.176)
KM_{ni}	-0.000290***	(0.0000210)
KM_{ni}^2	1.22e-08***	(1.29e-09)
Log R_{it}/L_{it}	0.504***	(0.00878)
Log y_{it}/y_{nt}	0.126***	(0.0194)
Log IM_{nit}	0.0979***	(0.00261)
Constant	-5.861***	(0.157)
Observations		48,156
R-sq overall		0.3506

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 13: Random Effects regression on patent applications from foreigners.

The results of estimating equation (3.1) can be found in the following table. In the first line, the estimator of the human capital gap when the origin country has a higher level of human capital, is presented. As expected, the sign is negative. The intuition behind this result is that, when a technology was created with and/or for a higher level of human capital than the one available in the country where the technology is been protected, the less likely is that it is going to be successfully implemented. Therefore, technology diffusion between countries with large differences in terms of human capital, decreases.

In the second line, the effect of the human capital gap is presented when the country where the patent was originated has a lower level of human capital than the country where the invention is been patented. The positive sign is, once again, expected. The higher the level of human capital level of the origin country, the closest it gets to the knowledge level of the country where the technology is to be protected, and the more likely is for the new technology to be useful for the receiver country.

3.5. Model

The purpose of this section is to present a model that captures the facts previously exhibited: in developing countries, more firms are creating technologies rather than adopting foreign and probably more advanced technologies; and imitators have higher levels of human capital in comparison with innovators. In the next section, the model is calibrated in order to understand the effect of this mechanism on TFP levels.

The model of this paper is borrowed from Acemoglu and Zilibotti (1999). In their paper, the authors argue that lack of intellectual property rights and other barriers to technology transfer induce R&D firms to target their innovations toward the needs of the advanced economies, which are inappropriate for less developed countries, mainly because those technologies were developed for a different composition of human capital. The focus on differences in skill endowments makes this model very appropriate for my analysis, in which human capital gaps will explain intensities on technology diffusion and on innovation.

However, Acemoglu and Zilibotti (1999) assume that no technologies are invented in less developed countries, and that they adopt all technologies available from the advanced economies because the cost of doing so is small. I change this assumption and instead, a cost of adopting the technologies is introduced. Since there is a mismatch of technological needs, the less developed countries will not adopt all technologies available and instead will generate innovations more suitable to their needs.

The first part of this section explains the main features of the model developed by Acemoglu and Zilibotti (1999). Next, I introduce new assumptions to the technical progress mechanism, to rationalize the patterns of innovation observed in less developed countries. In equilibrium, the number of firms adopting foreign technology will depend on the relative cost of innovation versus imitation, and on the endowments of human capital with respect to the frontier country.

3.5.1. Acemoglu and Zilibotti (1999) Model

Environment

Consider an economy consisting of two type of countries: an advanced one, which will be called the North, and a technologically laggard, which will be called the South. In addition, the North and the South differ in the abundance of skills. The North has H^N skilled and L^N unskilled workers, while the South has H^S skilled and L^S unskilled workers, where $\frac{H^N}{L^N} > \frac{H^S}{L^S}$.

There is a representative consumer with constant relative risk aversion preferences:

$$\int_t^\infty \frac{C(\tau)^{1-\sigma} - 1}{1-\sigma} \exp(-\rho(\tau-t)) d\tau,$$

where $C(\tau)$ is consumption at time τ and ρ is the discount rate.

The output aggregate comes out of a Cobb-Douglas function:

$$Y \equiv \exp \left[\int_0^1 \ln y(i) di \right], \quad (3.2)$$

where $y(i)$ denotes output in sector i . The price of the consumption aggregate in each period is normalized to 1.

Each final good $y(i)$ can be produced with two technologies: one uses unskilled labor (l) and a set of differentiated intermediate goods (“machines”), while the other uses skilled labor (h) and a different set of machines. Formally,

$$y(i) = \left[\int_0^{N_L} k_L(i, \nu)^{1-\beta} d\nu \right] [(1-i)l(i)]^\beta + \left[\int_0^{N_H} k_H(i, \nu)^{1-\beta} d\nu \right] [iZh(i)]^\beta, \quad (3.3)$$

where $k_z(i, \nu)$ is the quantity of machines of variety ν used in sector i together with workers of skill level z . The terms $(1-i)$ and Zi denote exogenous sector and technology specific

productivity levels. This implies that the skilled technology is relatively more productive in producing goods with higher indexes. The parameter $Z \geq 1$ measures the relative productivity of skilled workers. N_L and N_H are the number of machines that can be used with unskilled and skilled workers, respectively.

Given wages for skilled and unskilled workers (w_L, w_H) , rental prices of machines $\{\chi_L(\nu), \chi_H(\nu)\}$ and the price of their product $p(i)$, the final good producer demands machines $\{k_z(i, \nu)\}_{z \in \{L, H\}}$ and workers $((l(i), h(i)))$ every period in order to solve

$$\text{Max}_{l(i), h(i), \{k_z(i, \nu)\}_{z \in \{L, H\}}} p(i)y(i) - w_L l(i) - w_H h(i) - \int_0^{N_L} \chi_L(\nu) k_L(i, \nu) d\nu - \int_0^{N_H} \chi_H(\nu) k_H(i, \nu) d\nu. \quad (3.4)$$

This problem is fully characterized by the following interior set of first order conditions,

$$\begin{aligned} k_l(i, \nu) &= [(1 - \beta)p(i)((1 - i)l(i))^\beta / \chi_L(\nu)]^{1/\beta} \\ k_h(i, \nu) &= [(1 - \beta)p(i)(iZh(i))^\beta / \chi_H(\nu)]^{1/\beta} \\ l(i) &= \left(\frac{p(i)\beta \left[\int_0^{N_L} k_L(i, \nu)^{1-\nu} d\nu \right] (1 - i)^\beta}{w_L} \right)^{\frac{1}{1-\beta}} \\ h(i) &= \left(\frac{p(i)\beta \left[\int_0^{N_H} k_H(i, \nu)^{1-\nu} d\nu \right] (iZ)^\beta}{w_H} \right)^{\frac{1}{1-\beta}} \end{aligned} \quad (3.5)$$

Each type of machine is produced by a monopolist who owns the patent for that variety. Machines depreciate instantaneously and the marginal cost of production is equal to θ units of the final good. A monopolist producing a machine for sector z will set the machine price so as to maximize its profits,

$$\pi_z(\nu) = \text{Max}_{\chi(\nu)} (\chi(\nu) - \theta) \int_0^1 k_z(i, \nu) di, \quad (3.6)$$

subject to the demand equations given in (3.5). The profit maximizing price is $\chi_z(\nu) = \theta/(1 - \beta) = \chi$. Without loss of generality, the price is normalized to $\theta \equiv \delta^{\frac{\beta}{1-\beta}} (1 - \beta)^2$, so

that $\chi = \delta^{\frac{\beta}{1-\beta}}(1 - \beta)$. The parameter δ differs across countries and captures cross-country differences in the price of capital. In the North $\delta = 1$ and, typically, $\delta \geq 1$ in the South.

The pattern of comparative advantage embedded in the production function (3.3) makes skilled workers relatively more productive in high indexed goods. Therefore, there will exist a threshold sector $J \in [0, 1]$ which that only unskilled workers will be used to produce goods with $i \leq J$ and only skilled workers will be used to produce goods with $i \geq J$. Then, the production of good i can be written as:

$$y(i) = \begin{cases} \delta^{-1} p(i)^{\frac{1-\beta}{\beta}} N_L (1-i) l(i) & \text{if } 0 \leq i \leq J; \\ \delta^{-1} p(i)^{\frac{1-\beta}{\beta}} N_H i Z h(i) & \text{if } J < i \leq 1. \end{cases} \quad (3.7)$$

Technical progress takes the form of increases over time in N_L and N_H . This is an expanding variety model that allows technical change to be skill complementary. Also, the degree to which new technologies are skill complementary is endogenous.

Equilibrium

Market clearing conditions for labor and the fact that, given the Cobb-Douglas structure in (3.2), the expenditure on final goods is constant, the following conditions hold

$$\begin{aligned} p(i) &= P_L (1-i)^{-\beta} & \text{and } l(i) &= \frac{L}{J} & \text{for any } 0 \leq i \leq J; \\ p(i) &= P_H i^{-\beta} & \text{and } h(i) &= \frac{H}{1-J} & \text{for any } J < i \leq 1, \end{aligned}$$

where $P_L = p(0)$ and $P_H = p(1)$ are price indexes to be determined. The J point corresponds to the indifference point, where

$$\frac{P_H}{P_L} = \left(\frac{J}{1-J} \right)^\beta \quad (3.8)$$

To find J the condition of constant expenditure on final goods is used, which implies that

$P_H y(1) = P_L y(0)$. Then,

$$J = \left(1 + \left(\frac{N_H}{N_L} \frac{Z_H}{L} \right)^{1/2} \right)^{-1}. \quad (3.9)$$

Using the numeraire rule that $\exp[\int_0^1 \ln p(i) di] = 1$, the price indexes can be found:

$$P_L = e^{-\beta} \left(1 + \left(\frac{N_H}{N_L} \frac{Z_H}{L} \right)^{1/2} \right)^\beta$$

$$P_H = e^{-\beta} \left(1 + \left(\frac{N_H}{N_L} \frac{Z_H}{L} \right)^{-1/2} \right)^\beta$$

3.5.2. Technical Progress

At this point the model starts to differ from Acemoglu and Zilibotti (1999). New technologies are developed using final output. The R&D to invent a new variety of either type of machine costs μ . Firms can also imitate technologies from abroad, but they have to incur in a cost $\epsilon \leq \mu$ to introduce it to the country. It is assumed that this is not a payment to the inventors of the machine, but a cost to understand and adapt the technology. A firm that invents or brings a machine from outside obtains an indefinite patent or franchise to produce it.

I focus on one particular equilibrium, in which the North innovates in both types of technologies, and the South copies skilled-complementary technologies and innovates in unskilled-complementary technologies. In this equilibrium, the varieties available in each country differ. Formally, $N_L^N \leq N_L^S$ and $N_H^N > N_H^S$ and the law of motions of varieties are given by

$$\dot{N}_z^N = \frac{X_z^N}{\mu}, \quad \dot{N}_L^S = \frac{X_L^S}{\mu}, \quad \text{and} \quad \dot{N}_H^S = \frac{X_H^S}{\epsilon},$$

where X_z^C denotes total output devote to improve the technology of group $z \in \{L, H\}$ in country $C \in \{N, S\}$.

Symmetry across machines implies that $V_z^c(\nu, t) = V_z^c(t)$ for all ν , in particular

$$V_z^c(t) = \int_t^\infty \exp\left[-\int_t^\tau r(\omega) d\omega\right] \pi_z^c(\tau) d\tau$$

where $r(\tau)$ is the interest rate at date τ , and

$$\begin{aligned} \pi_L^C(\tau) &= (\chi - \theta) \int_0^{J^C} k_L^C(i, \tau) di = \delta^{\frac{\beta}{1-\beta}} (1 - \beta) \beta (P_L^C(\tau))^{1/\beta} L^C \\ \pi_H^C(\tau) &= (\chi - \theta) \int_{J^C}^1 k_H^C(i, \tau) di = \delta^{\frac{\beta}{1-\beta}} \beta (1 - \beta) (P_H^C(\tau))^{1/\beta} ZH^C \end{aligned}$$

are the flow profits.

Free entry implies $V_L^S = \mu$ and $V_H^S = \epsilon$. In Balanced Growth Path(BGP), the interest rate is constant, then

$$\frac{\pi_H^S}{\pi_L^S} = \frac{\epsilon}{\mu} \quad \Rightarrow \quad \frac{P_H^S}{P_L^S} = \left(\frac{\epsilon}{\mu} \frac{L^S}{ZH^S}\right)^\beta. \quad (3.10)$$

Just like in Acemoglu and Zilibotti (1999), the intuition of this formula is that, when skilled workers are more abundant, the market for skill-complementary machines is larger, and so the relative price of skill-intensive goods has to be lower. The new term is ϵ/μ : when the cost of bringing skill-intensive technologies is higher, there are less skill-complementary machines, and so the relative price of skill-intensive goods has to be higher.

Combining equations (3.10), (3.8) and (3.9), the relative productivity of skilled and unskilled workers along the BGP is found:

$$\frac{N_H^S}{N_L^S} = \left(\frac{\mu}{\epsilon}\right)^2 \frac{ZH^S}{L^S}. \quad (3.11)$$

In the North, the relative productivity depends only on the endowments $\frac{N_H^N}{N_L^N} = \frac{ZH^N}{L^N}$, but in the South it also depends on relative cost of imitation versus innovation.

Proposition 2 *There exists a stable BGP. Along this growth path, GDP, consumption, and*

varieties grow at a constant rate, that differs per country. More specifically, in the South the growth rate is

$$g^S = \frac{1}{\sigma} \left(\mu^{-1} \delta^{1-\beta} \beta (1-\beta) e^{-1} \left(L^S + \frac{\mu}{\epsilon} ZH^S \right) - \rho \right), \quad (3.12)$$

and in the North the growth rate is

$$g^N = \frac{1}{\sigma} \left(\mu^{-1} \beta (1-\beta) e^{-1} \left(L^N + ZH^N \right) - \rho \right). \quad (3.13)$$

Proof is equivalent to Acemoglu and Zilibotti (1999). In addition it has to be true that $g^N = g^S$ for the BGP to be stable, which means that

$$\delta = \left(\frac{L^N + ZH^N}{L^S + \frac{\mu}{\epsilon} ZH^S} \right)^{\frac{1-\beta}{\beta}}. \quad (3.14)$$

Finally, the ratio of expenditure imitation and innovation is derived from the fact that along the BGP $\frac{\dot{N}_H^S}{N_H^S} = \frac{\dot{N}_L^S}{N_L^S}$:

$$\frac{X_H^S}{X_L^S} = \left(\frac{\mu}{\epsilon} \right) \frac{ZH^S}{L^S}.$$

The relative endowments of the South reduce the fraction of resources spent in imitation, but the relative costs increases the fraction. Low levels of human capital in the South can explain less expenditure in the skilled-complementary technology developed in the North, despite the cost advantage.

σ	ρ	z	β
2	0.04	1.5	1/3

Table 14: Calibration Parameters

3.5.3. Productivity Differences between the North and the South

Following Acemoglu and Zilibotti (1999), total output per firm, can be decomposed into capital input, labor input and total factor productivity (TFP):

$$\begin{aligned}
 p^C(i)y_L^C(i) &= p(i) \underbrace{[(1-i)N_L]^\beta}_{a_L^C(i)} l^C(i)^\beta \left(\int_0^{N_L^C} k_L^C(i, \nu) d\nu \right)^{1-\beta} ; \\
 p^C(i)y_H^C(i) &= p(i) \underbrace{[iN_H]^\beta}_{a_H^C(i)} [zh^C(i)]^\beta \left(\int_0^{N_H^C} k_H^C(i, \nu) d\nu \right)^{1-\beta} .
 \end{aligned} \tag{3.15}$$

The parameter $a_z^C(i)$ corresponds to the productivity of firm i using technology z in country C . As shown on the left panel of figure 22, technology diffusion allows for a higher level of TFP for two reasons: increases the number skilled-complementary machines, and induces a larger number of firms to use the more productive and skilled-complementary technology. However, as shown in the right panel of figure 22 differences in TFP between the North and the South may still persist when the South has less human capital than the North, for two reasons: less firms use the more productive technology, and there are less skilled-complementary technologies available. There is a caveat to the analysis: there are more unskilled-complementary technologies available in the South, so this effect can decrease the TFP differences between the two countries.

3.6. Calibration

In this section I calibrate the model to simulate the economies of the selected Latin American countries for the survey done by The World Bank (2010). First, the following parameters are assumed.

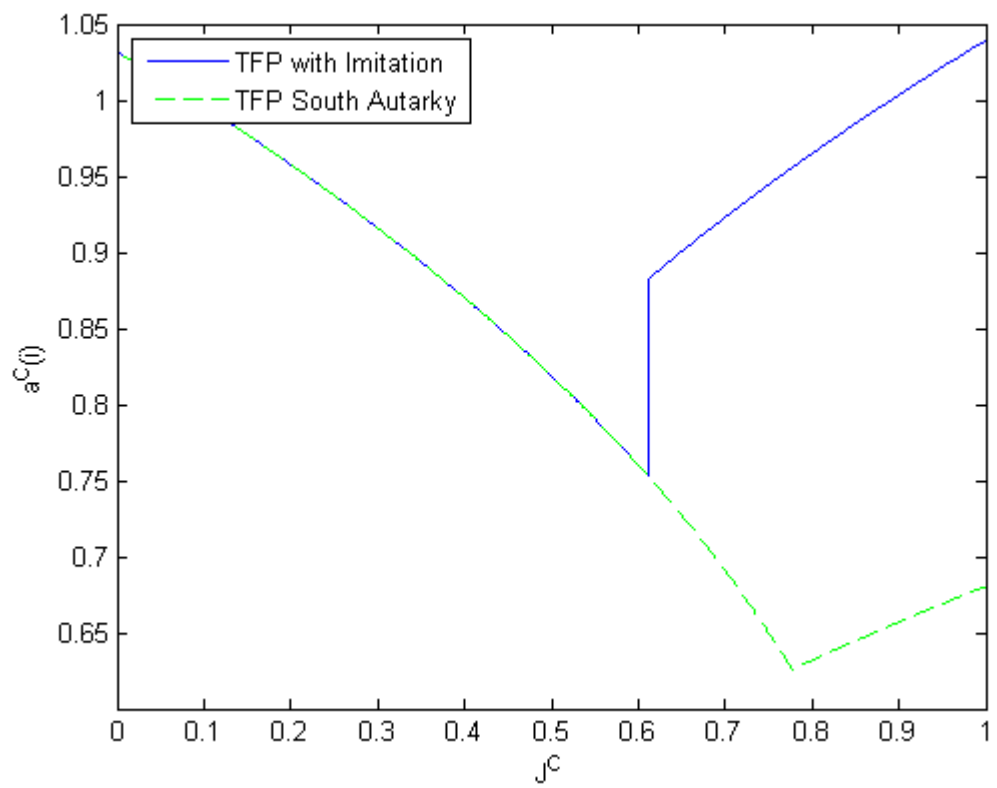


Figure 22: Simulated TFP South TFP with and without Technology Diffusion

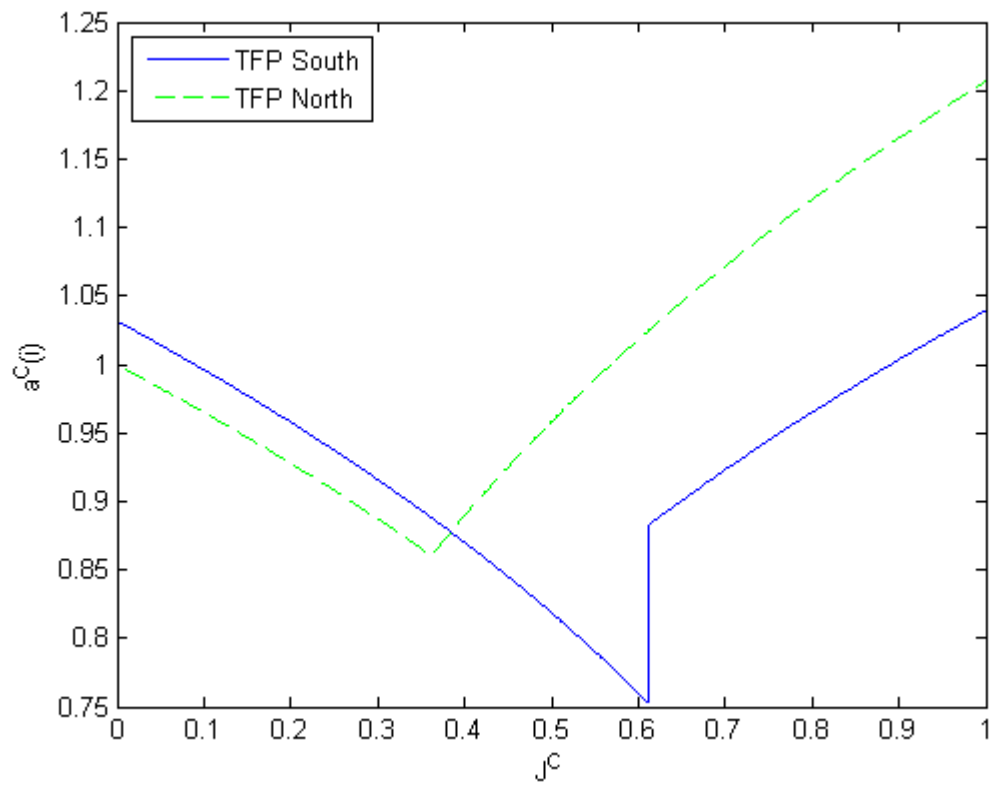


Figure 23: Simulated TFP North and South TFP with Technology Diffusion

The variable that I intend to replicate is the fraction of firms that are using unskilled-complementary technologies, defined as J in the model. Given the assumptions of the model, J also represents the fraction of firms using technologies developed locally, while $1 - J$ represents the proportion of firms using technologies developed abroad, i.e. the proportion of imitators ⁴. The true J for every country in the South is assumed to be the proportion of firms using local innovations over the total number of firms using some type of expansion strategy. These statistics are shown in section 3.3 and correspond to the database constructed by The World Bank (2010).

Equation (3.9) shows the formula to estimate J . The cost of innovation (μ) can be pinned down using equation (3.13). The value for the growth rate in the North (g^N) is assumed to be the average growth rate of the United States between 2001 and 2010, calculated using Real GDP data from Feenstra et al. (2013). The skilled and unskilled population is approximated using the proportion of the population that has some tertiary education in 2010 estimated by Barro and Lee (2013) and the total employment estimated by Feenstra et al. (2013) of the same year. The cost of imitation (ϵ) is estimated in order to minimize the difference between the true J and the estimated one. The ratio μ/ϵ is found to be 1.9316.

The following figure and table 15 compare the estimated results with the true value. The model tends to underestimate the proportion of local innovators, but the patterns across countries are similar. Moreover the correlation between the true and the estimated values, is 0.5309.

The implication of these results is that, given the human capital available in the Latin American countries, and the assumed model, it is optimal for the majority of the firms to develop local innovations to try to increase their productivity.

To understand the impact of mismatch of abilities plus a cost of imitation $\epsilon \in (0, \mu)$, I

⁴Recall that it is assumed that $N_L^S \geq N_L^H$ which means that unskilled-complementary technologies are developed in the South, and $N_H^S < N_H^N$ which means that skilled-complementary technologies are developed in the North

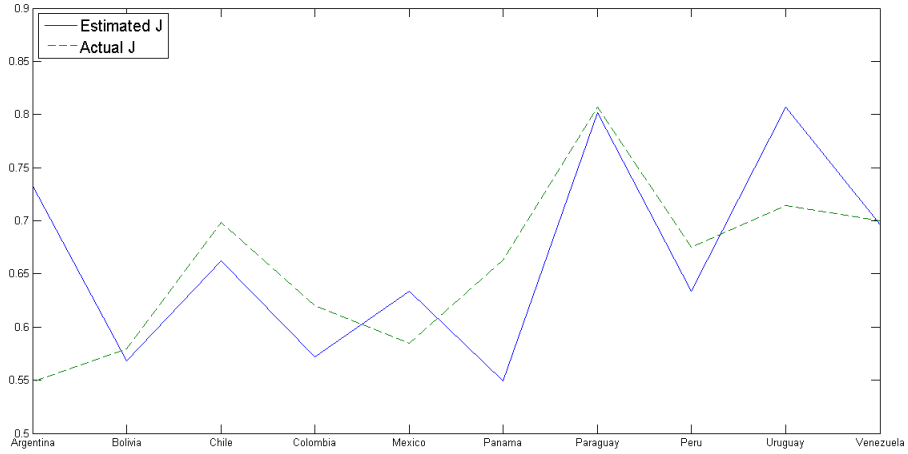


Figure 24: Technology diffusion without mismatch of skills

Countries	Estimated J	Actual J
Argentina	0.7328	0.5481
Bolivia	0.5682	0.5792
Chile	0.6622	0.6985
Colombia	0.5719	0.6199
Mexico	0.6339	0.5846
Panama	0.5491	0.6629
Paraguay	0.8018	0.8072
Peru	0.6339	0.6755
Uruguay	0.8069	0.7143
Venezuela	0.6966	0.7002

Table 15: Estimated and Actual proportion of firms using local innovations

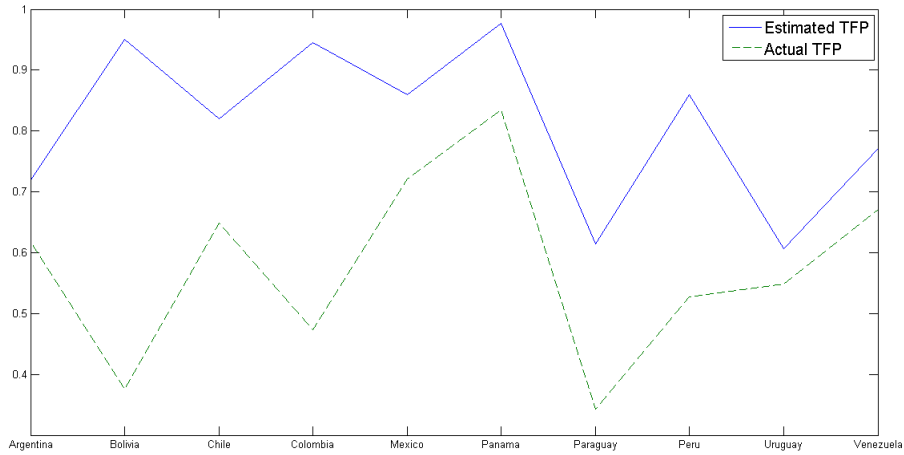


Figure 25: Estimated and Actual TFP

estimate the impact of this mechanism on TFP. The estimated TFP using equation (3.15), compared with the actual TFP in 2010 Feenstra et al. (2013) is presented in the following figure.

The model overestimates the relative TFP of the countries, which is expected since the model also predicts a higher bias towards skilled-complementary machines, as seen in table 15. This bias is also expected since the model does not take into consideration other variables that might affect differences in TFP, like institutions or the development of the financial market. However, the correlation between the two TFP measures is 0.2731, and the model can account for a 45% of the differences in productivity between the selected Latin American countries and United States.

3.7. Conclusion

Differences in TFP across countries have persisted over time, and technology has not diffused as fast as expected to eliminate these differences. In this paper I show that, rather than importing frontier technologies, most firms in developing countries, are creating technologies that are at least locally novel. I also show that innovators tend to have less skilled workers than imitators. These two observations are consistent with the existence of a skills mismatch

between advanced economies and developing countries, which makes frontier technologies less productive in the developing world.

I extend the model developed by Acemoglu and Zilibotti (1999), incorporating innovation from firms in less developed economies and costly imitation of frontier technologies, and calibrate it to match the proportion of firms innovating in ten Latin American countries. The correlation between the observed and estimated data is 55%, and the mechanism described in this paper could account for 45% of the differences in TFP of the selected countries with respect to the United States.

APPENDIX

A.1. Derivation of the Share of Downstream Varieties bought at Home

The distribution of $c_{1,j}$ is given by equation (1.11). Using variable transformation it can be shown that $c_{1,H}^{-n\theta_2}$ follows a Fréchet distribution with shape parameter $\beta = n/\theta_2$ and scale parameter $\mu = \Phi_1^{\frac{1}{\beta}}$.

$$\begin{aligned} \Pr \left[C_{1,H}^{-n\theta_2} = (c'_H) \right] &= -\Pr \left[C_{1,H} = (c'_H)^{-\frac{1}{n\theta_2}} \right] \times -\frac{1}{n\theta_2} (c'_H)^{-\frac{1}{n\theta_2}-1}, \\ &= \Phi_1 \frac{1}{\theta_2} T_1^{\frac{1}{\theta_2}} \exp \left(-\Phi_1 T_1^{\frac{1}{\theta_2}} (c'_H)^{\frac{-1}{\theta_2}} \right) (c'_H)^{\frac{-1}{\theta_2}-1}. \end{aligned}$$

Equivalently, it can be shown that $1/c_{1,F}^{-n\theta_2}$ follows a Weibull distribution with shape parameter $\alpha = n/\theta_2$ and scale parameter $\lambda = \Phi_1^{-\frac{1}{\alpha}}$.

$$\begin{aligned} \Pr \left[C_{1,F}^{n\theta_2} = (c'_F) \right] &= \Pr \left[C_{1,F} = (c'_F)^{-\frac{1}{n\theta_2}} \right] \times \frac{1}{n\theta_2} (c'_F)^{-\frac{1}{n\theta_2}-1}, \\ &= \Phi_1 \frac{1}{\theta_2} T_1^{\frac{1}{\theta_2}} \exp \left[-\Phi_1 T_1^{\frac{1}{\theta_2}} (c'_F)^{\frac{1}{\theta_2}} \right] (c'_F)^{\frac{1}{\theta_2}-1}. \end{aligned}$$

As proved in Nadarajah (2005), the c.d.f. of the product of a Weibull Distribution and a Fréchet distribution when $\alpha = \beta$ can be expressed as

$$F(\nu) = \frac{1}{1 + A},$$

for $A = \left(\frac{\mu\lambda}{\nu} \right)^\beta$. From this result follows that the c.d.f. of $\left(\frac{c_{1,H}}{c_{1,F}} \right)^{-n\theta_2}$ can be expressed as

$$\begin{aligned} F(\nu) &= \Pr \left[\left(\frac{C_{1,H}}{C_{1,F}} \right)^{-n\theta_2} \leq \nu \right], \\ &= \frac{1}{1 + \frac{\Phi_1}{\Phi_1} (\nu)^{\frac{-1}{\theta_2}}}, \\ &= \frac{(\nu)^{\frac{1}{\theta_2}}}{1 + (\nu)^{\frac{1}{\theta_2}}}. \end{aligned} \tag{A.1}$$

A.2. Proof of Proposition 1

The proof follows from Theorem 1.14 in Dharmadhikari and Joag-Dev (1988): *Let X be a unimodal random variable. If $\max\{X - m, 0\}$ is stochastically larger than $-\min\{X - m, 0\}$, then X has a mode M satisfying $M \leq m \leq \mu$, where m is defined as the median of X , and μ is the mean of X .*

Define $Z \equiv \frac{1}{1+\nu d^n}$, and the c.d.f. of ν is defined in equation (A.1). By using variable transformation, the c.d.f of Z can be found, and is equal to

$$\begin{aligned} \Pr [Z \leq z] &= \int -\Pr \left[\nu = d^n \left(\frac{1}{z} - 1 \right) \right] \times -\frac{d^n}{z^2} dz, \\ &= \frac{1}{1 + d^{-\frac{n}{\theta_2}} \left(\frac{1}{z} - 1 \right)^{\frac{1}{\theta_2}}}. \end{aligned} \quad (\text{A.2})$$

Definition 1 X is unimodal about some point $M = M[F]$, called a mode of X , when $F(x)$ is convex for $x \in (-\infty, M)$ and concave for $x \in (M, \infty)$.

Proposition 3 The random variable Z is unimodal.

Proof: Redefine (A.1) as a function of the random variable $\frac{1}{\omega}$, when $n = n_1 = n_2$:

$$G\left(\frac{1}{\omega}\right) = \frac{1}{1 + \left(\frac{1}{\omega}\right)^{\frac{1}{\theta_2}}}.$$

Taking second derivatives it can be shown that $G\left(\frac{1}{\omega}\right)$ is convex for $\omega \leq \left(\frac{\theta_2}{1-\theta_2}\right)^{\theta_2}$ and concave for $\omega \geq \left(\frac{\theta_2}{1-\theta_2}\right)^{\theta_2}$.

Since convexity is invariant under affine maps, define $\frac{1}{z} = d^n \frac{1}{\omega} + 1$, and evaluate $G\left(\frac{1}{\omega}\right)$ in $\frac{1}{z}$:

$$G\left(\frac{1}{z}\right) = \frac{1}{1 + \left(d^{-n} \left[\frac{1}{z} - 1\right]\right)^{\frac{1}{\theta_2}}}.$$

Notice that the previous equation corresponds to the c.d.f. of Z defined in (A.2). Since the mode of $G\left(\frac{1}{\omega}\right)$ is $\left(\frac{\theta_2}{1-\theta_2}\right)^{\theta_2}$, the mode of $G\left(\frac{1}{z}\right)$ is $M = \frac{1}{d^n\left(\frac{1}{\theta_2}-1\right)^{\theta_2+1}}$. Additionally, $G\left(\frac{1}{z}\right)$ is convex for $z \in (0, M]$ and concave for $z \in [M, 1)$. Then z is unimodal about M .

Q.E.D.

Definition 2 A number m is said to be a median of Z if $\Pr[Z \leq m] \geq \frac{1}{2}$ and $\Pr[Z \geq m] \leq \frac{1}{2}$.

The median of the random variable Z is equal to

$$m = \frac{1}{d^n + 1}. \quad (\text{A.3})$$

Definition 3 The $\max\{Z - m, 0\}$ is stochastically larger than $-\min\{Z - m, 0\}$ if $\Pr[\max\{Z - m, 0\} \geq z'] \geq \Pr[-\min\{Z - m, 0\} \geq z']$ for all z' , and for some z' , $\Pr[\max\{Z - m, 0\} \geq z'] > \Pr[-\min\{Z - m, 0\} \geq z']$.

Proposition 4 Define m as the median of Z . The $\max\{Z - m, 0\}$ is stochastically larger than $-\min\{Z - m, 0\}$, when iceberg transport costs are strictly greater than one (i.e. $d > 1$).

Proof: The first condition of definition 3 can be rewritten as

$$\begin{aligned} \Pr[Z \geq z' + m] \Pr[Z \geq m] + \Pr[0 \geq z'] \Pr[Z < m] \geq \\ \Pr[Z \leq m - z'] \Pr[Z < m] + \Pr[0 \geq z'] \Pr[Z \geq m], \end{aligned}$$

which is equivalent to

$$1 - \Pr[Z \leq z' + m] \geq \Pr[Z \leq m - z']. \quad (\text{A.4})$$

Case 1: $|z'| < m < 1 - m$. For this case, the strict inequality of equation (A.4) is proven.

By contradiction suppose that

$$1 - \frac{1}{1 + d^{-\frac{n}{\theta_2}} \left(\frac{1}{z'+m} - 1 \right)^{\frac{1}{\theta_2}}} \leq \frac{1}{1 + d^{-\frac{n}{\theta_2}} \left(\frac{1}{m-z'} - 1 \right)^{\frac{1}{\theta_2}}}.$$

This equation can be simplified to

$$(1 - m)^2 - (z')^2 \leq d^{2n} m^2 - d^{2n} (z')^2.$$

By manipulating equation (A.3), the following equality is obtained: $1 - m = md^n$. Replacing this equality in the previous step, the inequality changes to

$$\begin{aligned} d^{2n} &\leq 1, \\ 2n \log(d) &\leq 0, \end{aligned}$$

which is a contradiction for every $d > 1$ ¹.

Case 2: $m \leq |z'| < 1 - m$. Suppose equation (A.4) does not hold, then

$$\begin{aligned} 1 - \Pr [Z \leq z' + m] &< \Pr [Z \leq m - z'] \leq \Pr [Z \leq 0], \\ 1 - \Pr [Z \leq z' + m] &< 0, \\ \Pr [Z \leq z' + m] &> 1, \end{aligned}$$

which is a contradiction, because $\Pr [Z \leq z] \leq 1$ for all z .

Case 3: $m < 1 - m \leq |z'|$. Suppose equation (A.4) does not hold, then

$$\begin{aligned} 1 - \Pr [Z \leq z + m'] &< \Pr [Z \leq m - z'], \\ 1 - 1 &< 0, \end{aligned}$$

¹By construction $n > 1$.

which is a contradiction.

Then, $\Pr [\max\{Z - m, 0\} \geq z'] \geq \Pr [-\min\{Z - m, 0\} \geq z']$ for all z' , and for $|z'| < m$, $\Pr [\max\{Z - m, 0\} \geq z'] > \Pr [-\min\{Z - m, 0\} \geq z']$.

Q.E.D.

Proposition 5 *The median m of the random variable Z , as defined in (A.3), satisfies $m \leq \mu$ where μ is equal to the mean of Z , when trade costs are strictly larger than one (i.e. $d > 1$).*

Proof: Since Z is a unimodal random variable, and $\max\{Z - m, 0\}$ is stochastically larger than $-\min\{Z - m, 0\}$ for $d > 1$, from Theorem 1.14 in Dharmadhikari and Joag-Dev (1988) follows that $m \leq \mu$.

Q.E.D.

From proposition 5 follows that

$$\begin{aligned} m &\leq \mu, \\ \frac{1}{d^n + 1} &\leq \int_0^\infty z dF(z,) \\ &= \frac{1}{\theta_2} \int_0^\infty \frac{1}{d^n \nu + 1} \frac{(\nu)^{\frac{1}{\theta_2} - 1}}{\left[1 + (\nu)^{\frac{1}{\theta_2}}\right]^2} d\nu, \end{aligned}$$

and thus proposition 1 is proven.

Q.E.D.

A.3. Latin American Database

Since 2002, the World Bank has collected firm-level data, through face-to-face interviews, from top managers and business owners in over 130,000 companies in 135 countries. The survey is applied to a representative sample of an economy's private sector and covers a broad range of business environment topics including access to finance, corruption, infras-

Country	Year of Interview			Total Observations
	2010 only	2006 only	2006 and 2010	
Argentina	556	565	996	2,117
Bolivia	182	433	360	975
Chile	603	587	860	2,050
Colombia	636	694	612	1,942
Mexico	1,270	1,270	420	2,960
Panama	241	480	248	969
Paraguay	208	460	306	974
Peru	686	318	628	1,632
Uruguay	320	334	574	1,228
Venezuela	171	351	298	820
Total	4,873	5,492	5,302	15,667

Table 16: Enterprise Surveys Database

structure, crime, competition, and performance measures The World Bank (2010).

In 2006 and 2010, a special set of questions were incorporated to the survey for ten Latin-American countries. These questions are useful for the purposes of this paper, and therefore I use this data set for the analysis.

The survey was applied to 5,492 firms in 2006 and to 4,873 firms in 2010, plus 2,651 firms that were interviewed both years. Around a third of the firms are in the manufacturing sector.

The following table classifies Latin-American firms according to their expansion strategies.

A.4. Variable Description

1. P_{nit} : Total patents grants direct and PCT national phase entries. Count by filing office and applicants origin. Data from WIPO. Year Range: 1996-2011 - WIPO
2. L_{it} : Number of persons engaged (in millions) - Feenstra et al. (2013).
3. HK_{nit} : Index of human capital per person. Average years of schooling and assumed

Expansion Strategy		Frequency	Proportion within group	Proportion respect to Total
No Expansion Strategy		2,452	100	49.20
Imitation	Only Imitation	317	41.12	6.37
	+ Local Innovation	260	33.72	5.23
	+ Frontier Innovation	28	3.63	0.56
	+ Local & Frontier Innovation	166	31.53	3.34
	Total	771	100	15.50
Local Innovation	Only Local Innovation	1,406	65.55	28.26
	+ Imitation	260	12.12	5.23
	+ Frontier Innovation	313	14.59	6.29
	+ Imitation & Frontier Innovation	166	7.74	3.34
	Total	2,145	100	43.12
Frontier Innovation	Only Frontier Innovation	33	6.11	0.66
	+ Imitation	28	5.19	0.56
	+ Local Innovation	313	57.96	6.29
	+ Imitation & Local Innovation	166	30.74	3.34
	Total	540	100	10.85
Total Firms Sample		4,975	100	100

Table 17: Proportions of firms following Expansion Strategies

rate of return -Feenstra et al. (2013).

4. Km_{ni} : Distance between capitals - Skrede
5. IM_{nit} : Imports from country i to country n UN divided by Real GDP Feenstra et al. (2013).
6. R_{it} : Researchers in R&D (per million people). Researchers in R&D are professionals engaged in the conception or creation of new knowledge, products, processes, methods, or systems and in the management of the projects concerned. Postgraduate PhD students (ISCED97 level 6) engaged in R&D are included UNESCO.
7. y_{it} : TFP level at current PPPs (USA=1) - Feenstra et al. (2013).

A.5. Calibration Database

1. Percentage Tertiary: percentage of the total population aged 15 and over that has some tertiary education in 2010 Barro and Lee (2013)

Country	Percentage Tertiary	Employment	TFP
Argentina	0.1118	14.8714	0.6186
Bolivia	0.2078	3.8247	0.3761
Chile	0.1497	7.6967	0.6482
Colombia	0.2053	19.4002	0.4731
Mexico	0.1662	44.2049	0.7211
Panama	0.2208	1.4556	0.8347
Paraguay	0.0786	2.9187	0.343
Peru	0.1662	10.9482	0.5279
Uruguay	0.0763	1.5471	0.5481
Venezuela	0.1307	9.9661	0.6712

Table 18: Data used for calibration

2. Employment: number of persons engaged (in millions) in 2010- Feenstra et al. (2013).
3. TFP: TFP level at current PPPs (USA=1) 2010 - Feenstra et al. (2013).

A.6. Patents Database

Low Human Capital		Middle Human Capital		High Human Capital	
Office	Observations	Office	Observations	Office	Observations
Brazil	626	Austria	545	Armenia	326
China	780	Bulgaria	546	Australia	780
China Macao SAR	196	Chile	629	Belgium	600
Croatia	480	China Hong Kong SAR	773	Canada	782
Egypt	638	Finland	629	Cyprus	230
Italy	745	France	685	Czech Republic	622
Kyrgyz Republic	288	Germany	735	Denmark	470
Mexico	757	Greece	656	Estonia	650
Mongolia	410	Iceland	395	Hungary	604
Peru	532	Kazakhstan	475	Ireland	526
Portugal	478	Latvia	500	Israel	613
Sierra Leone	32	Lithuania	516	Japan	813
Spain	597	Luxembourg	391	Netherlands	623
Thailand	445	Malaysia	617	New Zealand	733
Turkey	636	Malta	375	Norway	685
United Kingdom	741	Poland	684	Republic of Korea	752
Uruguay	375	Republic of Moldova	367	Russian Federation	779
Zimbabwe	206	Romania	611	Slovakia	574
		Serbia	493	Slovenia	490
		Switzerland	532	Sweden	600
		Tajikistan	275	Ukraine	715
				United States of America	850
Total	8,962	Total	11,429	Total	13,817

Table 19: Observations for the regression

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