CENTRAL EUROPEAN UNIVERSITY

ESSAYS ON INTERNATIONAL TRADE AND HETEROGENEITY

By

Călin-Vlad Demian

Submitted in partial fulfillment for the

degree of Doctor of Philosophy at

Central European University

Supervisor: Miklós Koren

Budapest, October 2016

10.14754/CEU.2016.08

CENTRAL EUROPEAN UNIVERSITY
DEPARTMENT OF ECONOMICS

The undersigned hereby certify that they have read and recommend to the Department of Economics for acceptance a thesis entitled **"Essays on International Trade and Heterogeneity"** by **Calin Vlad Demian**.
Dated: October 5, 2016

I certify that I have read this dissertation and in my opinion it is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.
Chair of the Thesis Committee:

László Mátyás

I certify that I have read this dissertation and in my opinion it is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.
Advisor:

Miklós Koren

I certify that I have read this dissertation and in my opinion it is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.
Internal Examiner:

Sergey Lychagin

I certify that I have read this dissertation and in my opinion it is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.
External Examiner:

Alejandro Cunat

I certify that I have read this dissertation and in my opinion it is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.
Internal Member:

Alessandro De Chiara

I certify that I have read this dissertation and in my opinion it is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.
External Member:

Péter Elek

10.14754/CEU.2016.08

I certify that I have read this dissertation and in my opinion it is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.
External Member:

David DeRemer

10.14754/CEU.2016.08

CENTRAL EUROPEAN UNIVERSITY

DEPARTMENT OF ECONOMICS

Author: **Călin-Vlad Demian**

Title: **Essays on International Trade and Heterogeneity**

Degree: **Ph.D.**

Dated: October 5, 2016

Hereby, I testify that this thesis contains no material accepted for any other degree in any other institution and that it contains no material previously written and/or published by another person except where appropriate acknowledgement is made.

Signature of the author: ______________________

Călin-Vlad Demian

10.14754/CEU.2016.08

Disclosure of co-author countribution

Title of the paper: Exchange rate movements, firm-level exports and heterogeneity

Co-authors: Antoine Berthou, Emmanuel Dhyne

The nature of cooperation and roles of the individual co-authors and approximate share of each co-author in the joint work are the following. Antoine came up with the initial empirical specification and paper motivation. Both co-authors assisted in shaping the logic and general direction of the paper. Antoine provided the demand shifters data for the regressions. Emmanuel assisted with the robustness checks. Both authors assisted massively with data collection. My main contribution was data management, the theoretical model, along with various extensions to the basic regression specification as well as final polishing of the paper.

10.14754/CEU.2016.08

Abstract

This thesis consists of three chapters: two single authored and one co-authored; each chapter investigates a different way in which varying forms of heterogeneity impact the effects of trade.

Chapter 1 presents a computable general equilibrium model that investigates the role trade liberalization has on skilled and unskilled wages. The model allows for endogenous skill formation as workers choose to become skilled or remain unskilled in response to new market conditions. I find that there is a substantial difference in how the skill premium changes depending on which sector is liberalized and on initial country conditions.

Chapter 2 also builds a computable general equilibrium model, investigating the welfare impact of EU institutions through free trade. I find that cross-sector input-output linkages play an important role in quantifying the gains from trade, which are orders of magnitude larger than what traditional models predict.

Chapter 3 is a joint work with Antoine Berthou and Emmanuel Dhyne, looking at the role firm heterogeneity has in estimating the elasticity of trade. The paper contains a theoretical model delivering sharp predictions which are then tested empirically against a novel dataset. We find that there is a substantial difference in elasticity between high and low productivity firms, as well as between sectors.

I provide more details on the contributions of the three chapters of the thesis below.

Chapter 1: Trade, the Skill Premium and Global Inequality

Chapter 1 investigates the role trade liberalization has on shaping both between and within country inequality. I build a Ricardian model in the spirit of Eaton and Kortum that features an arbitrary number of countries, capital-skill complementarity and four sectors each taking care of a different part of the production process. Within each country there are skilled and unskilled workers and whether a worker acquires education is determined endogenously given market prices and wages.

I calibrate the model to the year 2005 for a wide range of countries, both developing and developed and simulate a 10% symmetric drop in trade costs. I find there is a rich set of ways in which trade affects inequality.

I identify two opposing effects through which changes in trade costs influence inequality. First, as inputs become cheaper because of lower trade costs, firms will increase the demand for skilled workers due to capital-skill complementarity; however, as the consumption bundle is cheaper and acquiring education less costly, more workers may choose to become skilled increasing the supply. These two effects offset each other and which one dominates depends on country specific factors and which sector is liberalized.

Liberalizing capital goods increases inequality in developed countries and lowers it in poorer ones. Conversely, liberalizing foodstuff will increase inequality in developing countries the most.

Overall, my model does a good job replicating empirical patters for several waves of trade liberalization. If workers can respond to the new economic conditions and the shares of skilled and unskilled labor can adjust, inequality may increase or decrease. However, the supply of labor must be free to adjust so trade liberalization should go hand in hand with encouraging school enrolment and other forms of training.

Chapter 2: The European Union and the Gains from Trade

In Chapter 2, I investigate the effect the EU had in increasing countries welfare through cheaper trade. I build a similar model to the one in Chapter 1 that I calibrate to the countries of the European Union. I examine the welfare gains by looking at two distinct facets of membership: joining the EU and using the Euro.

For the first scenario, I look at the 2004 enlargement wave. I estimate the changes in trade costs between 2003 and 2006 for trade between new and old members and then compute the changes in welfare, assuming that this had been the only shift in policy. I find that while gains are positive for all countries, new entrants gained significantly more than old members from enlargement, up to 5.5%. I break down total gains by transmission mechanism and find that allowing for interconnectedness across sectors significantly amplifies the changes in welfare.

In my second counterfactual, I ask what would have happened had Greek abandoned the Euro at the onset of its sovereign debt crisis in 2009. The losses due to higher trade costs would be around 2% of GDP. Greece being forced to have balanced trade would incur another 1.5% in losses. Currency devaluation, while boosting external competitiveness, would further decrease welfare. Coupling depreciation with running a trade surplus would not incur considerable extra losses over the balanced budget scenario. However, these losses are measured in the best of possible worlds, abstracting from addition costs of default, public sector payment issues, social unrest, inflation or unemployment.

Chapter 3: Exchange Rate Movements, Firm-level Exports and Heterogeneity

Chapter 3 looks at the role productivity heterogenity has in firms' exchange rate elasticity. We build a heterogeneous firms model where firms choose to export and set their price both domestically and abroad in terms of the exchange rate and the number of competing firms. In addition, firms source some of their inputs from abroad. The model delivers sharp predictions regarding the differences in elasticities between firms of varying productivities, between productive and unproductive sectors, between diverse and uniform sectors and between sectors that are reliant on intermediates from abroad and those that are not.

We test the model's predictions using a novel dataset of highly disaggregated firm-based data for a panel of 11 European economies over 8 years. We find substantial variability in the exchange rate: more productive and more diverse sectors exhibit lower elasticities and the least productive firms are 3 times more sensitive to exchange rate movement that the most productive ones. We also find that the use of imported inputs explains a large part of exchange rate heterogeneity: sector with a large share of importing firms exhibit lower elasticity. We believe that the discrepancy between the responses of small and large firms provides some new light on the "International Elasticity Puzzle".

Acknowledgements

First of all, I would like to express my deepest gratitude to my supervisor, Miklos Koren, for all his support over the course of my time at CEU. Without his continuing advice and encouragement this thesis wouldn't have been possible.

I am also very grateful to the institutional environment at CEU, which gave me the support and opportunity to present my work various international workshops, seminars and conferences.

I also benefited extensively from working with my colleagues at the ECB, especially Paloma Garcia-Lopez and Filippo di Mauro. I also thank for my two co-authors, Antoine Berthou and Emmanuel Dhyne, for all their hard work and guidance they provided.

Finally, I would like to thank my friends and family, who have supported me through this long journey.

Contents

List of Figures

10.14754/CEU.2016.08

List of Tables

10.14754/CEU.2016.08

Chapter 1

Trade, the Skill Premium and Global Inequality

1.1 Introduction

The link between trade and inequality is still one of the major issues of contention in international economics. A large body of empirical work investigated the effect of freer trade on the skill premium both in developed countries and in developing ones with ambiguous results. After trade liberalization, some countries saw the relative returns to skilled labor increase whereas others saw a decrease in inequality, regardless of their level of development. This paper builds a theoretical model that explains the mixed patterns observed in the data.

Traditional trade models, built using the Heckscher-Ohlin framework, deliver sharp predictions: upon opening up to trade, all countries should see a rise in the return to their abundant factor, i.e. rich countries should see a rise in the returns to skilled labour whereas the opposite should happen in poor countries. However, these cut and dry predictions sit uncomfortably with some of the empirical evidence: in many, but not all, developing countries, liberalization led to increased inequality, while some developed countries have become more equal in the past two decades, despite increasing globalization.

My paper starts from the insight of Tinbergen [1975] who argues that inequality changes are the result of two opposing forces: the demand for skilled labor due to technological progress and the supply of skilled labor due to education. While a large part of the international trade literature, both theoretical and empirical, considers the shares of skilled and unskilled workers to be constant over time, I argue that the returns to education change in response to international exposure, inducing some workers to acquire education and others to forgo it. The process of skill-upgrading due to international trade has been documented in several papers such as Atkin [2012], Munshi and Rosenzweig [2003] or Oostendorp and Doan [2013].

Table 1.1 shows the output of regressing the share of tertiary educated workers on trade openness. To control for varying country specific characteristics and initial levels of education, I included country fixed effects. Trade openness is defined as imports + exports divided by GDP. While column 1 shows there is a strong contemporaneous correlation between trade and skill levels, this says little about the effect of trade on schooling decisions as acquiring education is a lengthy process. To better control for the direction of causality, I regress the share of tertiary educated workers, in turn, on 5, 10 and 15 year lagged values of trade-openness. All three regressions show a positive and significant effect of trade openness on the amount of schooling pursued.

Table 1.1: Regression of share of tertiary educated workers on trade openness

	Contemporenous	5 Year Lag	10 Year Lag	15 Year Lag
Trade Openness	2.737104**	4.345154**	4.794471**	4.584827**
Standard error	0.912269	1.045775	1.219431	1.50379
N	454	326	247	168

Note: The regression was run at 5 year intervals from 1965 to 2005 due to availability of education data. Observations where trade openness was >1.5 were dropped from the sample. This restriction does not influence the results qualitatively in any way. The results are robust to alternative specifications such as including various controls or including all lags at the same time or specifying a log-log equation.

But of course, correlation, even across many years, is not causation. I propose a causal mechanism that links trade openness to inequality changes and the relative supply of skilled and unskilled labor. If workers are heterogeneous and weigh the rewards of being skilled or unskilled against the cost of education, a much richer picture emerges that can explain why, upon liberalization, some countries experienced greater inequality while others became more equal.

I build on the model in Parro [2013], which I extend in several dimensions. There are an arbitrary number of countries and in each country there are four sectors: agriculture, manufacturing, capital goods and final goods. All sectors use both skilled and unskilled labor as inputs along with intermediate goods from other sectors and all markets are perfectly competitive. Skilled labor is complementary with capital and both are substitutable with unskilled labor. On the consumer side, households only consume goods from the final sector and agriculture, requiring a minimum consumption level of the latter.

The main feature of my model is that the shares of skilled and unskilled labor are endogenously determined: workers choose whether to become skilled or not. To become skilled, and earn the higher wage, workers must pursue education, during which time they do not earn any income. To sustain themselves during their formative years, workers have access to an outside option, which reflects every obstacle and opportunity available in the pursuit of higher education. It includes, but is not limited to, savings, property, help from parents, scholarship availability, etc. Reflecting different abilities and different backgrounds, the outside option is heterogeneous across workers and it is also differently distributed across countries. Taking into account relative wages and prices and their outside option, workers choose to acquire education or not. For some workers their outside option is so low that should they choose to become skilled, during their formative years their living would be so beggarly that they'd rather remain unskilled, despite the prospect of high future earnings.

I identify several transmission mechanism through which changes in trade costs influence inequality. Upon liberalization, as sectors are linked through the input-output matrix, the price of production inputs will decrease. Firms react by adjusting their demand for skilled and unskilled workers in order to maximize profits. As skilled labor is complementary with capital, its demand relative to unskilled labor will increase in response to lower capital goods prices, raising its price. The marginal worker, who is indifferent between acquiring education or not, will be enticed to become skilled. The increase in the supply of skilled labor will have an opposite effect and counteract the rise in skill premium.

However, in addition to this substitution effect, there is an income effect present: lower trade costs generally imply lower consumption prices for households. As the utility function is concave in income, facing lower prices, skilled workers' utility increases by less than that of the unskilled ones. The marginal workers will choose not to become educated, lowering the supply of skilled workers and raising the relative wage. In a general equilibrium setting, the income and substitution effects interact and their net effect is ambiguous.

I also find that there is a strong sectoral effect and the resulting pattern of inequality depends on which sector is liberalized. This is largely in part due to different roles the sectors play in the economy: whether they are used as intermediate or consumption goods and how much of the trade cost change gets passed on to consumers; opening the economy has a classical Stopler-Samuelson effect: inequality changes depend on the factor content of trade and the skill premium will tend to increase in net exporter countries.

Furthermore, countries' initial conditions matter: changes in the skill premium, whatever their direction, will be lower in countries with a high initial stock of skilled labor. The way inputs are used in the production function and the state of technology also plays a role as firms choose between substitutable inputs. For instance, in countries with a lower share of value added, the changes in inequality will be lower than in countries with a large value added input.

Endogenizing the labor supply changes the model's results in a substantial way and makes my model consistent with a number of empirical features. First, it allows for national income divergence. Secondly, the predicted increase in skill premium is quantitatively more in line with the magnitudes observed in the data. Thirdly, and probably most importantly, my modelling choice allows in certain cases for inequality to decrease, in a manner which, as I will show later, is backed up by the data.

I calibrate the model to the year 2005 and about 80 countries, both developed and developing. After recovering key parameters from the data, I run several counterfactuals: I sequentially investigate a symmetric 10% trade costs reduction in agriculture, manufacturing and capital goods for all countries.

Liberalizing manufacturing lowers the price of inputs and ultimately the price of households' consumption bundle. As utility is concave, it will increase more for unskilled workers upon liberalization. The marginal worker will get a higher utility by forgoing education education: inequality increases in almost all countries, but more so in poor and developing ones.

As I consider symmetric liberalization, lower trade costs in agriculture make unskilled workers in the poorest countries worse off: Increased foreign demand for foodstuff raises local prices. The marginal worker can no longer afford to acquire education and becomes unskilled. However, this increases the supply of unskilled workers, further lowering their wage. Inequality increases in almost all countries, but more so in poor and developing ones.

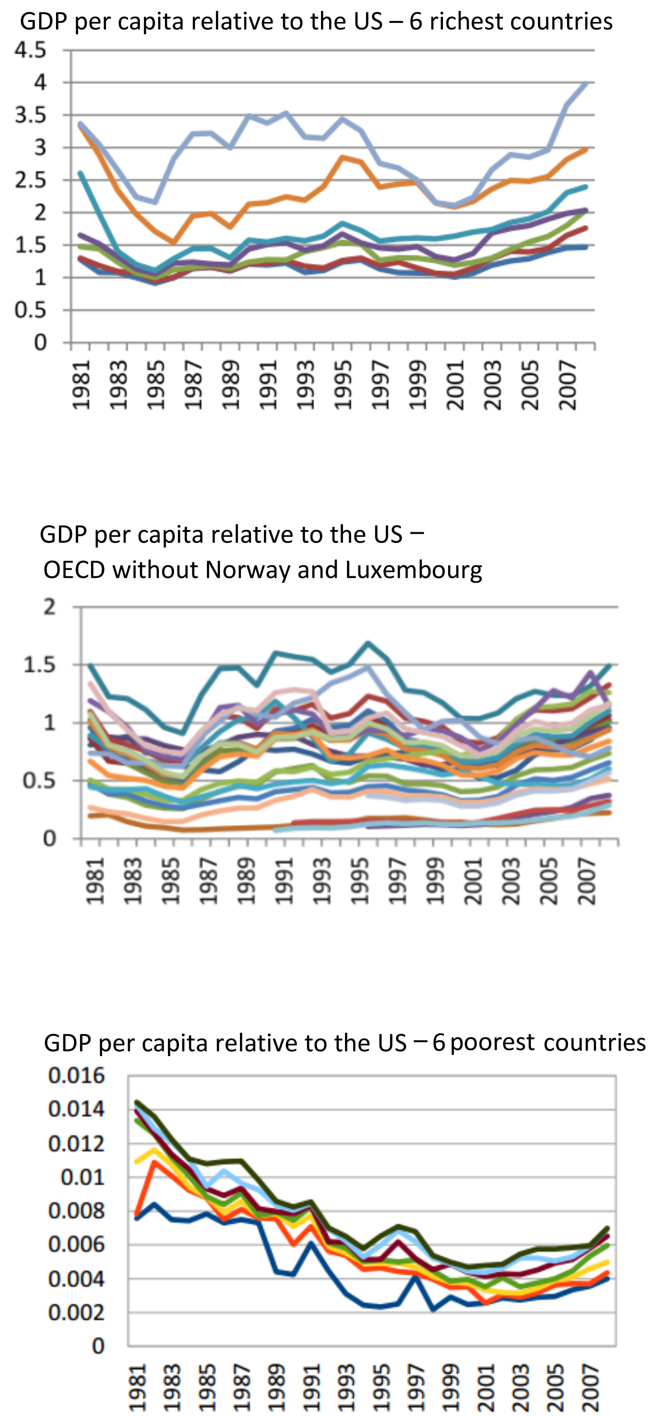
On the other hand, if capital goods are liberalized, due to capital-skill complementarity the demand for skilled labor increases relative to the demand for unskilled one. As the price of capital and skilled labor move in opposite directions, they partially offset each other so the net effect of lower trade costs on consumer prices is less pronounced than in the first two cases. Consequently, acquiring education becomes more desirable as the income effect dominates the substitution one: skilled workers' utility increases relative to that of unskilled workers as the wage premium increases by more than prices decrease. The increased supply of skilled labor offsets the rise in skill premium and in some cases it may actually reverse it. I find that the skill premium decreases in developing countries and increases in rich ones.

Looking at the welfare implications, liberalizing any sector results in a net utility gain for skilled workers in all countries, especially in poor countries, where the benefits accrue only to a handful of people. For unskilled workers, the picture is not so rosy. Liberalizing manufacturing and capital goods increases the utility of unskilled workers across the board, but in the case of agricultural liberalization, utility decreases in the poorest countries. Agricultural liberalization at the same time lowers unskilled wages and raises food prices.

In order to paint a full picture of trade and inequality I also look at the effect of trade on cross-country convergence. Figure 1.1 shows the evolution of average income per capita in the richest 6 countries, poorest 6 countries, and OECD countries relative to the US. The graphs indicate a clear divergence between rich and poor countries.

In the model, for each of the three counterfactuals I measure inequity in two ways: I look at the dispersion of average national income in the and compare it to benchmark case and I look at the ratio between the average income of the richest 10 countries and that of the poorest 10. By both measures, agriculture and manufacturing liberalization increase convergence, whereas liberalizing capital goods increases inequality. This is intuitive as

Figure 1.1: Average income per capita relative to the US



Source: World Bank. The bundle of countries differs each year according to their GDP per capita rich countries are the main producers of capital goods and the benefits from symmetric liberalization will accrue mostly to them.

The rest of the paper is organized as follows: Section 2 reviews the extant literature, Section 3 presents the theoretical model, Section 4 illustrates the transmission mechanisms in the model, Section 5 describes the data and the calibration sources, Section 6 explores several counterfactual scenarios and Section 7 concludes.

1.2 Related Literature

Given the broad scope of my paper, it ties into several different stands of literature, all of which offer mixed results. First and foremost, it is related to the voluminous literature on globalization and the skill premium. Most theoretical work in this area has been done through the prism of Hecksher-Ohlin models. These models predict that trade liberalization will narrow the income gap between rich and poor countries and, at the same time, raise the relative return of the abundant factor. In rich countries this implies an increase in the skill premium while in poor countries the gap between skilled and unskilled wages should narrow.

While the sharp predictions of these simple models do an accurate job explaining the increase in inequality in developed countries and the decrease in inequality in developing ones up to about the 80s, they fail on multiple fronts. In many developing countries, liberalizing in the 80s and 90s led to increased inequality, while in developed countries, with the exception of the US and UK, inequality growth has succumbed or even reversed over the past two decades, despite continuing globalization.

Faced with this discrepancy, researchers began looking for alternative transmission mechanisms. Davidson et al. [1999] proposed a trade model with search frictions and unemployment. They find that this has a major effect on the distributive effects of trade. Peter Neary built several oligopolistic models (2002a, 2002b) in which firms are large in their respective markets. Feenstra and Hanson argue in several papers (1995, 1997) that FDI could play an important role in explaining inequality in developing countries. They extend the Hecksher-Ohlin model to account for trade in intermediary goods and show, both theoretically and empirically, that trade can indeed increase inequality in both developing and developed countries.

Grossman and Rossi-Hansberg [2008] continue this line of though and build a trade in tasks model where some tasks are performed by low skilled workers and others by skilled ones and firms choose to offshore some of their tasks. They find that offshoring acts in a way similar to an increased supply of unskilled workers but, under certain circumstances, offshoring can be Pareto improving.

Several other papers have investigated the effects of offshoring on inequality: Ebenstein et al. [2014], for instance, find evidence that offshoring affected inequality through sector relocation from manufacturing to other sectors. Carluccio et al. [2015] further extend the Feenstra and Hanson [1995] model by incorporating heterogeneous firms in their framework. They find that factor proportion trade operates within industries and there is a positive correlation between productivity and skill intensity; firms offshore the most labour intensive tasks first, lowering the domestic demand for unskilled work. Mitra and Ranjan [2010] incorporate unemployment and search into an offshoring model and find that offshoring can lower unemployment in that sector.

In explaining the link between globalization and inequality, another leading theory, that this paper subscribes to, is skill-biased technology as trade shifts demand towards skilled labor. Two recent papers in this vein are Burstein and Vogel [2012] and Parro [2013]. Both papers employ Ricardian models in which skilled labour is complementary with capital so liberalization increases the demand for skilled workers. They find trade unambiguously increases inequality in all countries, albeit more in developing ones. In the case of Burstein and Vogel, however, the results stem from explicitly modelling trade as being skilled-biased *ex ante*. A related paper is Nigai [2012], which proposes a different mechanism though which trade generates inequality: upon liberalization firms earn more but most of those gains accrue to the owners of capital.

Some authors have even argued that in rich countries the osverved changes in inequality have more to do with productivity than trade. Lawrence et al. [1993], using US data from the 1980s, find that the compensation per worker closely mimics output per worker and the growing gap between skilled and unskilled workers' income has more to do with technological change than trade liberalization. Berman et al. [1994] similarly ascribe the increasing skill premium to increased demand for skilled labor due to technological reasons rather than trade. However, these papers consider the substitution effect as a sufficient statistic for trade-caused inequality despite this being the case for only a narrow class of production functions; they measure technology as the residual so it is well possible that trade has caused other changes in the production function.

In recent years, a number of papers have taken advantage of more detailed datasets and looked more closely at the mechanisms of globalization and inequality in developing countries. Goldberg and Pavcnik [2007] survey the more recent literature on developing countries with a special focus on Latin America. The paper indicates that inequality increases contemporaneously with a change in trade and there may be a causal link. While this may be true for the countries they investigate, it is far from veridical for all developing countries, as they themselves admit. Asian countries liberalized in the 60s and 70s and saw a inequality decrease but there is not enough data to clearly identify the causal pathway. Moreover, the link between trade and inequality does not even hold for all Latin American countries: Behrman et al. [2003] note that inequality has increased in only 7 out of 18 Latin American countries that underwent liberalization in the 80s.

This evidence is not new, going at least as back as Papageorgiou et al. [1990], who in a study of nineteen countries find that in the course of liberalization, inequality increased, decreased or had non-monotonic behavior. Wood [1997] document an increase in the skill premium in Hong Kong, Argentina, Chile, Colombia, Costa Rica, Uruguay and Mexico and a narrowing in Korea, Taiwan, Singapore and Malaysia.

One key factor in determining inequality appears to be education and the initial stock of skilled labor. Kijima [2006], using Indian data, finds that the increase in skill premium is a result of changes in returns to measurable skills, specifically education. Chamarbagwala [2006], also on Indian data, confirms her findings, arguing that increased wage inequality resulted from increased skill demand. Ripoll [2005] builds a dynamic overlapping generations model with skill acquisition and heterogeneous education costs amongst workers. Taking the model to data, she documents an increase in inequality in Israel and a decrease in Greece. She concludes that country specific factors such as demographics, physical capital and the initial ratio of skilled to unskilled workers are paramount in determining the path and size of the skill premium. Mamoon and Murshed [2008] use a broad range of inequality indicators to examine the impact of trade against the initial relative stocks of skilled and unskilled labor. They also find that initial conditions matter: countries which initially have a high share of skilled workers experience less inequality than those who do not.

Another factor that may be significant in explaining the direction inequality changes is the nature of the sector being liberalized. Amiti and Konings [2007] investigate liberalization in Indonesia, one of the poorest countries in the world, and find that tariff reductions on production goods decrease the skill premium whereas final goods' tariff reductions have a negligible effect on the skill premium.

An evident feature of the data is that education shares have been going up in the world, almost monotonically, regardless of trade conditions. Atkin [2012], using highly disaggregated cohort data looks at the effect of liberalization in Mexico on school enrollment. He finds that liberalization makes entering the job market more attractive than continuing education for a large number of teens. Similar effects are noted with US industrialization in the early 20th century by Goldin and Katz [1997]. Both of these liberalization episodes involved low skilled professions. On the other hand, papers looking at the impact of outsourcing IT jobs in India (Munshi and Rosenzweig [2003], Shastry [2012]) find that school enrolment increased as these job demanded high skills. In line with the evidence in Amiti and Konings [2007] cited above, Federman and Levine [2004] find that for Indonesia in the 1980s and 1990s, a period which included both rapid liberalization and industrialization, there is a positive link between the number of skilled workers (manufacturing) in a district and school enrolment. Oostendorp and Doan [2013] examine changes in skill premium, both from a Mincerian perspective and by looking at changes in the composition of labor in Vietnam. They find evidence of skill upgrading in most sectors; while overall the skill premium increases, they also document a decrease in the return to education in export oriented sectors.

As I also look at the impact of trade on cross-country inequality, my paper is also related to the growth and income convergence literature. While early papers such as Barro [1991] or Mankiw et al. [1992] found evidence for convergence, later research (Quah [1996] or Easterly and Levine [2000]), using a broader sample, argued for $\sigma-$divergence: the dispersion of income per capita and that rich countries become richer while poor ones become poorer.

In the trade literature, liberalization and convergence was investigated by Sachs et al. [1995] who split countries into 'open' and 'closed'. They find that among open countries, poor ones have higher growth rates, an effect not seen among closed ones. Similar arguments in favor of trade and convergence were put forth by Ben-David (1996, 1998, 1998) and Frankel and Romer [1999] among others. One recent paper that links income convergence and trade is Waugh [2010]. He finds that trade barriers account for a significant share of inequality and lowering the asymmetry of trade costs between rich and poor countries would go a long way towards aligning incomes. This paper has come under criticism in Egger et al. [2012], who, using a different calibration, obtains much more modest results.

Finally, it should be noted I am not the first to consider endogenous factor supply changes. However, despite growing evidence of an extensive side adjustment of the labor supply, only a handful of international trade papers allow for varying endowments of skilled and unskilled labor. Among the few exceptions are Findlay and Kierzkowski [1983], Deardorff [2000] and Kreickemeier [2009] who investigate endogenous skill formation in the context of Hecksher-Ohlin models and Larch and Lechthaler [2009] who build a Melitz type model with endogenous skill selection of workers. Their results are mixed, depending on modelling choices: Findlay and Kierzkowski find increases in the skill premium whereas Kreickemeier sees inequality decrease.

1.3 The Model

In this paper I build a multi-country multi-sector Ricardian model in the tradition of Eaton and Kortum [2002]. Unlike New Trade models that assume love of variety, in Ricardian models the main motive for trade is technological differences between countries. Therefore, while any country can theoretically produce each and every good, they will specialize only in those where they have a comparative advantage. The starting point is Parro [2013], which I extend in several dimensions.

Let the world consist of N countries. In each country there is a non-traded, homogeneous, final goods sector and three heterogeneous, traded sectors: manufacturing, agriculture and capital. Manufacturing and capital goods act strictly as intermediary sectors. While it can be argued that households directly consume manufactured goods, such as footwear or electronics, empirical evidence has shown that even imports of final consumer goods have a large share of value added in the destination country [Rousslang and To, 1993] so the final consumption bundle has a great deal of tertiary value added. My modelling choice is also consistent with evidence that indicates intermediary goods make up the bulk of international trade (Feenstra and Hanson [1997], for instance).

For the remainder of the paper I will use i or n subscripts to denote countries, j superscripts to denote sectors, and s and u to indicate skilled and unskilled labor.

1.3.1 Workers

Workers have the choice of being skilled or unskilled. In order to become skilled, they must pursue costly higher education. I do not explicitly model higher education costs but rather treat education costly in terms of forgone wages. Higher education lasts for d_i years, during which workers do not receive any wages but they must still consume in order to sustain themselves. For the duration of their studies, workers have access to an endowment R, drawn from a country specific distribution $G_i(R)$, with positive support.

Specifically, when choosing to acquire education, workers compare the discounted future stream of utilities they will receive from the incomes for each skill level. Let $V(I)$ be the indirect consumption utility obtained by workers with income I. Then, a worker with endowment R chooses between the following two utilities utility streams

$$\begin{aligned} \Sigma V^u &= \int_0^\infty e^{-\rho t} V\left(I^u\right) dt \\ \Sigma V^s\left(R\right) &= \int_0^d e^{-\rho t} V\left(I^r\right) dt + \int_d^\infty e^{-\rho t} V\left(I^s\right) dt \end{aligned} \tag{1.1}$$

where I^s and I^u are the incomes for skilled and unskilled labor and $I^r = \frac{R}{d}$ is the per period income the worker earns while studying.

Once they acquire education, all skilled workers earn the same income, I^s. This specification leads to a strict separation of skilled and unskilled workers based on the value of R. R represents more than simply family wealth as poor but clever students can still acquire education; The outside option takes on a broader interpretation such as access to scholarships, free education etc. For this reason, the outside option does not form part of the utility of workers who forgo education. As the distribution of endowments is continuous, there is a marginal worker with endowment $\bar{R}$ who is indifferent between being skilled or unskilled[1].

$$\Sigma V^s \left(\bar{R}\right) = \Sigma V^u \tag{1.2}$$

From the above equation, by expanding the discounted utilities, a closed form solution for $V(\bar{R})$ can be easily derived:

$$V\left(I^u\right) = e^{-\rho d} V\left(I^s\right) + \left(1 - e^{-\rho d}\right) V\left(\bar{R}\right) \tag{1.3}$$

Given the value of $\bar{R}$ and the strict separation of skilled and unskilled workers, the share of skilled workers, s, will be the mass of G_i above $\bar{R}$, i.e. cdf$(\bar{R}) = (1 - s)$.

1.3.2 Households

Households consume agricultural and final goods. Of the former, they must consume a minimum amount in order to survive. Besides indicating that agriculture fulfils a basic survival need, non-homothetic preferences also account for several patterns in the data: trade intensity in agriculture is lower than for manufacturing, in poor countries a large share of income is spent on subsistence and even developed countries have a restrictive trade policy concerning agriculture, the Common Agricultural Policy in the EU, for instance[2].

[1] This is always the case due to my choice of utility, detailed below: As utility is concave and negative for small values of R, no matter what the difference between I^s and I^u is, there will be a $\bar{R} > 0$ such that $\Sigma V^s \left(\bar{R}\right) = \Sigma V^u$.

[2] See Markusen [2010], Simonovska [2010], Fieler [2011] for an in-depth look at non-homothetic preferences and their role in trade puzzles.

Given an income, I_i, a household in country i maximize the following utility function

$$U_i = \frac{\left(\left(q_i^f\right)^\beta (a_i - \bar{a})^{1-\beta}\right)^{1-\sigma}}{1-\sigma}$$

subject to the budget constraint

$$p_i^a a_i + p_i^f q_i^f = I_i$$

where a_i and q_i^f are household consumption of the agricultural and final good, respectively, and $\bar{a}$ is the minimum agricultural consumption. Solving the maximization problem results in households' demand for agriculture and final goods:

$$p_i^a a_i = I_i (1-\beta) + \beta p_i^a \bar{a}$$
$$p_i^f q_i^f = \beta (I_i - p_i^a \bar{a})$$

Substituting the demand back in the utility function I get the indirect utility associated with income I_i

$$V_i (I_i) = \left(\frac{\beta (I_i - p_i^a \bar{a})}{p_i^f}\right)^{\beta(1-\sigma)} \left(\frac{I_i (1-\beta)}{p_i^a} + (\beta - 1) \bar{a}\right)^{(1-\beta)(1-\sigma)} \tag{1.4}$$

Given two levels of income I_i: I_i^s and I_i^u for skilled and unskilled workers, respectively, by combining equations (1.3) and (1.4), one can solve for the threshold endowment $\bar{R}$ as a function of wages, prices and parameters.

1.3.3 Production

In all sectors, production is realized combining both types of labor and intermediate inputs. Labor is immobile across countries but mobile within a country and, as a result, wages are equalized across sectors. In each of three traded sectors, $j = \{m, k, a\}$, there is a continuum of goods, ω^j, which any country can produce.

Each country i has a different level of efficiency in the production of each good in each sector. Let $x_i^j (\omega^j)$ denote the efficiency of producing good ω^j. Firms draw their productivity from a Frechet distribution with shape parameter θ^j and country-sector specific location parameters λ_i^j. θ^j governs the dispersion of productivity, and a higher value of θ^j implies more heterogeneity. The production of each good ω^j uses an intermediary bundle of goods from each other sectors. Let a_i, m_i and k_i be the intermediary bundles of agriculture, manufacturing and capital goods, respectively. All goods in a sector are aggregated in constructing the intermediary bundles:

$$j = \left[\int_{\Omega^j} \omega^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}$$

where η is the within sector elasticity of substitution and Ω^j is the set of possible goods in sectors j. In the production function capital is complementary with skilled labor and they are aggregated in a CES function with parameter $\rho < 0$. Then, this bundle is aggregated with the output of unskilled labor in a CES function with parameter $0 < \vartheta < 1$. The capital-skill bundle is country and sector specific while the shares in which it is mixed with unskilled labor are just country specific[3]. The production functions in traded sectors has the following functional form:

$$y_i^j(\omega^j) = x_i(\omega^j) \left\{ (\delta_i)^{1-\vartheta} (u)^{\vartheta} + (1-\delta_i)^{1-\vartheta} \left(\chi_i^j\right)^{\vartheta} \right\}^{\frac{\alpha_i^j}{\vartheta}} \left[m^{\xi_i^j} a^{1-\xi_i^j} \right]^{1-\alpha_i^j} \tag{1.5}$$

where

$$\chi_i = \left[\left(H_i^j\right)^{1-\rho} (s)^{\rho} + \left(1-H_i^j\right)^{1-\rho} (k)^{\rho} \right]^{\frac{1}{\rho}}$$

is the capital-skilled labour bundle, $y_i^j(\omega^j)$ is the output of assortment ω^j in sector j and country i, u is unskilled labor, s is skilled labor, H_i^j and δ_i are shares between 0 and 1, $0 \leq \alpha_i^j \leq 1$ is the share of value added in sector j and country i, and $0 \leq \xi_i^j \leq 1$ is the share of the manufacturing bundle relative to the agriculture bundle in each sector and country. For the capital goods sector, I assume that $\xi_i^k = 1$ so there is no intermediate agricultural demand from capital goods. As firms operate in a perfectly competitive environment, they are price takers and face the following minimization problem:

$$\min p_i(\omega^j) y_i^j(\omega^j) = p_i^m m(\omega^j) + w_i^u u(\omega^j) + w_i^s s(\omega^j) + p_i^k k(\omega^j) + p_i^a a(\omega^j)$$

[3]This restriction is due to data availability issues: I did not have enough data moments to match a fully heterogeneous production function. I chose to restrict δ to be common across sectors rather than H as this approach resulted in more sensible modeling parameters

subject to the production function. Solving the problem, it can be shown that:

$$p_i(\omega^j) = \Upsilon_i^j x_i(\omega^j)\left\{\delta_i (w_i^u)^{\frac{\vartheta}{\vartheta-1}} + (1-\delta_i)\,(p_i^{\chi})^{\frac{\vartheta}{\vartheta-1}}\right\}^{\frac{\alpha_i^j(\vartheta-1)}{\vartheta}} \left[(p_i^m)^{\xi_i^j}(p_i^a)^{1-\xi_i^j}\right]^{1-\alpha_i^j} \tag{1.6}$$

where

$$p_i^{\chi,j} = \left[H_i^j (w_i^s)^{\frac{\rho}{\rho-1}} + \left(1-H_i^j\right)\left(p_i^k\right)^{\frac{\rho}{\rho-1}}\right]^{\frac{\rho-1}{\rho}} \tag{1.7}$$

and Υ is a sector-country specific constant that depends solely on parameters[4]. For the sake of simpler notation, let b_i^j be the cost of the input bundle:

$$b_i^j = \frac{p_i(\omega^j)}{x_i(\omega^j)} = \Upsilon_i^j\left\{\delta_i (w_i^u)^{\frac{\vartheta}{\vartheta-1}} + (1-\delta_i)\,(p_i^{\chi})^{\frac{\vartheta}{\vartheta-1}}\right\}^{\frac{\alpha_i^j(\vartheta-1)}{\vartheta}} \left[(p_i^m)^{\xi_i^j}(p_i^a)^{1-\xi_i^j}\right]^{1-\alpha_i^j}$$

In the final goods sector there are a continuum of producers but the goods are homogeneous. The production function is similar to that in the traded sectors

$$y_i^f = \left\{(\delta_i)^{1-\vartheta}(u)^{\vartheta} + (1-\delta_i)^{1-\vartheta}\left(\chi_i^f\right)^{\vartheta}\right\}^{\frac{\alpha^f}{\vartheta}} m^{1-\alpha^f}$$

resulting in a similar price formula to that the trade goods

$$p_i^f = \Upsilon_i^f\left\{\delta_i (w_i^u)^{\frac{\vartheta}{\vartheta-1}} + (1-\delta_i)\left(p_i^{\chi,j}\right)^{\frac{\vartheta}{\vartheta-1}}\right\}^{\frac{\alpha_i^f(\vartheta-1)}{\vartheta}} \left[p_i^m\right]^{1-\alpha_i^f} \tag{1.8}$$

Deriving the full model follows the steps in section 3 of Alvarez and Lucas [2007]. For the sake of brevity, I will not repeat them here but only sketch the derivations, results and implications. Shipments from country i to country n are subject to iceberg trade costs, τ_{ni}^j. When assembling the intermediate bundle of goods, firms only purchase good ω from the cheapest location in the world. The final price of good ω, in country n will be

$$\mathrm{p}_n^j(\omega) = \min\left\{p_{ni}\left(\omega^j\right), i = 1...N\right\} \tag{1.9}$$

where the cost of good ω^j in country n supplied from country i, and $p_{ni}(\omega^j) = p_i(\omega^j)\tau_{ni}^j$ is the production cost of country i multiplied by bilateral trade costs. As productivity is Frechet distributed, it can be shown that prices are Weibull distributed and $p^{\theta j}$ are exponentially

4

$$\Upsilon_i^j = \left(\alpha_i^j\right)^{-\alpha_i^j}\left(\xi_i^j\left(1-\alpha_i^j\right)\right)^{-\xi_i^j(1-\alpha_i^j)}\left(\left(1-\xi_i^j\right)\left(1-\alpha_i^j\right)\right)^{-(1-\xi_i^j)(1-\alpha_i^j)}$$

distributed. When firms choose suppliers in (1.9), their choice is equivalent to choosing over the prices to the power of θ, as the domain is positive. Finally, $\mathrm{p}_{\mathrm{n}}^{\mathrm{j}}(\omega)^{\theta}$, as the minimum of several exponentially distributed variables, is itself exponentially distributed. Integrating over the set of goods, one obtains the price index and the price of intermediate bundles, for each sector and country. The price indices for the aggregate intermediate goods and the final goods are

$$p_n^j = A^j \left[\sum_{i=1}^{N} \left[b_i^j \tau_{ni}^j \right]^{-\frac{1}{\theta^j}} \lambda_i^j \right]^{-\theta^j} \tag{1.10}$$

where $A^j = \left[\Gamma \left(1 + \theta^j \left(1 - \eta \right) \right) \right]^{(1-\eta)}$ is a constant. Country i will buy good ω from country n only if its price plus trade costs is the lowest it can find. The probability that country i will buy good ω form country n is the probability that country n is the cheapest source of good ω for country i. Therefore bilateral trade shares are just the probabilistic representations that goods purchased by country n from country i are the cheapest goods country n can find. Using the same steps as in deriving the price indices, the bilateral shares are

$$\pi_{ni}^j = \frac{\left(b_i^j \tau_{ni}^j \right)^{-1/\theta^j} \lambda_i^j}{\sum\limits_{l=1}^{n} \left(b_r^j \tau_{nl}^j \right)^{-1/\theta^j} \lambda_l^j} \tag{1.11}$$

For the final goods sector $\pi_{ii}^f = 1$.

Trade is unbalanced sector by sector and also at a country level. Let D_i be the total deficit of country i. I further assume that the deficit is equally distributed to households and they can use the extra income in purchasing goods so $I_i^l = w_i^l + \frac{D_i}{L_i}$[5], where $l = \{u, s\}$. In each country, the share of skilled workers is s_i and the share of unskilled ones is $(1 - s_i)$. $\overline{w_i}$, the average income of workers in country i, is:

$$\overline{w_i} = w_i^u \left(1 - s_i \right) + w_i^s s_i \tag{1.12}$$

Country i's total expenditure on sector j, X_i^j is the sum of final household demand, if it exists, and demand for intermediary goods from other sectors. Let the output value of a sector be $Y_i^j = p_i^j y_i^j$ and let the input share of factor q be $\gamma_i^{q,j}$, where q refers to labor

[5] Appendix 3 of the second paper in this thesis shows, in a similar model, that this the trade deficit must be part of the household income for the budget conditions to hold. The same reasoning applies here as well.

as well as intermediate goods. Then, demand for intermediary goods from sector q will be $\gamma_i^{q,j} Y_i^j$. On the other had, sector j's output has two destinations: domestic consumption and exports: $Y_i^j = \sum_{n=1}^{N} \pi_{ni}^j X_n^j$. Therefore, a country's demand system can be represented as:

$$\begin{aligned}
X_i^a &= \sum_{j\in\{a,m\}} \gamma_i^{a,j} \sum_{n=1}^{N} \pi_{ni}^j X_n^j \quad + \left[\left((1-\beta)\left(\overline{w_i} + \tfrac{D_i}{L_i}\right) + \beta p_i^a \bar{a}\right) L_i\right] \\
X_i^m &= \sum_{j\in\{a,m,k,f\}} \gamma_i^{m,j} \sum_{n=1}^{N} \pi_{ni}^j X_n^j \\
X_i^k &= \sum_{j\in\{a,m,k,f\}} \gamma_i^{k,j} \sum_{n=1}^{N} \pi_{ni}^j X_n^j \\
X_i^f &= \left[\beta\left(\overline{w_i} + \tfrac{D_i}{L_i} - p_i^a \bar{a}\right) L_i\right]
\end{aligned} \tag{1.13}$$

where the summation term is intermediate demand from the other sectors and the square bracket terms are household demand. At the same time, I impose the market clearing condition that a country's expenditure plus its deficit must be equal to expenditures of all other countries on goods from that country

$$X_i^m + X_i^a + X_i^k = \sum_{n=1}^{N} \left(\pi_{ni}^m X_n^m + \pi_{ni}^a X_n^a + \pi_{ni}^k X_n^k\right) - D_i \tag{1.14}$$

In the agriculture and manufacturing sectors, intermediate shares are given by $\gamma^{a,j} = (1-\alpha^j)(1-\xi^j)$ and $\gamma^{m,j} = (1-\alpha^j)\xi^j$, respectively. For capital goods, the share is a bit more involved due to the nested CES nature of the production function. Still it is rather straightforward to derive:

$$\gamma_i^{k,j} = \alpha_i^j (1-\delta_i) \frac{\left(p_i^{\chi,j}\right)^{\frac{\vartheta}{\vartheta-1}}}{\delta_i (w_i^u)^{\frac{\vartheta}{\vartheta-1}} + (1-\delta_i)\left(p_i^{\chi,j}\right)^{\frac{\vartheta}{\vartheta-1}}} \left(1-H_i^j\right) \left(\frac{p_i^k}{p_i^{\chi,j}}\right)^{\frac{\rho}{\rho-1}} \tag{1.15}$$

where $p^{\chi,j}$ is as defined in (1.7). Similarly, the share of skilled labor in sector j is:

$$\gamma_i^{s,j} = \alpha_i^j (1-\delta_i) H_i^j \left[1 + \frac{\delta_i}{(1-\delta_i)} \left(\frac{w_i^u}{p_i^{\chi,j}}\right)^{\frac{\vartheta}{\vartheta-1}}\right]^{-1} \left[1 + \frac{H_i^j}{(1-H_i^j)} \left(\frac{w_i^s}{p_i^{k,j}}\right)^{\frac{\rho}{\rho-1}}\right]^{-1} \tag{1.16}$$

To close the model, payment to skilled labor must equal the skilled wage bill:

$$\sum_{j=\{a,m,k,f\}} \gamma_i^{s,j} Y_i^j = (1 - s_i)\, w_i^s L_i \tag{1.17}$$

Given parameters' values and the data observed trade deficits, equations (1.3), (1.4) and (1.10) - (1.17) fully characterize the equilibrium.

1.4 Data and Calibration

1.4.1 Data Sources

In calibrating the model, I use 2005 as the base calibration year, largely due to data availability. The model requires a fair amount of data, not all of which is available in a single dataset. The data I need falls into four categories: trade data, production parameters, utility parameters and population data.

Population statistics, number of workers and GDP, are taken from the World Bank database. As not all countries have all data for 2005, when reasonable, some data is imputed using the closest available year. When no nearby years are available, the country is dropped from the sample as, for the model to be solvable, all data must be available for all countries. After trimming cases where data is not available I am left with 80 viable countries listed in Appendix A1.1 along with their Gini coefficients. In addition, I assume an extra 'country', the rest of the world, henceforth ROW. For ROW parameters are computed either as the difference between world statistics and observed countries, in the case of population, trade and GDP, or as the average of available countries for production and utility parameters.

To match data inequality moments I need Gini coefficients, the share of people within a country with tertiary education and the average duration of tertiary education. The Gini coefficients are taken either from the UN WIIDER dataset or from the OECD database and the main source on education data is the Barro-Lee dataset [Barro and Lee, 2001], complemented with data on tertiary education from the World Bank.

Trade data comes from the UN COMTRADE database. I use SITC classification 3rd revision and I consider goods under code 0 as agriculture, those under code 7 are capital goods and the rest as manufacturing.

In calibrating the non-homothetic utility parameters, I use prices for agricultural goods from the World Bank International Price comparison program and the share of agriculture in consumption from the FAO Food Security database.

Obviously, no data source will have exact information for CES parameters under my functional representation, but δ_i, H_i^j and α_i^j can be recovered from the input output tables provided by the World Input Output Database from intermediate demand shares, $\gamma_i^{j,k}$, and value added data. I assume the share of value added in the final goods sector is the same as in manufacturing, $\alpha_i^f = \alpha_i^m$. For countries with no data, I input the sample average.

To calibrate more 'abstract' parameters, I follow the established literature as closely as possible: the elasticity of substitution between skilled and unskilled workers is taken from Burstein and Vogel [2012] and the complementarity between skilled labor and capital goods is taken from Parro [2013]. The dispersions of productivity in manufacturing and capital goods are the same as in Parro [2013] and productivity dispersion in agriculture is from Xu [2012], who estimates it using micro-level prices.

1.4.2 Mapping the Observables to Parameters

All the model's parameters are listed in Table 1.2, along with their provenance. For key parameters derived in this section, it also shows their value or, if varying across countries, theier average along with the standard deviation and the interquartile range.

1.4.2.1 w^s and w^u

I proxy total disposable income in the economy by GDP. Knowing population and GDP, I compute $\overline{w}_i = \frac{GDP_i}{L_i}$. Using the data shares of skilled and unskilled workers in each country, I recover w_i^u and w_i^s using equation (1.12). I make an initial guess for w^s. As (1.12) is linear, I immediately recover w^u. Using the shares of skilled and unskilled workers, and my wage guesses, I compute the Gini coefficient and compare it to the data one. If they are dissimilar, I adjust my guess of w^s until for each country the model Gini matches the data Gini.

1.4.2.2 β and $\bar{a}$

Households' expenditure on agriculture is given by

$$X_i^a = \left[(1-\beta)\left(\overline{w_i} + \frac{D_i}{L_i}\right) + \beta p_i^a \bar{a}\right] L_i$$

I know everything in the above equation except for β and $\bar{a}$. I use a numerical search procedure over the parameter space to find values such that the above equation is as close as possible to *data share of agriculture consumption* $\cdot (GDP_i + D_i)$ for all countries.

Adding non-homothetic preferences goes a long way towards matching the patters in the data: the correlation between model and data consumption shares is around 60 %. Without minimum consumption it would be less than 10%. Once I know $\bar{a}$ and β, I can also recover household expenditure on final goods, $X_i^f = \beta(\bar{w}_i + \frac{D_i}{L_i} - p_i^a \bar{a})$, a value which I will use in the next step.

1.4.2.3 Domestic expenditure shares

I rewrite the demand equations (1.13) as functions of domestic expenditure, exports and imports:

$$\begin{bmatrix} \pi_{ii}^a X_i^a + \text{Imports}_i^a \\ \pi_{ii}^m X_i^m + \text{Imports}_i^m \\ \pi_{ii}^k X_i^k + \text{Imports}_i^k \end{bmatrix} = \begin{bmatrix} \gamma^{a,a} & \gamma^{a,m} & \gamma^{a,k} \\ \gamma^{m,a} & \gamma^{m,m} & \gamma^{m,k} \\ \gamma_i^{k,a} & \gamma_i^{k,m} & \gamma_i^{k,k} \end{bmatrix} \begin{bmatrix} \pi_{ii}^a X_i^a + \text{Exports}_i^a \\ \pi_{ii}^m X_i^m + Exports_i^m \\ \pi_{ii}^k X_i^k + Exports_i^k \end{bmatrix} + \begin{matrix} \left[(1-\beta)\left(\overline{w_i} + \frac{D_i}{L_i}\right) + \beta p_i^a \bar{a}\right] L_i \\ \gamma_i^{m,f} X_i^f \\ \gamma_i^{k,f} X_i^f \end{matrix}$$

Intermediate shares γ, total imports and total exports and come from the data and Household demand of final and agricultural goods were computed in the previous step. For each country, I have a linear system of 3 equations in 3 unknowns: $\pi_{nn}^a X^a$, $\pi_{nn}^m X^m$ and $\pi_{nn}^k X^k$. Once domestic expenditures are known, total expenditure is easily computed as domestic expenditure plus imports. Finally, I derive the bilateral shares of trade π_{ni}^j by dividing bilateral trade flows to total expenditure.

1.4.2.4 p^k and p^m

In order to recover prices for manufacturing and capital goods, I follow Waugh [2010]: For each country n, I divide import shares (1.11) for all its trading partners to domestic shares and I get an equation that links trade costs, countries' input bundle costs and their technology levels in each sector.

$$\frac{\pi^j_{ni}}{\pi^j_{nn}} = \left(\frac{b^j_i}{b^j_n}\tau^j_{ni}\right)^{-\frac{1}{\theta^j}} \frac{\lambda^j_i}{\lambda^j_n} \tag{1.18}$$

Taking logs of (1.18) and rearranging I have an equation that, for each sector, has known values on the left hand side and country fixed effects on right hand side.

$$\ln\frac{\pi^j_{ni}}{\pi^j_{nn}} = \ln\left[\left(b^j_i\right)^{-\frac{1}{\theta^j}}\lambda^j_i\right] - \ln\left[\left(b^j_n\right)^{-\frac{1}{\theta^j}}\lambda^j_n\right] - \frac{1}{\theta^j}\ln\tau^j_{ni} \tag{1.19}$$

However, equation (1.19) is not identified, as it would still hold for any arbitrary scaling of costs across countries. I therefore impose the constraint that fixed effects sum up to zero[6] and run a constrained OLS. The identified country fixed effects are equal to $\ln(b^{j\,-\frac{1}{\theta^j}}_i\lambda^j_i)$ and I recover trade costs as the exponential of the regression residual multiplied by θ^j. Recall from (1.10), that prices are given by

$$p^j_n = A^j\left[\sum_{i=1}^N \left(b^j_i\right)^{-\frac{1}{\theta^j}}\lambda^j_i\left(\tau^j_{ni}\right)^{-\frac{1}{\theta^j}}\right]^{-\theta^j}$$

where I now know everything on the right hand side.

1.4.2.5 H^j and δ

From (1.15) that the share of capital in each country and each of the four sectors is

$$\gamma^{k,j}_i = \alpha^j_i\left(1-\delta_i\right)\frac{\left(p^{\chi,j}_i\right)^{\frac{\vartheta}{\vartheta-1}}}{\delta_i(w^u_i)^{\frac{\vartheta}{\vartheta-1}} + (1-\delta_i)\left(p^{\chi,j}_i\right)^{\frac{\vartheta}{\vartheta-1}}}\left(1-H^j_i\right)\left(\frac{p^k_i}{p^{\chi,j}_i}\right)^{\frac{\rho}{\rho-1}}$$

In the above system, there are 4 equations and 5 unknowns, 4 H^j_i and δ. In addition,

[6] While other papers in the literature typically impose some additional functional form on trade costs and identifies effects such as distance or common language, I have no use for them here and my theoretical specification disallows any correlation between these and the fixed effects

the share paid to skilled labour must equal its wage bill

$$\sum_{j=\{a,m,k,f\}} \gamma_i^{s,j} Y_i^j = (s_i)\, w_i^s L_i$$

where $\gamma_i^{s,j}$ is given by (1.16). I make an initial guess for the vector (H^j, δ) and plug it in the above system. I adjust my initial guesses until I solve the system. Note that only at this point do I have enough information to compute the price of the final good from (1.8).

1.4.2.6 λ^j

At this point I know all prices and all production function parameters. I can therefore solve for the input bundle cost, b_i^j in every sector. I plug these estimates in the fixed effects from Section 5.2.4 and recover λ^m and λ^k.

To recover λ^a, I follow a slightly different strategy. From (1.11) the domestic shares in agriculture are

$$\pi_{nn}^a = \frac{\left(b_i^a\right)^{-1/\theta^a} \lambda_n^a}{\sum_{l=1}^{n} \left(b_l^a \tau_{nl}^a\right)^{-1/\theta^a} \lambda_l^a} = \frac{\left(A^a\right)^{-1/\theta^a} \left(b_i^a\right)^{-1/\theta^a} \lambda_n^a}{\left(p_n^a\right)^{-1/\theta^a}}$$

where I know everything except for λ^a. Once I recover the technology parameters, I use the same equation for bilateral shares to recover trade costs in agriculture. The estimated relative productivities for all sectors can be found in Appendix Table A1.1, where I use the United States as a reference country.

1.4.2.7 $G(R)$

In line with the literature on wealth I assume the outside option G to be exponentially distributed with parameter μ_i. I compute the indirect utility for both skilled and unskilled workers. Using (1.4) and data on the duration of education, d_i, I find the value of $\bar{R}_i$, the outside option of the indifferent worker. I then solve for μ_i, such that the data observed shares of unskilled workers are equal to the cumulative of $\bar{R}_i$, i.e.

$$(1 - s_i) = \text{cdf}\left(\bar{R}_i\right)$$

Table 1.2: Model parameters

Description	Parameter	Source/Derivation	Mean	S.D.	IQR	Country specific
Total income	GDP	Data	–	–	–	Yes
Country population	L	Data	–	–	–	Yes
Average wage	$\bar{w}$	GDP/L	–	–	–	Yes
Skilled wage	w^s	Section 1.4.2.1	10.6	12.8	14.1	Yes
Unskilled wage	w^u	Section 1.4.2.1	57.6	53.9	75.5	Yes
Minimum agricultural consumption	$\bar{a}$	Section 1.4.2.2	0.25	–	–	No
Share of agriculture in consumption	β	Section 1.4.2.2	0.71	–	–	No
Exports	$\pi_{ni}X_n$	Data	–	–	–	Yes
Domestic share of expenditure on agriculture	$\pi_{nn}X_n^a$	Section 1.4.2.3	0.95	0.03	0.03	Yes
Domestic share of expenditure on manufacturing	$\pi_{nn}X_n^m$	Section 1.4.2.3	0.61	0.19	0.24	Yes
Domestic share of expenditure on capital	$\pi_{nn}X_n^k$	Section 1.4.2.3	0.66	0.15	0.19	Yes
Bilateral shares	π_{ni}	Section 1.4.2.3	–	–	–	Yes
Traded sectors' expenditure	X_n^j	$\sum \pi_{ni}^j X_n^j + \pi_{nn}^j X_n^j$	–	–	–	Yes
Final Good expenditure	X^f	$X^f = \beta(\bar{w} + \frac{D}{L} - p^a\bar{a})L$	–	–	–	Yes
Prices in manufacturing and capital	p^m, p^k	Section 1.4.2.4	–	–	–	Yes
Trade costs in manufacturing and capital	τ^m, τ^k	Section 1.4.2.4	7.25	7.05	4.70	Yes
I-O share	$\gamma^{k,j}$	Data	–	–	–	Yes
Relative use of manufacturing to agriculture	ξ^a	Data	0.21	0.03	0.00	Yes
Relative use of manufacturing to agriculture	ξ^m	Data	0.95	0.03	0.01	Yes
Share of value added	α^a	Data	0.63	0.03	0.00	Yes
Share of value added	α^m	Data	0.63	0.05	0.00	Yes
Share of value added	α^k	Data	0.85	0.03	0.00	Yes
Share of value added	α^f	Data	0.62	0.05	0.00	Yes
CES share of skilled workers	H^a	Section 1.4.2.5	0.40	0.14	0.21	Yes
CES share of skilled workers	H^m	Section 1.4.2.5	0.31	0.12	0.15	Yes
CES share of skilled workers	H^k	Section 1.4.2.5	0.24	0.10	0.13	Yes

Table 1.2: Model parameters

Description	Parameter	Source/Derivation	Mean	S.D.	IQR	Country specific
CES share of skilled workers	H^f	Section 1.4.2.5	0.22	0.10	0.13	Yes
CES share of unskilled workers	δ	Section 1.4.2.5	0.38	0.22	0.40	Yes
Productivity distribution location	λ^j	Section 1.4.2.6	See Appendix Table A1.1			Yes
Prices in agriculture	p^a	Data	–	–	–	Yes
Trade costs in agriculture	τ^a	Section 1.4.2.6	10.0	11.8	8.29	Yes
Education duration	d	Data	3.10	0.26	0.25	Yes
Outside option distribution parameter	$\mu(R)$	Section 1.4.2.7	4.51	5.80	6.72	No
Elasticity between skilled and unskilled labor	ϑ	Other literature	0.4	–	–	No
Elasticity between capital and skilled labor	ρ	Other literature	-0.5	–	–	No
Elasticity in aggregating goods	η	Other literature	2	–	–	No
Productivity dispersion in manufacturing	θ^m	Other literature	0.19	–	–	No
Productivity dispersion in capital goods	θ^k	Other literature	0.21	–	–	No
Productivity dispersion in agriculture	θ^a	Other literature	0.21	–	–	No

1.5 Transmission Mechanism

The main model in this paper has a lot of moving parts, each contributing to the impact of liberalization on wages and prices. In order to build an intuition for the transmission mechanisms, I consider a simpler model and only analyze it from the perspective of a single country, that moves from autarchy to free trade.

I assume that there is no manufacturing sector, i.e $\xi^j = 0, \forall j$ and agriculture only acts as an intermediate for the agricultural sector, $\alpha = 1, \forall j \neq a$. To further simplify the example, $H^k = H^f = H$ and in agriculture production is realized without any capital intermediaries, $H^a = 1$. Further, let preferences be homothetic so there is no minimum agricultural consumption required. Finally, trade is balanced at the country level but still unbalanced sector by sector.

While these assumptions simplify the model, they play little role in its qualitative predictions. The economy moves from autarchy to free trade[7]. Note that in this section I will be using slightly different notation from the rest of the paper. Under this parametrization, the expenditure equations for Home country become:

$$\begin{array}{ccccc} DX^a + \mathrm{I}^a & & (1-\alpha)\left(DX^a + \mathrm{E}^a\right) & + & (1-\beta)\left(w^s s + w^u(1-s)\right)L \\ DX^k + \mathrm{I}^k & = & \gamma^{k,k}\left(DX^k + \mathrm{E}^k\right) & + & \gamma^{k,f} DX^f \\ DX^f & & & & \beta\left(w^s s + (1-s)w^u\right)L \end{array} \tag{1.20}$$

where DX is the domestic expenditure on domestically produced goods, I is imports and E is exports. The payment to skilled labor is the same as in equation (1.17):

$$w^s sL = \gamma^{s,a}\left(DX^a + \mathrm{E}^a\right) + \gamma^{s,k}\left(DX^k + E^k\right) + \gamma^{s,f} DX^f$$

where

$$\gamma^{s,a} = \alpha\left(1-\delta\right)\left[1 + \tfrac{\delta}{1-\delta}\left(\tfrac{w^u}{w^s}\right)^{\frac{\vartheta}{\vartheta-1}}\right]^{-1}$$
$$\gamma^{s,f} = \gamma^{s,k} = \left(1-\delta\right)H\left[1 + \tfrac{\delta}{1-\delta}\left(\tfrac{w^u}{p^X}\right)^{\frac{\vartheta}{\vartheta-1}}\right]^{-1}\left[1 + \tfrac{H}{(1-H)}\left(\tfrac{w^s}{p^k}\right)^{\frac{\rho}{\rho-1}}\right]^{-1}$$

[7] For the purpose of this section the exact value of τ doesn't matter, although it will affect the size of trade flows.

are the shares paid to skilled labor in the three sectors and

$$\gamma^{k,k} = y^{k,f} = (1-\delta)(1-H)\left[1+\tfrac{\delta}{1-\delta}\left(\frac{w^u}{p^\chi}\right)^{\frac{\vartheta}{\vartheta-1}}\right]^{-1}\left[1+\tfrac{1-H}{H}\left(\frac{p^k}{w^s}\right)^{\frac{\rho}{\rho-1}}\right]^{-1}$$
$$p^\chi = \left[H(w^s)^{\frac{\rho}{\rho-1}} + (1-H)\left(p^k\right)^{\frac{\rho}{\rho-1}}\right]^{\frac{\rho-1}{\rho}}$$

Substituting in the the values of DX^a, DX^k and DX^f into the wage equation and and normalizing the unskilled wage to 1, I get the following value for the skilled wage, which also equals the skill premium:

$$w^s = \underbrace{\frac{1-s}{s}\frac{(1-\beta)\frac{\gamma^{s,a}}{\alpha}+\beta\frac{\gamma^{s,k}}{\gamma^{s,k}+\gamma^{u,k}}}{1-\left((1-\beta)\frac{\gamma^{s,a}}{\alpha}+\beta\frac{\gamma^{s,k}}{\gamma^{s,k}+\gamma^{u,k}}\right)}}_{\text{Domestic Effect}} + \underbrace{\frac{1}{s}\frac{\frac{\gamma^{s,a}}{\alpha}\left(\frac{NX^a}{L}\right)+\frac{\gamma^{s,k}}{\gamma^{s,k}+\gamma^{u,k}}\left(\frac{NX^k}{L}\right)}{1-\left((1-\beta)\frac{\gamma^{s,a}}{\alpha}+\beta\frac{\gamma^{s,k}}{\gamma^{s,k}+\gamma^{u,k}}\right)}}_{\text{Trade Effect}} \tag{1.21}$$

where NX are the net exports in each sector with $NX^a + NX^k = 0$. For a country under autarchy, the Trade Effect will be 0 as $NX^a = NX^k = 0$.

In equation (1.21), both the Domestic Effect and the Trade one have the same denominator and it is easy to check that it is always positive. Further, it is also obvious the numerator of the Domestic Effect is positive, ensuring that the skilled wage is positive. Nothing guarantees the skilled wage will be higher than the unskilled one but under reasonable parametrization this should be the case, i.e. the value added by skilled workers in production is higher than that of unskilled ones.

While this simple set up is still much too complicated for any sort of analytical solution, it is possible to tease out several transmission channels and identify the factors which will influence the skill premium.

Let us consider a country opening up to trade in both sectors. As trade is balanced overall, the country will be a net exporter in one sector and a net importer in the other. Upon opening up, the first order change is through the numerator of Trade effect, as NX ceases to be 0. The numerator is a weighted sum of the country's trade position in each sector, with the the relative shares skilled workers receive in each sector as weights.

If a country is an agricultural net exporter, the skill premium will tend to increase as long as the income share going to skilled workers in agricultures is higher than in capital goods. Similarly, inequality will increase if the country is a a net exporter of capital goods and skilled workers get a larger share of value added than unskilled workers in the capital sector compared to the agricultural one. The effect of changes in the skill premium boils down to:

$$\frac{\gamma^{s,a}}{\alpha} NX^a <?> \frac{\gamma^{s,k}}{\gamma^{s,k}+\gamma^{u,k}} NX^a$$

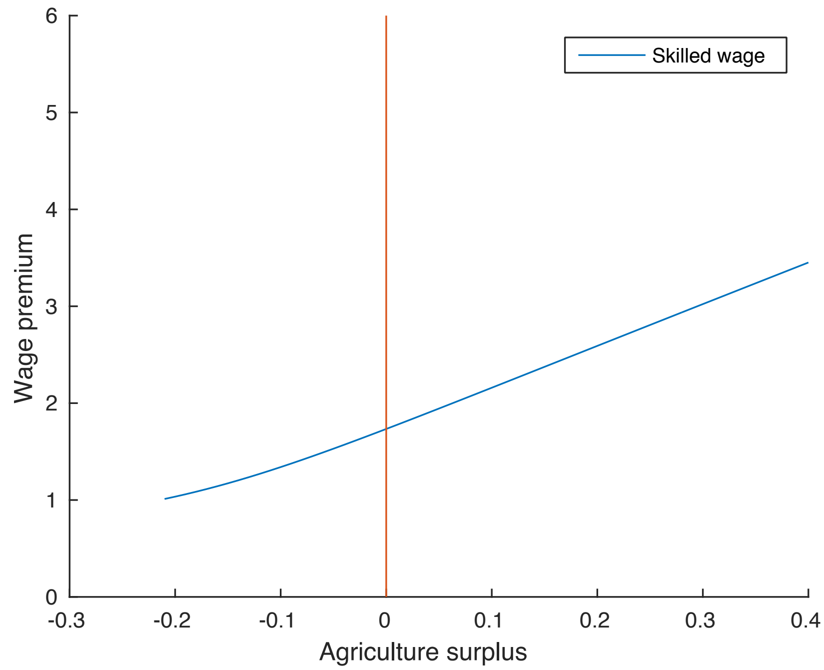
If $NX^a > 0$, whenever $\frac{1-\delta}{1+\frac{\delta}{1-\delta}\left(\frac{1}{w^s}\right)^{\frac{\vartheta}{\vartheta-1}}} > \frac{\gamma^{s,k}}{\gamma^{s,k}+\gamma^{u,k}}$ the skill premium will rise. If $NX^a < 0$, the opposite holds. This result is similar to predictions in the Hecksher-Ohlin framework which argues that liberalizing would increase returns to the abundant factor. However, the mechanism here is Ricardian in nature, as whether a country is a net exporter or net importer depends on the pattern of trade costs and comparative advantage a country enjoys in a given sector.

Changes in the skill premium will also have an effect, admittedly a modest one, on the choice firms make to allocate resources in the production process, affecting the shares of production factors, γ. While this effect cannot be captured analytically Figure 1.2 plots the evolution of the skill premium as a function of NX^a/L using the mean parameters from Table 1.2 as calibration. The effect is almost linear and would be completely linear if I ignored the general equilibrium effect on γ. Note that for large trade deficits in agriculture, the skilled wage becomes lower than the unskilled one. This is because, in this simple set-up, I hold prices fixed and impose an external trade adjustment, only allow the skilled wage to move.

A second channel through which liberalization influences the skill premium is the relative shares of skilled and unskilled workers in the economy. As the Trade Effect is inversely proportional to s, the effect on the skill premium will be lower in an economy with more skilled workers.

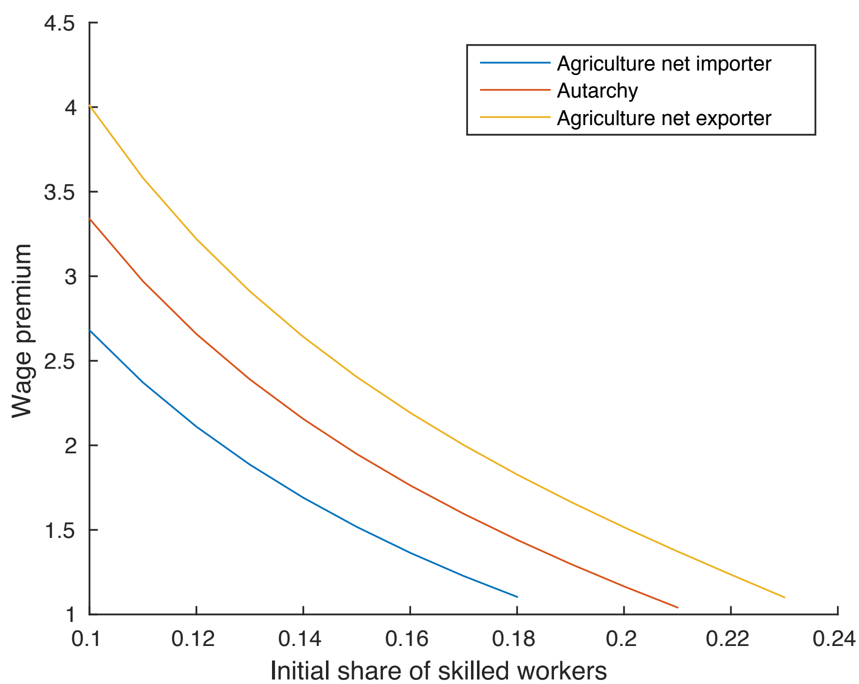
Figure 1.3 plots the evolution of the skill premium as a function of the initial stock of skilled workers, for several values of NX^a/L, using the mean parameters from Table 1.2 as calibration.

Figure 1.2: Stylized changes in the skill premium as a result of trade liberalization



Note: The red line indicates the skill premium under autarchy in my given calibration

Figure 1.3: Stylized changes in the skill premium as a result of trade liberalization



In the general equilibrium setting the effects of this second channel are more pronounced: following liberalization, the price of goods decreases, raising the utility of both skilled and unskilled workers. As the utility function is concave, unskilled workers' utility will rise more. As prices have gone down, the required level of wealth to acquire education has also decreased and more workers choose to become skilled, raising s. This will lower Domestic Effect of the skill premium also minimize the impact of the Trade Effect. Whether this effect is enough to dominate the increase inequality due to liberalization in net exporter countries ultimately depends on the country specific parameters.

In addition to the two channels illustrated above, in the full model, the unskilled wage is not fixed at 1 so it will also change upon liberalization. In the general equilibrium framework the following additional model properties can be inferred.

Proposition 1:

- *As unskilled labor is substitutable with the capital-skill bundle, an decrease in capital prices will lower the share unskilled labor gets paid.*

Proposition 2:

- *A drop in capital prices will increase the share of revenue going to skilled labor, potentially raising the skill premium*

Finally, in a general equilibrium framework, the changes in wages reverberate back into the shares skilled and unskilled workers receive.

Proposition 3:

- *A change in unskilled wages will have a positive effect on the share skilled workers receive.*
- *A change in skilled wages will have a negative effect on the share skilled workers receive.*

The exact mathematical formulation of the above 3 propositions can be found in Appendix A1.3. While the individual channels are easy to identify and general trends can be predicted, in the full model framework, their cumulative impact will highly depend on country specific characteristics and parametrizations.

1.6 The Quantitative Implications of the Model

Keeping relative technology levels fixed, I ask what happens to inequality and relative incomes if I allow trade costs to vary. I examine inequality in several ways: How does across countries inequality and convergence change? How does inequality within countries change? What are the welfare implications for skilled and unskilled workers and how are the gains from trade distributed? To assess these effects, I pursue a simple counterfactual scenario: In turn, I lower trade costs by 10% in each sector. I choose this approach as in practice trade liberalization is a gradual process, affecting different industries at different points in time and it allows me to identify heterogeneity between liberalizing various sectors. The magnitude of changes in trade costs I choose is roughly what can be observed over a 10 year period in the World Bank's trade cost dataset.

The algorithm to solve for the counterfactual equilibria is as follows: I guess an initial vector of skilled and unskilled wages, $\mathbf{w}$, in the neighbourhood of the original wage values. I then solve for prices using the price equation (1.10). Once prices are updated, I compute the new shares of skilled and unskilled workers such that (1.2) holds. Knowing prices, wages and trade costs, I calculate the bilateral shares. I compute expenditures and check whether the balanced budget conditions and (1.17) hold. If they do not, I adjust my guess of $\mathbf{w}$ until the model converges. Due to the high dimensionality of the problem, there are multiple instances of $\mathbf{w}$ that solve the equations, at least up to a numerical approximation. I restrict the solutions space by imposing that variables in ROW remain constant in the counterfactual. This restriction is enough to pin down a unique solution, at least in the local neighbourhood of the data values.

The counterfactual results can be found in Tables 1.3 and 1.4 and Figures 1.4 through 1.8. In each figure, countries are sorted by current GDP per capita to highlight the different effect of liberalization on poor and rich countries[8].

I run my model in two specifications: with and without the endogenous skill selection mechanism. The results when I keep the share of skilled labor fixed can be found in Figure

[8]Sorting by the initial share of skilled workers produces almost identical graphs as poor countries strongly tend to be skill deprived.

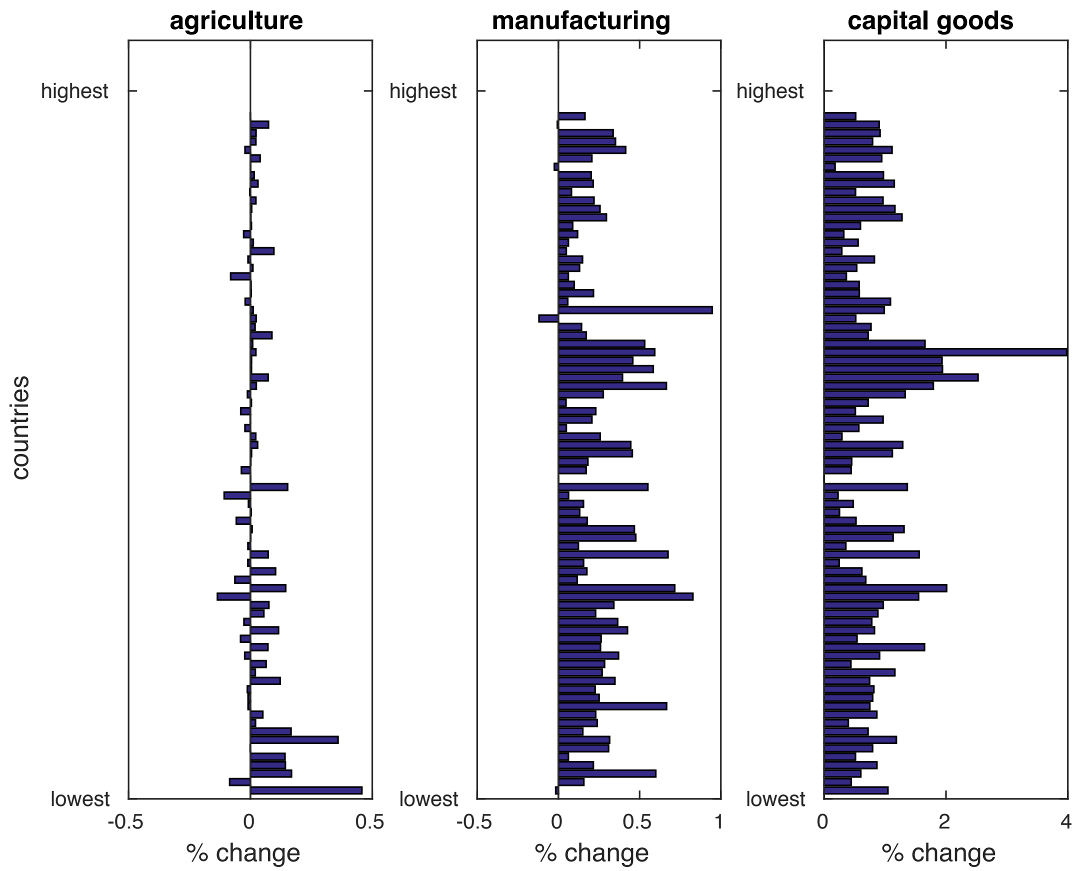
1.4 and are similar to those of Parro [2013]: Liberalizing manufacturing and capital goods leads to an overall increase in skill premium in most countries. The mechanism at work is the following: liberalization in a sector decreases the price of that sector, spurring higher demand for that sector's goods. As sectors are linked through intermediate goods, demand will increase in the other sectors as well, albeit in a smaller proportion. Consequently, there will be a positive demand shift for both labor types in all sectors. More so, as capital is complementary with skilled labor, increased demand for capital further raises the demand for skilled labor. As a result, the demand for skilled labor increase by more than that for unskilled one. This feedback loop is strongest in the case of capital goods liberalization as, obviously, demand for capital goods will be increase most in this case. As the supply of labor is fixed, the only effect liberalization has is through wages. For manufacturing and capital goods liberalization inequality increases in all countries regardless of their level of development.

In the case of lower trade costs in agriculture, inequality does not increase across the board and actually decreases in some countries, albeit with no clear pattern. There is no systematic link between changes in the skill premium and countries' status as a net exporter or importer. On the other hand, there is an obvious realtionship between how poor a country is and how large the increase in inequality is. This pattern is present only for agricultural liberalization, due to the direct use of foodstuff by households; Additionally imposing a minimum consumption threshold reinforces this effect[9].

The rest of this section explores what happens when the supply of skilled labor is free to vary in response to the new market conditions. I perform the same counterfactual exercises as above. Table 1.3 details some correlations between key variables by sector liberalization. The first two rows put a numerical value on, and confirm, the predictions of the simple model. The correlation between skill premium changes and net exports in liberalized sector is positive indicating that the skill premium increases with the size of net exports. Furthermore, the skill premium will tend to increase in net exporting countries and decrease in net importers. The sign correlation between these two variables are 72.91%, 36.66% and 35.08% for the

[9] A similar calibration exercise with $\bar{a} = 0$ confirms this is the case.

Figure 1.4: Relative changes in skill premium by liberalization type without labor adjustment



three liberalization exercises, respectively.

The correlation between absolute changes in skill premium and the initial share of skilled workers is negative, confirming the intuition that the skill premium increases most in countries with a low initial stock of skilled workers. The remaining rows detail the correlations between changes in wages and the initial welfare of countries and will be commented upon below, where relevant.

In assessing the impact of trade on cross-country inequality, the main variable of interest will be the average income per capita, $\bar{w}$. It should be noted that average incomes do not necessarily increase in all countries in all counterfactuals, although they do go up in most cases. However, as this is nominal income and prices decrease after liberalization, it says little about the gains or losses of workers.

Table 1.3: Correlation between key variables by type of liberalization

Correlation between		Sector liberalization: Agriculture	Manufacturing	Capital
Sector Net Exports	ΔSkill premium	24.12%	12.71%	21.75%
Initial s	|ΔSkill premium|	-41.62%	-31.51%	-25.15%
Intial GDP/L	$\Delta\bar{w}$	-22.84%	-17.17%	30.75%
	Δw^s	-25.81%	-16.11%	35.46%
	Δw^u	-27.90%	-12.78%	30.92%
	ΔSkill premium	-26.85%	-9.75%	27.58%
	ΔShare skilled	-13.42%	-12.56%	11.35%

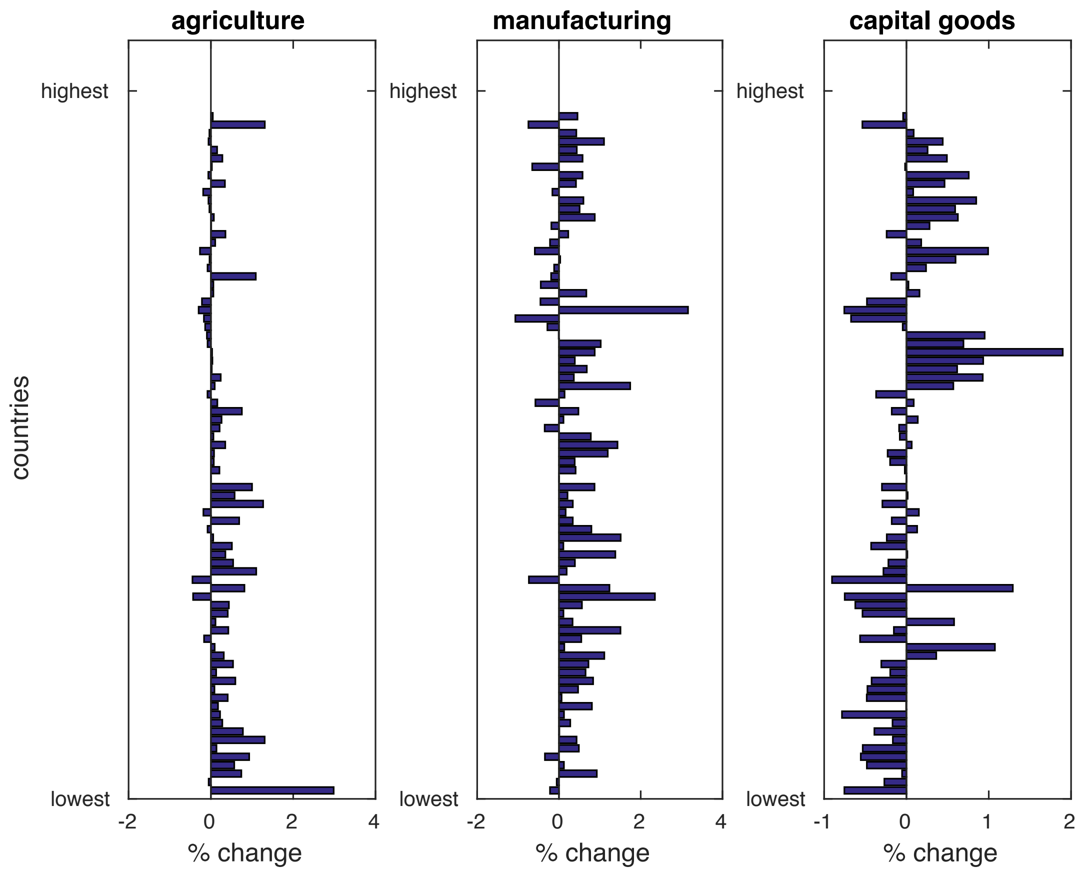
I plot the changes between countries' average wage before and after liberalization in Figure 1.5. I find that liberalizing agriculture slightly decreases across country inequality while lowering trade costs in capital goods slightly increases it and freer trade in manufacturing has mixed results. The correlation between the change in average wage and current GDP per capita is negative for agriculture and manufacturing, contributing to convergence, whereas upon liberalizing capital goods, income is positively correlated with the size of changes. Despite the strong visual impact of Figure 1.5, the change is quite small, of 1% on average.

Table 1.4: Inequality across countries by type of liberalization

	$var[log(\bar{w}_i)]$	$\bar{w}_i^{10rich}/\bar{w}_i^{10poor}$
Benchmark	2.134	68.306
Agriculture	2.128	68.023
Manufacturing	2.132	68.294
Capital	2.141	68.742

To analytically assess the changes in across country inequality, I follow Waugh [2010] and compute the variance of log income and the ratio of average income in the top 10 countries to the average income of the bottom 10 countries. The results are summarized in Table 1.4. While both lower trade costs in agriculture and manufacturing decrease the variance of log income, manufacturing increases the gap in income per capital between the richest and poorest 10 countries. Meanwhile freer trade in capital goods unambiguously increases across

Figure 1.5: Changes in the average wage



country inequality by all measures. As expected from the small change in average wage, the variance of log income is very small. These results contradict those of Waugh [2010] who finds that liberalizing trade would reduce 25 % - 50% of cross-country inequality. In this regard, my results are much more in line with Egger et al. [2012], who repeat Waugh's exercise using a different calibration and find less drastic results.

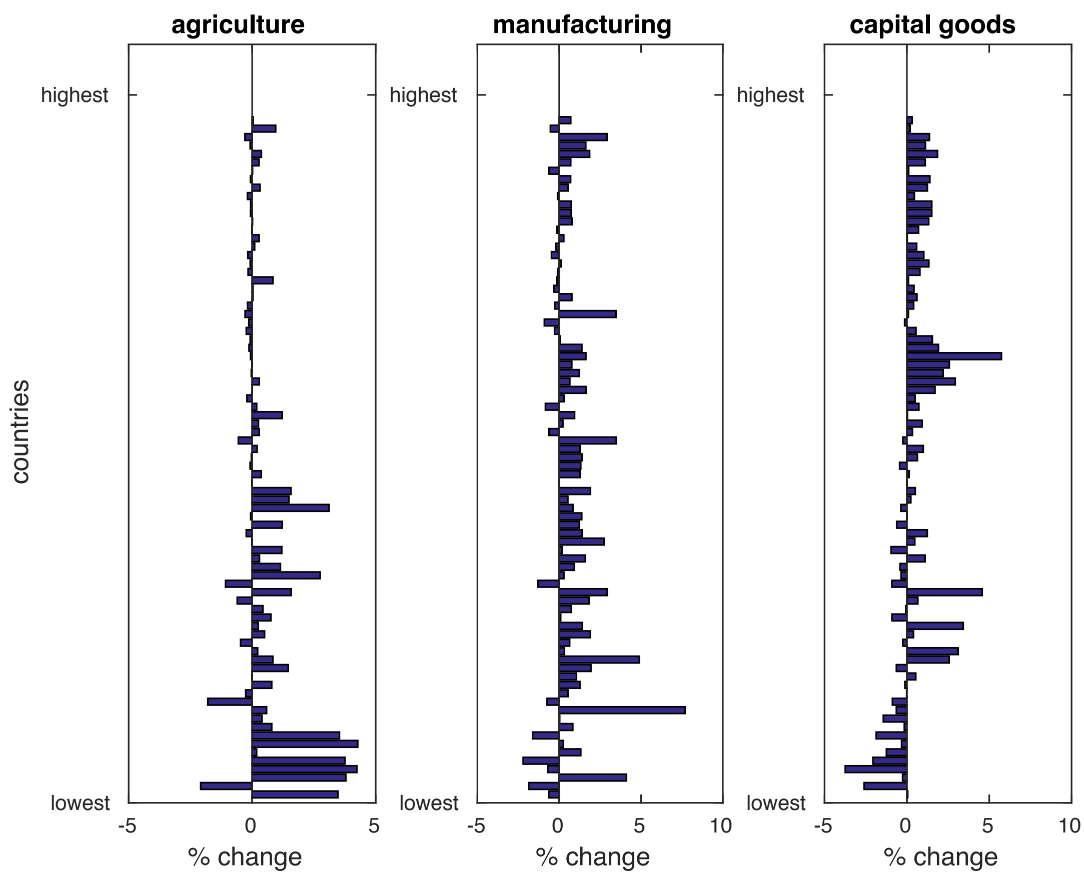
What happens within countries? The answer to this question is not straightforward and depends on country specific parameters and the sector being liberalized. The changes in skill premium for the three counterfactuals can be found in Figure 1.6. The first thing to note is that the scale of the response to liberalization is much larger than in the no supply adjustment case of Figure 1.4, bringing the model much more in line with the empirical evidence[10]. The

[10] Goldberg and Pavcnik [2007] document relative increases in the skill premium of double digits for several countries in the span of just a few years

second striking feature is how much changes in inequality vary across counterfactuals.

Let us consider the case of manufacturing liberalization first, as it is the most straightforward: Manufacturing is a key intermediate in all sectors so lowering trade costs decreases the input bundle cost for al sectors. The initial drop in manufacturing costs will have no impact on the shares paid to workers. However, lower input prices and increased demand will boost the demand for skilled labor as it is complementary with the now cheaper capital goods and decrease demand for unskilled workers which are substitutable.

Figure 1.6: Relative changes in skill premium by liberalization type with labor adjustment



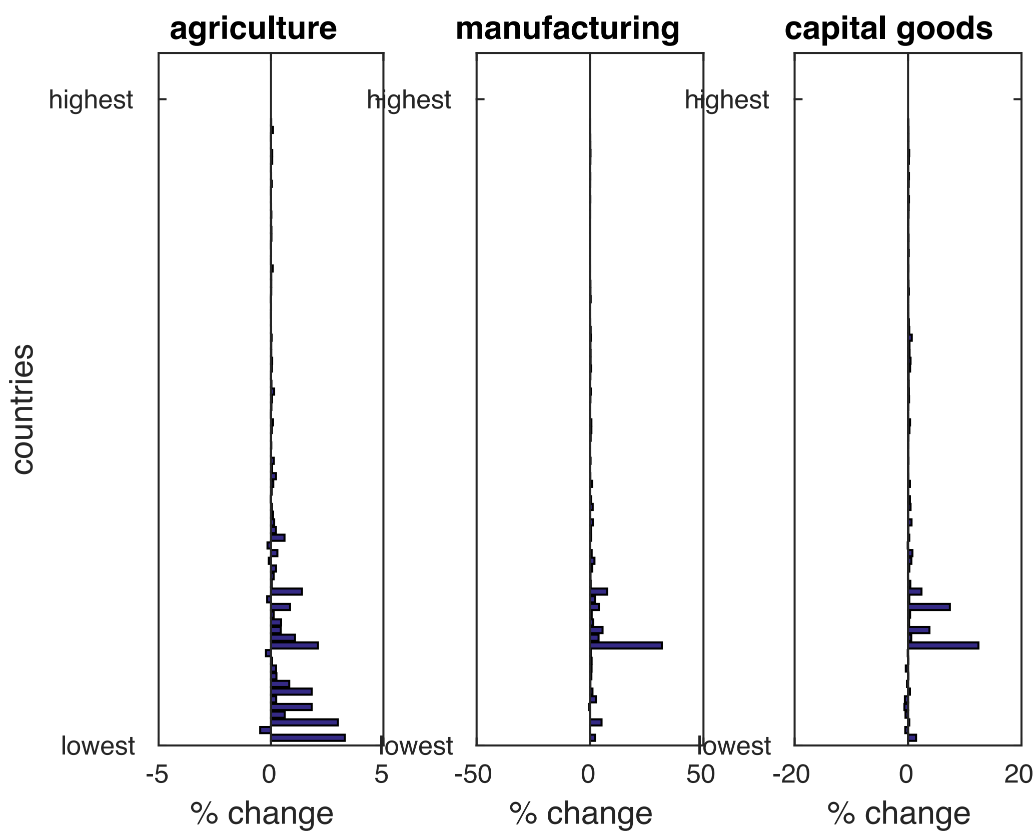
On the household side, all consumers, both skilled and unskilled, benefit from lower prices in consumption goods. As utility is concave in income, unskilled workers will benefit relatively more from this. The marginal worker, who is indifferent between acquiring education or remaining unskilled, will now earn extra utility by choosing not to acquire education, leading to a drop in the ratio of skilled to unskilled workers, despite the increased demand for skilled workers and increased returns to education; the income effect dominates the substitution effect.

In the case of agricultural liberalization a different process is present. Developing countries have a comparative advantage in foodstuff so they are net exporters of agricultural goods, a position deepened by symmetric bilateral liberalization. Following the intuition of the simple model in Section 5, net agriculture exporters should see their skill premium rise. This is confirmed by column A of Figure 1.6. As agricultural goods are predominantly used directly by households or as intermediates in agriculture, the impact of agriculture liberalization on prices in other sectors is limited. While lower trade costs should lead to cheaper foodstuff and increase welfare for poor workers, paradoxically the opposite happens. Increased global demand for the agricultural goods of developing countries pushes up their prices. As the outside option is fixed, more expensive foodstuff lowers the utility marginal worker's utility who can no longer afford to pursue education. This increases the supply of unskilled workers, lowering their wage. The opposite happens for skilled workers. While it would be more advantageous for workers to become skilled, they are simply priced out of the market.

When capital goods are liberalized, on the other hand, the price of capital drops, its demand increases and, due to complementarity, so does the demand for skilled labor, pushing up its wage. In developed countries capital is more widely produced and used and a lower price benefits both worker categories. Poor countries, as primary capital importers, see a drop in prices across the board. This increases utility for both worker categories but, at the same time, makes it cheaper to acquire an education, leading more workers to become skilled. As more people become skilled, the increased supply pushes down its wage, and decrease the Domestic Effect in equation (1.21). As s is initially very small, even tiny changes in the share of skilled workers have disproportionate effects. In this case the substitution effect dominates. This pattern is also consistent with the prediction of Section 5, that inequality will decrease in net importing countries.

So far the discussion has been in terms of nominal wages only, with little attention given to the actual welfare of workers. As skilled and unskilled workers consume different bundles of goods and post-liberalization price, wages and good quantities change, devising a price index is not straightforward. Rather, I can directly compare the utility of skilled and unskilled workers before and after liberalization.

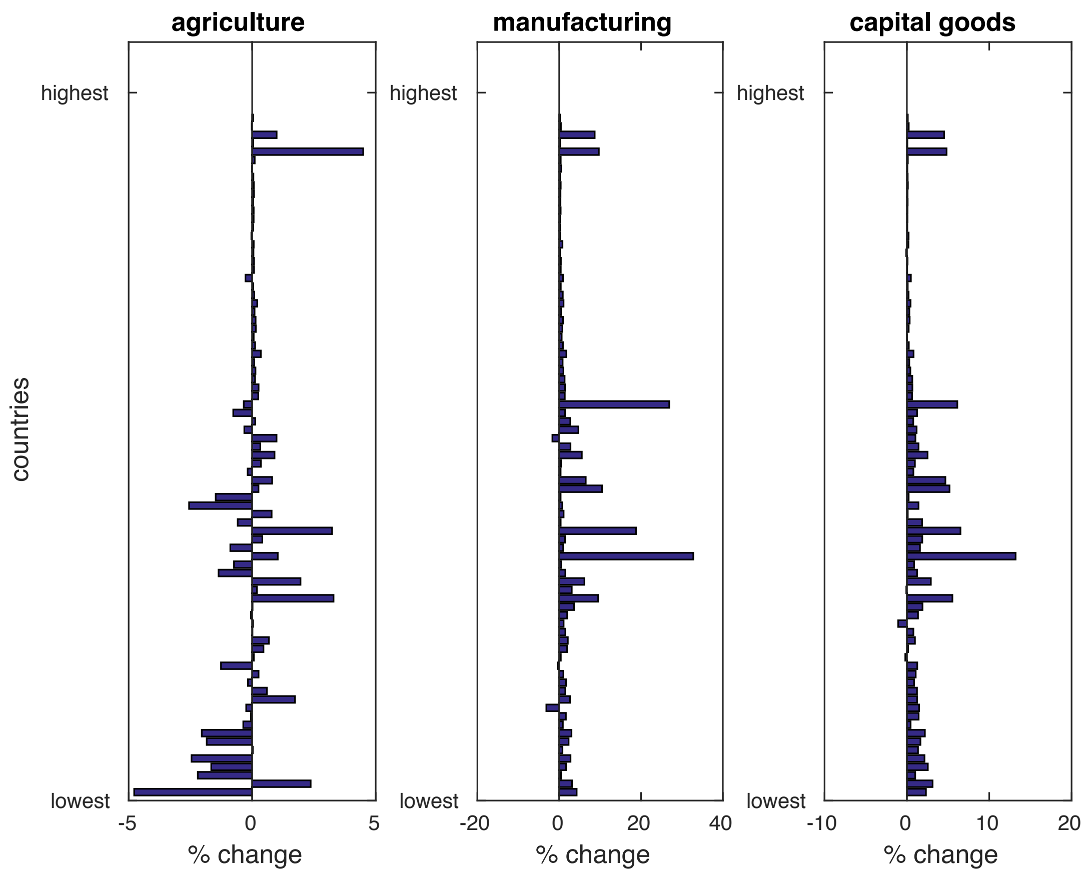
Figure 1.7: Changes in the utility of skilled workers



The utility of skilled workers increases across the board as can be seen in Figure 1.7, with a handful of exception. While it is hard to notice in the figure due to a few outliers where utility increased by double digits, the average increase in utility is 0.17%, 1.03% and 0.40% for the three liberalization types, respectively. There is a strong negative correlation between the increase in utility and the initial shares of skilled workers.

For unskilled workers, the picture is not so rosy. Liberalizing manufacturing and capital goods increase unskilled workers' utility in almost all countries, on average by 2.63% and 1.35%, respectively. The explanation is straightforward as liberalizing these intermediate goods lowers the prices in all sectors, allowing households to consume more. Liberalizing agriculture ends up hurting unskilled workers in the poorest countries though, by raising both prices and the supply of unskilled workers. Faced with both lower wages and higher prices, the poorest households are doubly affected.

Figure 1.8: Changes in the utility of unskilled workers



So how does my model fare at explaining the patterns in the data? First of all, by allowing for endogenous adjustments of the labor supply, I capture additional and important feature of the data: the pricing out of the poorest countries as documented in Mamoon and Murshed [2013] and the skill upgrading in countries liberalizing industry, as documented in Oostendorp and Doan [2013], for instance, who argue that after Vietnam's liberalization, over 10 years, the shares of workers with primary or less education has fallen by between 16 and 5%, depending on the sector.

Second, my results, while not delivering sharp predictions, sit comfortably in the literature: Galor and Tsiddon [1996] examine the link between the levels of human capital and inequality and find that the inequality pattern is driven by the initial distribution of human capital and Chamarbagwala [2006] also finds that initial factors play a pivotal role in determining the skill premium. Although more nuanced, my results are broadly consistent with Nigai [2012], who, looking at inequality in a Ricardian framework, also finds that liberalization hurts the poorest households.

Third, and most importantly, my approach allows for drops in inequality in a manner consistent with patterns observed in the data. That is, whether inequality increases or decreases depends on how much of the gains from trade are passed on to the unskilled workers. The different effects of liberalizing one sector or another potentially explains the different outcomes of trade liberalization across countries. Recent liberalization episodes were mainly concerned with opening up protected manufacturing or foods sectors. For instance, textiles, food and rubber were the most protected sectors in Brazil before liberalization [Pavcnik et al., 2004] and textiles manufacturing was a key component in Argentina's liberalization episode [Beker, 2012]. Meanwhile, when Asian economies liberalized in the 60s, lowering tariffs in capital goods was among their chief concerns; for instance, since the early 60s Thailand lowered tariffs on capital goods and increased them on consumer goods (Naya and Takayama [1990] page 113).

1.7 Conclusions

In this paper I investigated the impact of trade liberalization on income inequality. In doing so, I employed a multi-country, multi-sector Ricardian model with two types of labor, skilled and unskilled. The novel feature of my model is that it allows for endogenous skill selection and labor supply. Workers face heterogeneous education opportunity costs and the shares of skilled and unskilled workers are determined in equilibrium based on the relative utilities they can obtain.

I calibrate the model to the year 2005 and a wide range of developed and developing countries. I then perform various counterfactual and look at inequality both across countries and within them. My model is able to replicate several features of the data: it matches both the growing gap in average income between the richest and poorest countries. Within countries, if workers cannot acquire education, as may be the case in developing countries, the skill premium increases. If workers can respond to the new economic conditions and the shares of skilled and unskilled labor can adjust, inequality may increase or decrease and the distribution of welfare gains varies depending on which sector is liberalized and on how much do unskilled workers benefit. However, it should be kept in mind that the assumption of labor being free to adjust is rather strong and may be violated in practice, especially in poor countries where the opportunity cost of education is very high. Trade liberalization should therefore go hand in hand with encouraging school enrolment and other forms of training. This would promote long term growth and counterbalace workers' temptation to forgo education in exchange for immediate gains.

Bibliography

Alvarez, F. and Lucas, R. E. (2007). General equilibrium analysis of the Eaton–Kortum model of international trade. *Journal of Monetary Economics*, 54(6):1726–1768.

Amiti, M. and Konings, J. (2007). Trade liberalization, intermediate inputs, and productivity: Evidence from indonesia. *The American Economic Review*, pages 1611–1638.

Atkin, D. G. (2012). Endogenous skill acquisition and export manufacturing in mexico. Technical report, National Bureau of Economic Research.

Barro, R. J. (1991). Economic growth in a cross section of countries. *The quarterly journal of economics*, 106(2):407–443.

Barro, R. J. and Lee, J.-W. (2001). International data on educational attainment: Updates and implications. *Oxford Economic Papers*, 53(3):541.

Behrman, J., Birdsall, N., and Szekely, M. (2003). Economic policy and wage differentials in latin america.

Beker, V. A. (2012). A case study on trade liberalization: Argentina in the 1990s. Economics Discussion Paper 2012-3, Kiel Institute for the World Economy.

Ben-David, D. (1996). Trade and convergence among countries. *Journal of international Economics*, 40(3):279–298.

Ben-David, D. (1998). Convergence clubs and subsistence economies. *Journal of Development Economics*, 55(1):155–171.

Ben-David, D. and Loewy, M. B. (1998). Free trade, growth, and convergence. *Journal of economic growth*, 3(2):143–170.

Berman, E., Bound, J., and Griliches, Z. (1994). Changes in the demand for skilled labor within US manufacturing: Evidence from the annual survey of manufactures. *The Quarterly Journal of Economics*, 109(2):367–397.

Burstein, A. and Vogel, J. (2012). Globalization, technology, and the skill premium: A quantitative analysis. Technical Report 16459, National Bureau of Economic Research.

Carluccio, J., Cuñat, A., Fadinger, H., and Fons-Rosen, C. (2015). Offshoring and skill-upgrading in french manufacturing: A heckscher-ohlin-melitz view.

Chamarbagwala, R. (2006). Economic liberalization and wage inequality in india. *World Development*, 34(12):1997—-2015.

Davidson, C., Martin, L., and Matusz, S. (1999). Trade and search generated unemployment. *Journal of International Economics*, 48(2):271–299.

Deardorff, A. V. (2000). Policy implications of the trade and wages debate. *Review of International Economics*, 8(3):478–496.

Easterly, W. and Levine, R. (2000). Its not factor accumulation: Stylized facts and growth models.world bank. *Development Research Group, Washington, DC Processed*.

Eaton, J. and Kortum, S. (2002). Technology, geography, and trade. *Econometrica*, 70(5):1741–1779.

Ebenstein, A., Harrison, A., McMillan, M., and Phillips, S. (2014). Estimating the impact of trade and offshoring on american workers using the current population surveys. *Review of Economics and Statistics*, 96(4):581–595.

Egger, P., GEP, W., and Nigai, S. (2012). Asymmetric trade costs, trade imbalances, and the world income distribution.

Federman, M. and Levine, D. I. (2004). The effects of industrialization on education and youth labor in indonesia. *Berkeley Electronic Press*, 5(1):1243–1251.

Feenstra, R. C. and Hanson, G. H. (1995). Foreign investment, outsourcing and relative wages. Technical report, National bureau of economic research.

Feenstra, R. C. and Hanson, G. H. (1997). Foreign direct investment and relative wages: Evidence from mexico's maquiladoras. *Journal of international economics*, 42(3):371–393.

Fieler, A. C. (2011). Nonhomotheticity and bilateral trade: evidence and a quantitative explanation. *Econometrica*, 79(4):1069–1101.

Findlay, R. and Kierzkowski, H. (1983). International trade and human capital: A simple general equilibrium model. *The Journal of Political Economy*, pages 957–978.

Frankel, J. A. and Romer, D. (1999). Does trade cause growth? *American economic review*, pages 379–399.

Galor, O. and Tsiddon, D. (1996). Income distribution and growth: the kuznets hypothesis revisited. *Economica*, pages S103–S117.

Goldberg, P. K. and Pavcnik, N. (2007). Distributional effects of globalization in developing countries. Technical report, National bureau of economic research.

Goldin, C. and Katz, L. F. (1997). Why the united states led in education: Lessons from secondary school expansion, 1910 to 1940. Technical report, National Bureau of Economic Research.

Grossman, G. M. and Rossi-Hansberg, E. (2008). Trading tasks: A simple theory of offshoring. *The American Economic Review*, 98(5):1978–1997.

Kijima, Y. (2006). Why did wage inequality increase? evidence from urban india 1983–99. *Journal of Development Economics*, 81(1):97–117.

Kreickemeier, U. (2009). Trade, technology, and unemployment: the role of endogenous skill formation. *Canadian Journal of Economics/Revue canadienne d'économique*, 42(2):639–664.

Larch, M. and Lechthaler, W. (2009). Comparative advantage and skill-specific unemployment. *The BE Journal of Economic Analysis & Policy*, 11(1).

Lawrence, R. Z., Slaughter, M. J., Hall, R. E., Davis, S. J., and Topel, R. H. (1993). International trade and american wages in the 1980s: giant sucking sound or small hiccup? *Brookings papers on economic activity. Microeconomics*, 1993(2):161–226.

Mamoon, D. and Murshed, S. M. (2008). Unequal skill premiums and trade liberalization: Is education the missing link? *Economics Letters*, 100(2):262–266.

Mamoon, D. and Murshed, S. M. (2013). Education bias of trade liberalization and wage inequality in developing countries. *The Journal of International Trade & Economic Development*, 22(4):572–604.

Mankiw, N. G., Romer, D., and Weil, D. N. (1992). A contribution to the empirics of economic growth. *The quarterly journal of economics*, 107(2):407–437.

Markusen, J. R. (2010). Putting per–capita income back into trade theory. Technical report, National Bureau of Economic Research.

Mitra, D. and Ranjan, P. (2010). Offshoring and unemployment: The role of search frictions labor mobility. *Journal of International Economics*, 81(2):219–229.

Munshi, K. and Rosenzweig, M. (2003). Traditional institutions meet the modern world: Caste, gender and schooling choice in a globalizing economy.

Naya, S. and Takayama, A. (1990). *Economic Development in East and Southeast Asia: Essays in Honor of Professor Shinichi Ichimura*.

Neary, J. P. (2002a). Competition, trade and wages. In *Trade, investment, migration and labour market adjustment*, pages 28–46. Springer.

Neary, J. P. (2002b). Foreign competition and wage inequality. *Review of International Economics*, 10(4):680–693.

Nigai, S. (2012). On measuring the welfare gains from trade under consumer heterogeneity.

Oostendorp, R. H. and Doan, Q. H. (2013). Have the returns to education really increased in vietnam? wage versus employment effect. *Journal of Comparative Economics*, 41(3):923–938.

Papageorgiou, D., Choksi, A. M., Michaely, M., and mondiale, B. (1990). *Liberalizing foreign trade in developing countries: the lessons of experience*, volume 39. World Bank Washington.

Parro, F. (2013). Capital-skill complementarity and the skill premium in a quantitative model of trade. *American Economic Journal: Macroeconomics*.

Pavcnik, N., Blom, A., Goldberg, P., and Schady, N. (2004). Trade liberalization and industry wage structure: Evidence from brazil. *The World Bank Economic Review*, 18(3):319–344.

Quah, D. T. (1996). Twin peaks: growth and convergence in models of distribution dynamics. *The Economic Journal*, pages 1045–1055.

Ripoll, M. (2005). Trade liberalization and the skill premium in developing economies. *Journal of Monetary Economics*, 52(3):601–619.

Rousslang, D. J. and To, T. (1993). Domestic trade and transportation costs as barriers to international trade. *Canadian Journal of Economics*, pages 208–221.

Sachs, J. D., Warner, A., Åslund, A., and Fischer, S. (1995). Economic reform and the process of global integration. *Brookings papers on economic activity*, 1995(1):1–118.

Shastry, G. K. (2012). Human capital response to globalization education and information technology in india. *Journal of Human Resources*, 47(2):287–330.

Simonovska, I. (2010). Income differences and prices of tradables. Technical Report w16233, National Bureau of Economic Research.

Tinbergen, J. (1975). *Income distribution: Analysis and policies.*

Waugh, M. (2010). International trade and income differences. *The American Economic Review*, 100(5):2093–2124.

Wood, A. (1997). Openness and wage inequality in developing countries: the latin american challenge to east asian conventional wisdom. *The World Bank Economic Review*, 11(1):33–57.

Xu, K. (2012). Gains from trade and the food problem. *Available at SSRN 2020898*.

10.14754/CEU.2016.08

Chapter 2

The European Union and the Gains from Trade

2.1 Introduction

Outside the fall of communism, the formation and enlargement of the European Union (EU) has been the most significant political and economic event on the European landscape in recent memory. Over its almost seventy year life, the EU, in various forms, has gone from a loose free trade area to a political union with a common market and a common currency adopted by most of its members. However, recent turmoil in Europe has cast a shadow of doubt on the value of the project and critics have even called for halting integration and the abolishment of the Euro.

This papers looks into those claims and attempts to measure the gains countries reaped from joining the EU and how large the costs of a Euro exit would be. It is hard to deny that current EU members are better off, both politically and economically, than before accession, or that the promise of forthcoming membership has acted as a factor in favor of democracy and market reforms, for example in Spain, Portugal and Greece in the 80s or in former Communist countries in the 90s and 2000s. But how much of the change in well-being, stability and economic growth can be attributed to EU membership itself and how much of the positive changeswould have happened on its own as has been the case in other places around the world or even in non-EU European countries?

Rather than fully tackle this complicated, and probably impossible to definitively answer topic, this paper is more modest in scope and looks at the gains from trade only. While trade is just a facet of the EU structure, it is a central one and the free circulation of goods and services is one of EU's fundamental principles. I evaluate the gains from trade in two scenarios: First I look at the 2004 enlargement wave when the European Union, then 15 members strong, gained an additional 10 members, mostly from Central and Eastern Europe (CEE); in my second scenario, I consider what would have been the consequences of Greece exiting the Euro area in 2009.

In order to estimate the welfare gains and losses, I adopt and adapt the model developed by Caliendo and Parro [2012]. The model is a many sector version of the basic multi-country Ricardian model of Eaton and Kortum [2002]. The key feature of the model is that it allows for linkages across sectors within a country: the output of one sector can be used as an input in other sectors. The inclusion of sector interdependences amplifies the gains from trade liberalization by multiplying the channels through which gains are realized: a fall in the price of goods in sector j has an own sector effect but also an effect on prices in other sectors. in both counterfactuals the model's key parameters are recovered from the data in a manner consistent with the theoretical model.

As trade barriers fall, it becomes feasible to purchase goods that, until then, had been unaffordable due to high trade costs. This increased competitive pressure will make some importers switch suppliers, choosing the cheapest ones available under the new market conditions. More importantly, falling trade costs between countries i and n will make it profitable for some firms to source their intermediate goods from abroad instead of relying on more expensive domestic suppliers. In the case of a Greek exit, the opposite mechanism would be in play as trade cost go up.

Let us consider the 2004 EU enlargement wave. Following the fall of communism, throughout the 1990s, CEE countries took steps towards integration with their Western Europe counterparts. They started joining international institutions such as the World Trade Organisation and by the mid-1990s, many CEE countries had implemented bilateral trade agreements with the EU [Roaf et al., 2014]. By 1997, tariffs on EU exports to CEE had been abolished and, by 2002, tariffs on CEE exports to Western EU were also abolished. In addition, in preparation for EU membership, CEE countries adopted the Community acquis so that by the early 2000s, virtually all traditional trade barriers (quantitative restrictions, rules of origin, tariffs) between the EU and CEE countries and between CEE countries themselves had been abolished.

By the time they joined the EU, in mid 2004, the effects of these previous liberalization measures was winding down. Bussière et al. [2005], investigating the extent of trade integration between CEE countries and the Euro area, found that the share of trade with Western Europe in total trade had more or less stabilized and concludes that "trade integration between most of the largest CEECs and the Euro area is already relatively well advanced" and that, by 2003, trade flows were close to their 'potential' level.

Consequently, the main trade effect of EU enlargement was a fall in trade costs due to the abolitions of border controls on international shipments. While it may not seem like a big shift, the effects on trade volumes were considerable. Looking at the evolution of trade costs before and after accession, Hornok [2009] argues that the decrease in trade costs accelerated after 2004, especially for trade between new and old members and for some industries there is very clear break in trend around 2004.

I estimate trade costs before and after enlargement, in 2003 and 2006, respectively, based on the method in Chen and Novy [2009]. The estimates I get are consistent in magnitude with *ex-ante* prediction [Breuss, 2001] and other *ex-post* investigation in the literature [Hornok, 2009]. Once I know trade costs, I isolate the EU membership component and reduce 2003 trade costs by that amount. Then, holding everything else fixed to pre-enlargement data, I solve for the changes in the general equilibrium that would have occurred had the change in trade costs been the only one that had happened.

Looking at welfare changes, the results are broadly in line with expectations and previous findings in the literature (Klenow and Rodriguez-Clare [1997], Arkolakis et al. [2008], Waugh [2010], Blalock and Gertler [2008], Mohler [2009], for instance): new entrants gained more than incumbents several times over. There appears to be no significant link between country size and the magnitude of welfare gains although geographic proximity to the new entrants plays a part. For incumbents the gains are very small, often negligible, but for new members they are significant, going as high as 6%. Allowing sectors to be linked increases the gains from trade several times for all countries involved. My results are larger than previous estimates (Klenow and Rodriguez-Clare [1997], Arkolakis et al. [2008]) as these papers do not take the extra mechanisms into account.

In my second counterfactual, I ask what would have happened had Greece exited the Euro at the onset of its sovereign debt crisis. Using 2009 data, I estimate trade costs and then isolate the Eurozone membership component. I then shut it down for Greece, force it to balance its trade account and look at various currency depreciation scenarios. Overall, a Greek exit coupled with a balanced trade restriction would cause a 3.65% drop in Greek GDP and minor losses for other EU countries as their trade costs would increase as well, but Greece is only a minor trading partner for most of them. Depreciating the currency would entail additional welfare losses for Greece as imports become more expensive, up to 4.42%. In another set of counterfactuals, I assume Greece is forced to run a trade surplus in order to pay down its accumulated debt. Without currency depreciation, I find that welfare decreases by about 0.3% for each 5% of trade surplus. However, running a surplus is easier when coupled with depreciation: welfare decreases by only 0.2% for each 5% of trade surplus. In the case of 75% depreciation and 10% trade surplus, Greek welfare decreases by almost 5%.

I further ask what would be the average productivity boost needed for Greece to overcome the welfare losses from exiting the Euro. I find that a 2% raise in productivity across all sectors would suffice to offset the losses from trade. To put the size of this productivity change in perspective, the US economy total factor productivity grew by about 1.5% per year in the 2000s and by less than 1% in the 70s and 80s [Shackleton, 2013]. Whether Greece can achieve this growth and in what time is beyond the scope of this paper. While the GDP drop seems small compared to 25%+ loss Greece has actual experienced, it should be kept in mind that these are losses from higher trade costs alone and do not factor in the actual cost of default on the Greek economy nor other costs due to unemployment, inflation or social unrest due the government's impossibility to meet its obligations.

In Ricardian models, obtaining correct estimates for the distribution of technology across countries is of paramount importance. While Caliendo and Parro [2012] propose a method which is appealing due to its generality, it does not guarantee that the resulting estimates will respect the model's restrictions. In this paper I also makes a small methodological contribution to the literature by developing an estimation method that results in values consistent with the theoretical restrictions of the model.

The rest of the paper is organized as follows: Section 2 derives the theoretical model, Section 3 describes the data used and presents the identification and calibration strategies necessary to solve the model, Section 4 investigates the 2004 EU enlargement wave, Section 5 ponders the consequences of a Greek Euro exit and section 6 concludes.

2.2 Theoretical Model

The central feature of Ricardian models, going back to Ricardo's book in the early 19th century [1817], is that comparative advantage is the main determinant of trade patterns.

Building on this intuition, Eaton and Kortum [2002] develop a model that features multiple countries, trade in intermediaries and realistic geographic features. The framework's tractability and flexibility has spurred a significant literature: Burstein and Vogel [2012], Parro [2013], Donaldson [2010] or Costinot et al. [2012], to name just a few recent examples. In this paper, I use the multi-sector extension developed by Caliendo and Parro [2012] that I modify slightly: I assume that the sector specific labor share of output is common to all countries and that the distribution of productivities is common across sectors. While these changes make for a less rich model structure, they allow me to recover the dispersion of productivities in a manner consistent with the underlying theoretical model[1]. These changes should not affect the model's results much as I discuss the assumptions below. I also change the model not to include tariffs as they are not relevant to the case I am studying.

Let the world consist of N countries and, within each country, there are J sectors, all of which are traded[2]. In each sector, output is produced using a combination of labor

[1] Caliendo and Parro [2012]'s estimation strategy does not necessarily yield parameters consistent with their theoretical model and some of their numerical values are impossible given the model's assumptions.

[2] While traditionally services are considered non-traded, trade in services has been growing rapidly in recent decades at average rates of 10% a year. Not including them would be a needless restriction, especially given that I have data on it.

and intermediary goods, which may be sourced from any and all sectors. Labor is imobile across countries[3] but mobile across sectors within the country, equalizing the wage in various sectors. Trade is unbalanced at the sector level and also at the country level. Let S_n be the net trade surplus of country n.

In each sector there is a continuum of differentiated goods, ω^j. Production is constant returns to scale and markets are perfectly competitive. Any country can theoretically produce any good but they would do so with a different level of efficiency. Let $x_i^j(\omega^j)$ denote the efficiency of producing good ω^j in sector j in country i. All countries use the same production function, but some parameters may vary across countries:

$$y_i^j\left(\omega^j\right) = x_i^j\left(\omega^j\right)^{-\frac{1}{\theta}}\left(l_i\left(\omega^j\right)\right)^{\beta^j}\left(\prod_{k=1}^{J}\left(m_i^k\left(\omega^j\right)\right)^{\gamma_i^{k,j}}\right)^{1-\beta^j} \tag{2.1}$$

where subscripts denote country and superscripts indicate sectors, l_i is labor, m_i^k is intermediary goods from sector k, β^j is the share of labor in sector j, $\gamma_i^{k,j}$ with $\sum_k^J \gamma_i^{k,j} = 1$, is the share of intermediates from sector k used in the production of goods in sector j and θ is a parameter governing the dispersion of productivity, common across countries. Specifically, θ is a measure of the comparative advantage distribution and plays a crucial part in quantitatively determining the gains from trade. If θ is small, indicating dispersed productivities, then a change in trade costs will not cause a large shift in the patters of trade, as the comparative advantage some countries have will be stronger than the trade liberalization effect. If, on the other had, productivity is concentrated, then even small changes in the structure of trade costs can significantly alter the patters of trade. This is obvious from (2.1): By taking $\theta \to \infty$, the productivity term reaches 1, negating any comparative advantage due to technology. In this case, trade costs changes will spur larger shifts in the patterns of trade.

In each sector I assume a probabilistic representation of technology. That is, for each good ω^j, the productivity with which country i can produce it is drawn from an exponential distribution with parameter $z_i^{j\,-\theta}$. Distributions are assumed to be independent across

[3]This is an assumption with minor practical consequences: The European Commission estimates that between 2004 and 2009 only 1.6 million people migrated from new to old member states, which accounts for less than 1 % of the working-age population of the destination states.

countries and sectors. Using the law of large numbers this implies that $F_i^j(\mathbf{x})$ is also the fraction of goods for which the efficiency of country i in sector j is below $\mathbf{x}$.

As markets are perfectly competitive, firms make no profits and they minimize the cost of their input bundle

$$\min w_i l_i\left(\omega^j\right) + \sum_{k=1}^{J} p_i^k m_i^k\left(\omega^j\right)$$

subject to the production function (2.1), where w_i is the wage rate and p_i^k is the price of intermediate goods aggregate in sector k, to be defined shortly. Let c_i^j denote the cost of inputs that solves the above optimization problem. As the production function is an extended Cobb-Douglass, it can be easily shown that the cost of the input bundle is

$$c_i^j = \Upsilon_i^j w_i^{\beta^j}\left[\prod_{k=1}^{J}\left(p_i^k\right)^{\gamma_i^{k,j}}\right]^{1-\beta^j} \tag{2.2}$$

where Υ_i^j is a constant function of parameters[4]. International shipments between countries i and n are subject to iceberg transport cost $\tau_{in}^j = 1 + d_{in}^j$, which are allowed to be sector specific. These imply that in order for a quantity of 1 good j to arrive in country n from country i, a shipment of τ_{in}^j must be sent. Therefore, the price in country n of a good from sector j produced in country i is:

$$p_{ni}^j(\omega^j) = \frac{c_i^j \tau_{ni}^j}{x_i^j(\omega^j)^{1/\theta}} \tag{2.3}$$

On the consumer side, I assume a representative household that consumes goods from all sectors with a Cobb-Douglass utility. Formally, households in country n maximize the following two-tier utility function:

$$U\left(C_n\right) = \prod_{j=1}^{J}\left[C_n^j = \left[\int_0^1 u\left(\omega^j\right)^{(\sigma_j-1)/\sigma_j} du\right]^{(\sigma_j-1)/\sigma_j}\right]^{\alpha_n^j}$$

subject to the budget constraint

[4]Specifically,

$$\Upsilon_i^j = \left(\beta^j\right)^{-\beta^j}\left(1-\beta^j\right)^{-(1-\beta^j)}\prod_{k=1}^{J}\left(\gamma_i^{k,j}\right)^{-\gamma_i^{k,j}(1-\beta^j)}$$

$$\sum_{j=1}^{J} p_n^j C_n^j = \frac{I_n}{L_n}$$

where α_n^j is the share of sector j in the consumption of country n, and I_n is total household income and L_n is the active population.

The intermediate aggregators in country n search across all sources for good ω^j and purchase only from the cheapest location, given trade costs. Therefore, $p_n^j\left(\omega^j\right)$, the price of good ω^j in country n, will be:

$$p_n^j\left(\omega^j\right) = \min\left\{\tau_{ni}^j p_{ni}^j\left(\omega^j\right), i = 1...N\right\} \tag{2.4}$$

Integrating over the set of goods that country n purchases, it can be shown that the price index of sector j in country n is given by

$$p_n^j = A^j \left[\sum_i \left[\frac{\tau_{ni}^j c_i^j}{z_i^j}\right]^{-\theta}\right]^{-\frac{1}{\theta}} \tag{2.5}$$

where A^j is a sector-specific constant. Let π_{ni}^j be the share of goods in sector j that country n imports from country i. The share will be equal to the proportion of goods in country i whose price is the lowest county n can find. It can be shown that:

$$\pi_{ni}^j = \frac{X_{ni}^j}{X_n^j} = \frac{\left(\frac{c_i^j \tau_{ni}^j}{z_i^j}\right)^{-\theta}}{\sum_{r=1}^{N}\left(\frac{c_r^j \tau_{nr}^j}{z_r^j}\right)^{-\theta}} \tag{2.6}$$

where X_{ni}^j is the expenditure of country n on sector j goods from country i and X_n^j denotes the total expenditure of country n on sector j.

The budget condition for each country implies that total expenditure across all sectors should equal total sales to all countries minus the trade surplus:

$$\sum_{j=1}^{J} X_n^j + S_n = \sum_{j=1}^{J}\sum_{i=1}^{N} \pi_{in}^j X_i^j \tag{2.7}$$

where the right hand side equation also represent total production in country n. Finally, expenditure in sector j is given by the sum of household expenditure and firm demand in that sector to be used as intermediary in the other sectors of the economy.

$$X_n^j = \sum_{k=1}^{J} \left[\gamma_n^{k,j} \left(1 - \beta^k\right) \sum_{i=1}^{N} \pi_{in}^k X_i^k \right] + \alpha_n^j I_n \tag{2.8}$$

Household expenditure on sector j is $\alpha_n^j I_n$, where $I_n = w_n L_n - S_n$. Appendix A2.3 shows this must be the case for the expenditure and budget conditions to hold. That is, in surplus countries workers receive extra money besides their wages while in deficit countries their income is shrunk. Given a set of trade costs and parameters, equations (2.2), (2.5) - (2.8), fully characterize the equilibrium at time t.

2.2.1 Solving for the General Equilibrium

Rather than separately solve the model in the benchmark case and the counterfactual equilibrium, I compute the changes between the two equilibria and deduce the changes in welfare from changes in key variables. Let us assume an exogenous change in trade costs $\hat{\tau} = \tau'/\tau$. Holding S_n constant between equilibria, the economy will move to a new equilibrium, given by $\boldsymbol{w'}$ and $\boldsymbol{p'}$. The approach employed here is based on Dekle et al. [2007] and the full derivations can be found in the technical appendix of Caliendo and Parro [2012]. The equations needed to asses welfare changes are

$$\widehat{p}_n^j = \left[\sum_i \pi_{ni}^j \left[\widehat{\tau}_{ni}^j \widehat{c}_i^j \right]^{-\theta} \right]^{-\frac{1}{\theta}} \tag{2.9}$$

$$\hat{c}_i^j = \hat{w}_i^{\beta^j} \left[\prod_k^K \left(\hat{p}_i^k\right)^{\gamma_i^{k,j}} \right]^{1-\beta^j} \tag{2.10}$$

$$\widehat{\pi}_{ni}^j = \left(\frac{\widehat{c}_n}{\hat{p}_n^j} \widehat{\tau}_{ni}^j \right)^{-\theta} \tag{2.11}$$

where hatted variables are defined as the ratio between the new values and the old ones. The budget and market clearing conditions must hold under the new equilibrium as well.

$$X'^j_n = \sum_{k=1}^{J} \left[\gamma_n^{k,j} \left(1 - \beta^k\right) \sum_{i=1}^{N} \pi'^k_{in} X'^k_i \right] + \alpha_n^j \left(\widehat{w_n} L_n - S_n\right) \tag{2.12}$$

$$\sum_{j=1}^{J} X'^{j}_{n} + S_n = \sum_{j=1}^{J} \sum_{i=1}^{N} \pi'^{j}_{in} X'^{j}_{i} \tag{2.13}$$

The above five equations will form the body of my counterfactual assessment. The algorithm to solve for the equilibrium changes is as follows: First I guess a vector of values for $\widehat{\mathbf{w}}$. Then, given this guess, from (2.9) and (2.10), I solve for the vectors of changes in prices and costs, which I plug in (2.11) and obtain the estimated change in bilateral trade shares. Once I recover $\widehat{\pi}^{j}_{in}(\widehat{\mathbf{w}})$, I compute trade shares under the new cost structure $\pi'^{j}_{in}(\widehat{\mathbf{w}})$. (2.12) forms a linear identified system in $\boldsymbol{J}$ **x** $\boldsymbol{N}$ unknown expenditures, that can be easily solved. Plugging the new expenditures in (2.13), I check whether the balanced budget condition holds. If it does not, I adjust the guess for $\widehat{\mathbf{w}}$ until it does.

Total welfare gains are defined as changes in real income, $\hat{W}_n = \hat{w}_n / \prod_{j=1}^{J} \hat{p}^{j\,\alpha^j_n}_{n}$. From equations (2.10) and (2.11), wage changes can be recovered as a function of changes in prices and domestic shares and total welfare changes can be decomposed as:

$$\ln \hat{W}_n = -\sum_{j=1}^{J} \frac{\alpha^j_n}{\theta} \ln \hat{\pi}_{jj} - \sum_{j=1}^{J} \frac{\alpha^j_n}{\theta} \frac{1-\beta^j}{\beta^j} \ln \hat{\pi}_{jj} - \sum_{j=1}^{J} \alpha^j_n \frac{1-\beta^j}{\beta^j} \left(\ln \hat{p}^j_n - \sum_{k=1}^{J} \gamma^{k,j}_n \ln \hat{p}^k_n \right) \tag{2.14}$$

The first term represents the gains derived from the consumption of final goods, the second term represents gains derived from the consumption of intermediary goods and the third term represents price index effects.

2.3 Bringing the Model to the Data

In calibrating the model the main data source I use is the World Input Output Database, for the years 2003, 2006 and 2009. The dataset provides sector level information on the source and destination of intermediate goods for all EU countries along with several others and aggregate rest of the world. The dataset provides information for 35 sectors corresponding to the 3rd revision of ISIC classification. In order to match the level of aggregation in other data sources used in this paper, I use a slightly more aggregate classification and I recode the industries into 26 NACE2 sectors, listed in Table A2.2.

For the first counterfactual, I use 2003 and 2006 data while for the second one I use 2009 data. My base sample is the EU25 countries except for Malta, Cyprus and Luxembourg[5], while for 2009 I also include Romania and Bulgaria as distinct countries. I aggregate the rest of the detailed countries in an 'extra' country, the rest of the world, henceforth ROW. The full list of countries for the two counterfactuals can be fount in Table A2.3.

The calibration strategy is the same for both counterfactuals, only the years used being different. The share of labor, β_i^j, in each country and sector is defined as value added divided by total output. As I assumed that this share is sector specific but common across countries, I compute β^j as the across countries average of data β_i^j. This assumption, while obviously not true, is not as restrictive as it may seem at first glance. Figure 2.1 plots the heatmap of the share of labor across countries and sectors, while Table 2.1 presents the results of the ANOVA analysis across sectors and countries. Across country variability is sufficiently low to warrant my assumption, as most of the systemic variation comes from the sector component.

Table 2.1: ANOVA results for sectoral labor share variation

Source	**Partial SS**	**df**	**MS**	**F**	**Prob > F**
Model	13.009	47	0.277	49.22	0
Sector	12.160	25	0.486	86.49	0
Country	0.849	22	0.039	6.86	0
Residual	3.093	550	0.006		
Total	16.102	597	0.027		
Number of obs = 598					R-squared = 0.808
Root MSE = .075					Adj R-squared = 0.792

The share of goods imported from country i to country n in sector j is defined as

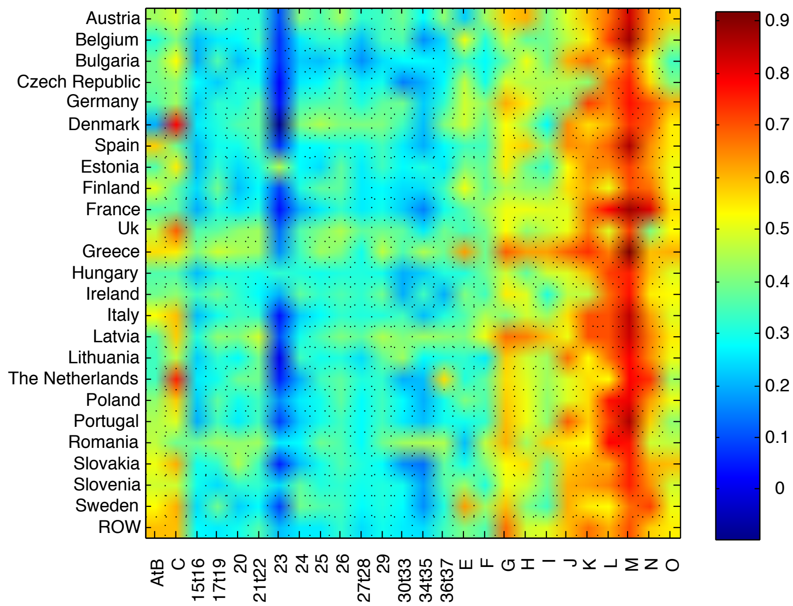
$$\pi_{ni}^j = \frac{Imports_{ni}^j}{Total\ Expenditure_n^j}$$

where *Total Expenditure* is the sum of *Imports* and *Output* minus *Exports*. These 3 fields can be easily recovered from the data. Given that there is no government in my model, I define household expenditure, I_n, as the sum of '*Final expenditure by households*' and '*Government expenditure*', assuming that government expenditures are actually indirect

[5]The countries were dropped as they had some particularities in their input output tables that made it difficult to use. As all three dropped countries are small, and in the case of Malta and Cyprus, the first counterfactual does not apply, their exclusion is not likely to affect the results.

household purchases that would eventually reach final consumers. The share of household expenditure on goods from sector j, α_n^j, is obtained by dividing that sector's household expenditure to total household expenditures in each country.

Figure 2.1: Labor shares across countries and sectors in 2009



Note: The sector codes correspond to the ones in Table A2.2; While this shows data for 2009, similar results are obtained for 2003 and 2006

Despite using a single source, the data will not map perfectly to the model equations for several reasons. In the IO tables, final consumption also includes '*Gross fixed capital formation*' and '*Changes in inventories and valuables*'. However, I cannot include them as, oftentimes, they are negative and large and would result in negative values for α^j. Secondly, in some sectors the value of output is less then that the sum of intermediary inputs, indicating negative value added (which in the model I restrict to be positive) while some countries do not provide data on some sectors; for instance, the curious absence of a leather and footwear sector in Sweden in 2006. Finally, my identification restriction of constant β^j across countries is bound to cause distortions as well. In addition, as in the construction of World Input-Output Database different data sources were used, there are bound to be measurement errors and inconsistencies.

Faced with these discrepancies, in order to ensure that the model equations hold, I assume β^j, α_n^j, π_{ni}^j, I_n and $\gamma_n^{j,k}$ are correct and I estimate model consistent X_n and S_n from equations (2.8) and (2.7). This approach is consistent with assuming a multiplicative error in trade flows[6] and is similar to the approach in Alvarez and Lucas [2007]. The differences between actual data trade surpluses and model S_n are small, measured in the tens of thousands of dollars, and the correlation coefficient is 97%. Similarly, X_n is close to data *Total Expenditure*, the difference being less than 10% . Once I have a model consistent estimate of the trade surplus, I can recover $w_n L_n$ by subtracting S_n from total final consumption.

In estimating trade costs, I follow the method used in Chen and Novy [2009] or Hornok [2009], among others. While their approach is developed in the context of a new-trade monopolistic competition model, the same trade cost index can be derived in my model as the resulting gravity equations are similar. From equation (2.11), if I multiply the bilateral trade shares of countries i and n in commodity j and divide them by both their domestic shares I get

$$\frac{\pi_{ni}^j \pi_{in}^j}{\pi_{nn}^j \pi_{ii}^j} = \frac{X_{ni}^j}{X_n^j}\frac{X_{in}^j}{X_i^j} / \frac{X_{nn}^j}{X_n^j}\frac{X^j{}_{ii}}{X_i^j} = \left(\frac{c_i^j \tau_{ni}^j}{z_i^j}\right)^{-\theta}\left(\frac{c_n^j \tau_{in}^j}{z_n^j}\right)^{-\theta} / \left(\frac{c_i^j}{z_i^j}\right)^{-\theta}\left(\frac{c_n^j}{z_n^j}\right)^{-\theta} \tag{2.15}$$

Rearranging (2.15), the average trade costs between i and n are given by

$$\overline{\tau_{ni}^j} = \sqrt{\tau_{ni}^j \tau_{in}^j} = \left(\frac{\pi_{ni}^j \pi_{in}^j}{\pi_{nn}^j \pi_{ii}^j}\right)^{\frac{1}{2\theta}} \tag{2.16}$$

When there are no bilateral trade flows between two countries in a sector, I assume that trade costs are infinitely large. Trade costs are assumed to be symmetric. This is likely to be true in the data as EU member countries have no quantitative restrictions on imports, border controls were abolished symmetrically and the rest of trade cost determinants such as geography are symmetrical.

[6] Trade flows are likely to be inconsistently measured across countries as there are various reporting thresholds and exemptions depending on sector, country and trade value. Also, trade data is sometimes collected by other agencies than the ones who collect domestic economic data.

2.3.1 Solving for θ

A key unidentified parameter is the dispersion of productivity, θ^j. As can easily be seen from (2.10), (2.14) or (2.15), its value will significantly influence the impact of trade measures on bilateral trade flows and welfare. The central role θ plays in determining the gains from liberalization is not singular to my model. Arkolakis et al. [2009] survey the literature on welfare gains from trade and finds that virtually all paper dealing with the topic use a version of (2.14) to quantify the magnitude of gains.

Typically θ is recovered form of a gravity type equation like (2.6)[7]. Traditionally, the logarithmic form of (2.6) is used and θ is recovered as the parameter on some observable trade cost, such as tariffs. For instance, Head and Ries [2001] estimate the trade elasticity based on the changes in bilateral trade flows as a result of trade liberalization episodes. They find estimates between 7.9 and 11.4. Romalis [2007] uses the same approach on CUSFTA and NAFTA data and obtains and estimate between 6.2 and 10.9. This approach is appealing due to its simplicity but it is not without issues. The central identifying assumption is that the entire change in trade frictions is due to changes in tariffs. However, tariff reductions are not exogenous and are likely correlated with other observed and unobserved trade barriers and economic conditions, resulting in biased estimates.

Caliendo and Parro [2012] use a similar approach and rely on triple difference across countries in order to estimate sectoral θs. However, tariff data is usually only available for a handful of countries, typically developed ones. Following their approach makes no sense in my case as tariffs had been mostly eliminated between the EU and CEE countries by the early 2000s.

In addition, the results of their estimation strategy do not always respect the restriction of $\theta > 1$[8] and their results are very fragile, slight sample modification causing wild swings in the estimates, sometimes yielding negative values. Moreover, the same criticism of endogenous tariffs can be applied.

[7] Feenstra [1994] and papers based on its methodology make an exception as they use second moments of changes in prices and expenditure shares, but as argued in Simonovska and Waugh [2011] their estimate has a different structural interpretation.

[8] If this does not hold, the goods productivity distribution is ill defined.

In their seminal paper, Eaton and Kortum [2002] alone propose three methodologies to recover θ, each yielding a different results. They use combinations of price indices, country effects, R&D expenditure and wage data to obtain the calibration parameter. Their estimates range from 3.6 to 12 depending on the method and their preferred estimate is of 8.28. Having a random sample of the goods in the economy they compute the price index in each country. They compute the ratio of consumer prices between two countries for each good, which, due to arbitrage reasons, will always be smaller, but very close to the true trade cost. They recover θ by regressing the ratio of import shares to domestic trade shares on the price indices in two economies and the proxied trade costs.

Simonovska and Waugh [2011] criticize the methods of Eaton and Kortum [2002] due to their severe small sample bias. Instead they propose a Simulated Method of Moments variant. Based on gravity equation coefficients they simulate a large number of goods from which they draw a random sample to serve as their "observed prices" in order to construct the price index and proxy trade costs. On the same sample as Eaton and Kortum [2002] they obtain a much smaller estimate of 4.42. Using the more refined and more recent EIU price dataset, they obtain even lower estimates, going as low as 2.47.

Donaldson [2010] estimates θ by looking at salt trade in India. He argues that, as salt is only produced in a few locations, the differences in the price of salt across markets fully reflect trade frictions. His estimates are in the range 3.8 – 5.2. Other estimates include Bernard et al. [2000] or Eaton et al. [2011] who estimate θ, using firm level sales data and obtain values in the range 3.6 – 4.8. Burstein and Vogel [2012]'s estimates based on skill intensity are 5.

Finally, Costinot et al. [2012] also use a form of the gravity equation to recover the trade elasticity in a multi-sector model without trade linkages. They argue that in a Ricardian world, firms operate in perfectly competitive markets and workers are paid their marginal product. Hence, the relative productivities across sectors and countries are fully reflected in the relative prices. They regress observed imports on the inverse of prices and fixed effects and recover the parameter of interest as the coefficient on wages.

While there have been several econometric attempts to recover this key parameter of interest, there is no best method and the estimated coefficients vary quite a lot. The lack of consensus is, in part, due to the fact that the interpretation of θ is usually model specific and values derived in one model may not perfectly reflect the underlying assumptions of another. Secondly, different models rely on different identification strategies, driven both by the model specification and data availability.

As the Caliendo and Parro [2012] estimation method is infeasible with my data and, as argued above, may not be consistent with the theoretical model, in this paper, I devise a θ estimation method that blends the methodology in Costinot et al. [2012] and Eaton and Kortum [2002]'s wage approach.

However, the data requirements for this method go beyond the input-output tables used earlier. I need two additional pieces of information: research and development data as well as detailed price data. R&D expenditure is taken from the OECD STAN database for 'early 2000s'. This data was not available for all countries[9]. Relative sectoral price levels were taken from GGDC Productivity Level Database [Timmer et al., 2007]. As prices were available for 1997 only, I adjust them for inflation using using the producer price indices from the EU KLEMS dataset.

Consider equation (2.6) for import and domestic shares in sector j for countries i and n, where for notational simplicity I replace $q_i^j = \prod_{k=1}^{J} \left(p_i^k\right)^{\gamma_i^{k,j}}$, the price of the intermediate bundle used in the production of sector j goods:

$$\begin{aligned}\pi_{ni}^j &= \left(\frac{\Upsilon_i^j w_i^{\beta^j} \left(q_i^j\right)^{1-\beta^j} \tau_{ni}^j}{z_i^j}\right)^{-\theta} \Bigg/ \left[\sum_{m=1}^{N} \left(\frac{\Upsilon_m^j w_m^{\beta^j} \left(q_m^j\right)^{1-\beta^j} \tau_{nm}^j}{z_m^j}\right)^{-\theta}\right] \\ \pi_{nn}^j &= \left(\frac{\Upsilon_n^j w_n^{\beta^j} \left(q_n^j\right)^{1-\beta^j}}{z_m^j}\right)^{-\theta} \Bigg/ \left[\sum_{m=1}^{N} \left(\frac{\Upsilon_m^j w_m^{\beta^j} \left(q_m^j\right)^{1-\beta^j} \tau_{nm}^j}{z_m^j}\right)^{-\theta}\right]\end{aligned} \tag{2.17}$$

Taking the ratio of shares, I arrive at

$$\frac{\pi_{ni}^j}{\pi_{nn}^j} = \left(\frac{\Upsilon_i^j w_i^{\beta^j} \left(q_i^j\right)^{1-\beta^j} z_n^j \tau_{ni}^j}{\Upsilon_n^j w_n^{\beta^j} \left(q_n^j\right)^{1-\beta^j} z_i^j}\right)^{-\theta} \tag{2.18}$$

[9] The Czech Republic, Denmark, Estonia, Latvia, Lithuania and Sweden had no R&D data available

Rearranging, I solve for w_i/w_n:

$$\frac{w_i}{w_n} = \left[\left(\frac{\pi_{ni}^j}{\pi_{nn}^j} \right)^{-\frac{1}{\theta}} \frac{\Upsilon_n^j (q_n^j)^{1-\beta^j} z_i^j}{\Upsilon_i^j \left(q_i^j\right)^{1-\beta^j} z_n^j \tau_{ni}^j} \right]^{\frac{1}{\beta^j}} \tag{2.19}$$

Now consider equation (2.18) for another sector k for the same two countries i and n. Plugging in the wages ratio from (2.19)

$$\left(\frac{\pi_{ni}^k}{\pi_{nn}^k} \right)^{\frac{1}{\beta^k}} = \left(\frac{\Upsilon_i^k \left(q_i^k\right)^{1-\beta^k} z_n^k}{\Upsilon_n^k (q_n^k)^{1-\beta^k} z_i^k} \right)^{\frac{-\theta}{\beta^k}} \left(\frac{\pi_{ni}^j}{\pi_{nn}^j} \right)^{\frac{1}{\beta^j}} \left[\frac{\Upsilon_i^j \left(q_i^j\right)^{1-\beta^j} z_n^j}{\Upsilon_n^j \left(q_n^j\right)^{1-\beta^j} z_i^j \tau_{ni}^j} \right]^{\frac{-\theta}{\beta^j}} \left(\tau_{ni}^k\right)^{\frac{-\theta}{\beta^k}} \tag{2.20}$$

While the above equation could be estimated as is, it is far more convenient to work with an equivalent version of it. Note that for a fixed reference sector j, the second and third terms of the multiplication in (2.20) are constant for imports in all other sectors in country n from i. That is, they can be incorporated in a pair-specific fixed effect. Taking logs, I get

$$\ln \left(\frac{\pi_{ni}^k}{\pi_{nn}^k} \right)^{\frac{1}{\beta^k}} = -\theta \mathrm{T}_{ni}^k + \ln \delta_{ni} - \frac{\theta}{\beta^k} \ln \tau_{ni}^k \tag{2.21}$$

where

$$T_{ni}^k = \frac{1}{\beta^k} \ln \left[\left(\Upsilon_i^k \left(q_i^k\right)^{1-\beta^k} z_n^k \right) \Big/ \left(\Upsilon_n^k \left(q_n^k\right)^{1-\beta^k} z_i^k \right) \right]$$

The intuition behind this specification is that the difference across sectors in imports from country i should be fully reflected in the different input costs of country i and bilateral trade costs. Identification of θ is achieved through the first term of (2.21). While prices, labor share and input-output data are readily available, the productivity term, z, is not directly observed. In a perfect competition world firms do not make any profits and workers are paid their marginal product. Therefore higher zs should be strongly correlated with the observed wages. I proxy productivity with the sectoral wage levels from the EU KLEMS dataset for the year 2003 and compute T_{ni}^k.

From an empirical point of view, I run the following regression:

$$y_{ni}^k = \mathrm{A}_{ni} - \theta T_{ni}^k + \varepsilon_{ni}^k$$

where y_{ni}^k is the ratio of trade share on the left hand side of (2.21), $A_{ni} = \ln \delta_{ni}$ is a fixed effect and the error term incorporates trade costs, measurement error in bilateral trade flows and other unobserved shocks which may influence trade flows. Running the above regression as OLS would likely produce inconsistent results. I do not directly observe all component of T_{ni}^k and I have to proxy them using producer prices and wages. Both of these are likely to be imprecisely measured causing regression dilution. Following Costinot et al. [2012], I choose to instrument productivities with the log of R&D expenditure ratios in each sector across countries. The use of R&D expenditure as a measure of technology appears in numerous papers, among them, Eaton and Kortum [1996], Kortum [1997], Eaton and Kortum [2002], Griffith et al. [2004]. While the link between Research and technology is fairly well established, I still need to make the identifying assumption that research and development has no other effect on bilateral trade shares than through the changes in productivity. In practice, I actually instrument the entire T_{ni}^k as this approach reduces the bias associated with instrumental variables[10].

Table 2.2: Estimates of θ

Estimation method	OLS	IV
θ	0.211	5.400
Robust Standard Error	(0.0368)	(1.015)
Observations	10788	4803

Table 2.2 provides the estimated dispersion of productivity with and without IVs. Column 1 is obtained by running OLS and Column 2 displays the results using instrumental variables. The OLS results are unreasonably small, a finding of Costinot et al. [2012] as well. The IV estimate is close to the average estimates in the literature and close to Costinot et al.'s preferred estimate. On one hand, this was to be expected as they use a similar methodology on almost the same set of countries. At the same time, it is reassuring, given that the samples were 6 years apart and there are notable differences in the estimation equation. Furthermore, the value I obtain is close to most reasonable estimates in the literature detailed above. Appendix A2.1 discusses alternative values for the dispersion parameter for the first counterfactual and whether heterogeneity matters.

[10]Monte Carlo tests showed that instrumenting in this fashion produces a closer estimate to the true value than just instrumenting the variable of interest.

2.4 The Impact of Joining the EU

On May 1^{st} 2004, The European Union experienced its largest enlargement wave, with the joining of eight Central and Eastern European (CEE) countries, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia and the Czech Republic, along with Cyprus and Malta. The countries joining the EU in 2004 entered the highest degree of economic integration: the single market with the eventual perspective of adopting the single currency, which some of them have done since.

Despite entailing a large set of changes, both politically and economically, for the purposes of this paper EU expansion will be treated solely as a trade block enlargement event. Nonetheless, even as trade-only event, EU enlargement has a few distinctive features. First of all, it takes place among highly diverse members in terms of both absolute and relative economic size. In 2003 GDP per capita in new members was just 46% of that in incumbent countries, based on World Bank data adjusted for purchasing power parity and constant prices. The same was true for labor productivity [Breuss, 2001]. More importantly, while trade liberalizations episodes usually involve tariff reduction, this was not the case for the 2004 EU expansion. Since 1997 there have been no tariffs on imports from CEE into EU15 and since 2002 none on exports to CEE from EU15, except for some agricultural products [Breuss, 2001]. This policy was the result of several European and interim agreements in the early 1990s, such as CEFTA (Central European Free Trade Agreement) in 1993 and BAFTA (Baltic Area Free Trade Agreement) in 1994. Concomitantly, traditional trade barriers (tariffs, quantitative restrictions, rules of origin) had been also abolished between the CEE countries themselves through various bilateral agreements.

As a result, by the time they joined the EU, trade integration between CEECs and the EU was already advanced and, de facto, the main trade effect of enlargement was the abolition of customs controls. Before joining the EU, lengthy border controls hindered trade, adding to the overall trade costs. While these costs are very real, their effect is indirect and quite hard to quantify. As customs controls were abolished only for land transport [Hornok, 2009], for the rest of the paper I will focus on CEE countries, as Malta and Cyprus saw no significant reduction in trade costs as a result of enlargement.

2.4.1 Estimating the Trade Cost Effect of Joining the EU

In order to assess the impact of EU enlargement on trade costs I need to isolate the change in trade costs due to border controls abolition. I assume the supraunitary part of trade costs has the following form:

$$\ln d^j_{ni,t} = \delta^j_{ni} + M^j_{n,t} + EU^j_{ni,t} + \varepsilon^j_{ni,t} \tag{2.22}$$

where δ^j_{ni} are time invariant components of trade costs such as distance, common border etc., $EU^j_{ni,t}$ is a dummy indicating if both countries in the bilateral trade relation are in the EU at time t, $M^j_{n,t}$ is an importer time-specific effect and $\varepsilon^j_{ni,t}$ is a random disturbance that reflects period specific trade costs. The inclusion of the time varying importer effects is aimed at correcting for any country specific shocks that may bias the estimate of the EU dummy: it controls for changes that may be related to EU accession but not directly linked to it such as judicial reform or infrastructure improvements; it also controls for changes in country specific regulations that exporters must abide by: for instance, furniture exporters from Sweden must respect Italian safety norms which may differ substantially from the domestic regulations, despite being part of the common market. I run equation (2.22) pooling years 2003 and 2006.

While the above specification is closely linked to the theoretical model, I check it against two other models: I run the regression controlling with time dummies only instead of country varying and I also run a random effects specification with importer effects. The results point in the same direction but are quantitatively somewhat different. Using only time dummies reduces the effect of EU membership as this specification only controls for common shocks whereas the RE model overstates the effect of EU membership. The results can be seen in Table 2.3. Overall, EU accession reduced trade costs between 5% and 20%, although in a few sectors trade costs appear to have gone up, albeit not in statistically significant manner.

Table 2.3: Effect of EU membership on trade costs

	Control		
Sector	Pair & Time	Pair & Importer	Random Effects & Importer
Agriculture, hunting, forestry and fishing	-0.137	-0.146	-0.189
	(0.0154)	(0.0181)	(0.0177)
Mining and quarrying	-0.159	-0.126	-0.285
	(0.0367)	(0.0447)	(0.0429)
Food , beverages and tobacco	-0.117	-0.125	-0.167
	(0.0125)	(0.0151)	(0.0149)
Textiles, textile , leather and footwear	-0.203	-0.149	-0.211
	(0.0419)	(0.0463)	(0.0395)
Wood and of wood and cork	0.0152	0.0223	0.00433
	(0.0126)	(0.0153)	(0.0149)
Pulp, paper, paper , printing and publishing	-0.0467	-0.0578	-0.0959
	(0.0131)	(0.0181)	(0.0175)
Coke, refined petroleum and nuclear fuel	-0.125	-0.0881	-0.143
	(0.0288)	(0.036)	(0.0348)
Chemicals and chemical	-0.0637	-0.0304	-0.122
	(0.0227)	(0.0257)	(0.024)
Rubber and plastics	-0.0206	-0.0187	-0.0492
	(0.0149)	(0.0189)	(0.0187)
Other non-metallic mineral	-0.0116	0.00571	-0.0134
	(0.0117)	(0.0148)	(0.0145)
Basic metals and fabricated metal	-0.054	-0.0255	-0.0468
	(0.0144)	(0.0154)	(0.0152)
Machinery, nec	-0.0647	-0.0581	-0.0841
	(0.0161)	(0.0196)	(0.019)
Electrical and optical equipment	-0.31	-0.27	-0.311
	(0.0267)	(0.0322)	(0.0289)
Transport equipment	-0.101	-0.0815	-0.192
	(0.0388)	(0.0441)	(0.0407)
Manufacturing nec; recycling	0.0461	0.0485	0.0155

Table 2.3: Effect of EU membership on trade costs

	Control		
Sector	Pair & Time	Pair & Importer	Random Effects & Importer
	(0.0181)	(0.0208)	(0.0195)
Electricity, gas and water supply	-0.0822	-0.0865	-0.15
	(0.0231)	(0.0265)	(0.0247)
Construction	-0.0437	-0.0574	-0.0498
	(0.024)	(0.0268)	(0.0257)
Wholesale and retail trade	-0.0237	-0.0257	-0.0615
	(0.0173)	(0.0209)	(0.0194)
Hotels and restaurants	0.0509	0.0369	-0.0233
	(0.0449)	(0.0446)	(0.0402)
Transport and storage and communication	-0.0549	-0.0635	-0.114
	(0.016)	(0.0209)	(0.0199)
Financial intermediation	0.00113	0.00467	-0.0643
	(0.0256)	(0.0313)	(0.0291)
Real estate, renting and business activities	-0.0458	-0.0414	-0.0981
	(0.0159)	(0.0204)	(0.0193)
Public admin and defence	-0.092	-0.0645	-0.119
	(0.0269)	(0.0327)	(0.0333)
Education	-0.0706	-0.081	-0.145
	(0.0248)	(0.0286)	(0.0278)
Health and social work	-0.172	-0.135	-0.175
	(0.0262)	(0.0292)	(0.0288)
Other community, social and personal services	-0.107	-0.0971	-0.152
	(0.0203)	(0.0243)	(0.024)

Note: Robust standard errors in brackets, the sector codes correspond to the ones in Table A2.2

I compute the counterfactual trade costs by removing the EU membership component from the 2003 trade costs. I then calculate $\hat{\tau}^j_{ni}$, which I plug into the system of equations (2.9) - (2.13), using 2003 data for the rest of the parameters. In a nutshell, my counterfactual asks, what if between 2003 and 2006 only trade costs had changed. Once I have solved for the changes in prices, wages and bilateral shares, I compute the welfare gains through equation (2.14). Table 2.4 and Figure 2.2 present the welfare gains from EU enlargement by country and broken down by source of gains.

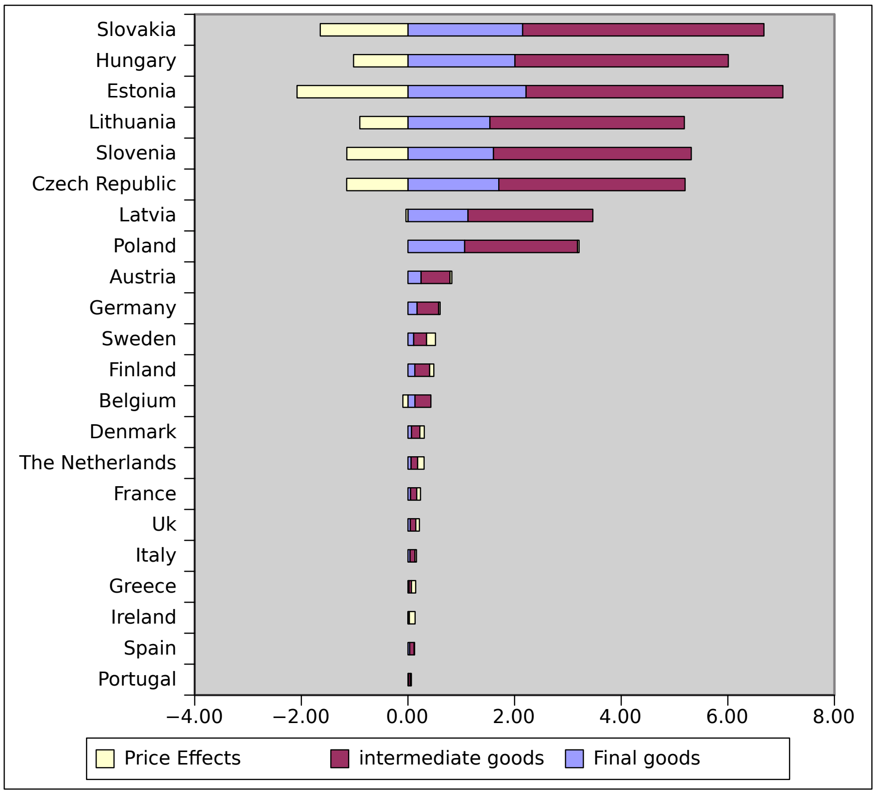
Table 2.4: Total gains from trade by country and source

	Final goods %	**Intermediate goods %**	**Price index effects %**	**Total gains%**
Austria	0.24	0.57	0.03	0.84
Belgium	0.11	0.30	-0.09	0.32
<u>Czech Republic</u>	1.80	3.81	-1.27	4.34
Denmark	0.07	0.17	0.09	0.33
<u>Estonia</u>	2.37	5.30	-2.32	5.35
Finland	0.14	0.32	0.09	0.54
France	0.06	0.13	0.08	0.27
Germany	0.19	0.45	0.03	0.68
Great Britain	0.05	0.12	0.08	0.25
Greece	0.02	0.05	0.10	0.17
<u>Hungary</u>	2.22	4.55	-1.16	5.62
Ireland	0.00	0.02	0.12	0.14
Italy	0.04	0.10	0.04	0.18
<u>Latvia</u>	1.05	2.36	-0.03	3.38
<u>Lithuania</u>	1.64	4.01	-1.10	4.55
The Netherlands	0.06	0.13	0.14	0.33
<u>Poland</u>	1.04	2.20	-0.06	3.18
Portugal	0.01	0.04	0.02	0.07
<u>Slovakia</u>	2.24	4.81	-1.75	5.30
<u>Slovenia</u>	1.68	4.01	-1.27	4.42
Spain	0.04	0.10	0.01	0.14
Sweden	0.12	0.27	0.19	0.58
ROW	0.00	0.00	0.03	0.03

Note: Underlined countries are new entrants

Overall, the results are broadly in line with expectations: new entrants gained significantly more than incumbents: Poland, the new entrant with the lowest gains, still had a welfare increase four times larger than Austria, the incumbent which enjoyed the largest gains. New members gained in the range of 3-5% while for incumbents, the welfare gains I observed are also positive and range from 0.07% to 0.84%. The numbers are sensible given the short time frame I consider and that these countries are much larger than their Eastern neighbors.

Figure 2.2: Source of welfare gains for EU countries



In all countries, allowing for sectors to be interdependent amplifies the gains from trade. The effect of price indices on liberalization is a mixed one. For a few countries, the ones that gained the most from liberalization, the price effects are negative, reducing the final welfare gain. This happens because the price of the final good declines by more than the price of intermediate inputs, lowering welfare. The results are in line with those of Caliendo and Parro [2012] who find that for NAFTA, as well, intermediate goods play a strong role in amplifying the size of the gains. However, in their case, the price index, which they break down into two distinct components, has a net effect close to zero. This is likely because the countries they consider are large, have a considerable domestic market so prices across all sectors are likely to move in tandem with wages, leaving the real wage unchanged.

Both among incumbents and new entrants there appear to be no systemic relation between the size of a country and how large are the benefits it reaps from cheaper trade, rejecting the Casella [1996] hypothesis. However, there appears to be a link between geographic proximity and gains: countries that already had strong economic ties gained the most. Among incumbents, countries situated colse to the new entrants, such as Austria, Finland or Germany gained the most and distant countries like Spain, Portugal and Ireland, had negligible gains.

2.5 Greek Exit from the Euro

This section examines what would be the trade effects of a Greek exit from the Euro Zone. Despite its prominence in the news, a brief review of the Greek crisis is welcomed. Towards the end of 2009, investors began fearing a sovereign Greek default, concerned about Greece's ability to meet its obligations. This led to a rise in Greek bond yields, further deprecating the Greek government's ability to finance its debt. By April 2010, Greek debt was downgraded to junk status by rating agencies. In response, the Eurozone countries and the IMF offered a bailout loan of 110 billion Euros conditional on Greek reforms. These measures proved insufficient and in late 2011 a second bailout package of 130 billion Euros was offered. Still, in 2012, Greece's government had the largest sovereign debt default in history and 10 year bond yields reached 30%. After a brief period of growth in 2014, in late 2014-early 2015 the situation deteriorated again and in June 2015 Greece became the first developed country to fail to repay an IMF loan. At the time of writing this, in mid 2016, despite deep austerity and a partial write-off, Greek public debt still stands around 180% of GDP and unemployment is close to 25%.

While some viewed it as a nightmare scenario, a popular chorus during the unfolding of the events called for a speedy exit from the Euro and adoption of a national currency at a depreciated exchange rate[11]. This would boost exports and also relapse the government's

[11] Nouriel Roubini and Paul Krugman were particularly strong proponents of this measure in a lot of popular press articles. See, for instance, Roubini [2011]

difficulty in servicing the debt.

In this section I ask what would have happened, had Greece exited the Euro in 2009, at the onset of its budget crisis. As my model does not feature government, financial markets or unemployment, it has no ambition of capturing the full and complex effect of a "Grexit", but rather this section is more modest in scope: it only aims to measure the welfare losses associated with higher trade costs due to Euro exit. I further impose the condition that Greece must run a balanced trade budget as it is unlikely it would be able to continue financing its deficit in the new conditions. In two alternative scenarios, I investigate what if Greece were to run a trade surplus to pay down its debt. I also examine the effects of various currency depreciation cases.

I calibrate the model to the year 2009 and the EU27 countries (minus Malta, Cyprus and Luxembourg) and an aggregate construct, the Rest of the World (ROW). Due to the lack of available data, I use the same value of θ as in the first counterfactual. I estimate bilateral symmetric trade costs using (2.16). In order to measure the effect of a Euro exit on trade costs, I regress their supraunitary component, d_{ni}^j on plausible determinants of trade costs and an Euro dummy. There is a sizeable literature on the effects of the Euro on trade flows in the EU, obtaining mixed results, ranging from a boost of 3% [Bun and Klaassen, 2007] to an increase of 38% [Bun and Klaassen, 2002]. However, rather that looking at the benefits of Euro membership over time, I am interested in the effect of the Eurozone in 2009 and 2009 alone. Therefore it is likely that the values I obtain are going to be towards the upper end of previous estimates as integration is stronger as time passes. The following regression is ran for each sector:

$$\ln d_{ni}^j = IM_n^j + EX_i^j + EZ_{ni}^j + D_{ni}^j + C_{ni}^j + CL_{ni}^j + \varepsilon_{ni}^j \tag{2.23}$$

where IM and EX are importer and exporter country dummies, respectively, EZ is a Eurozone dummy that takes the value 1 if both countries use the Euro, D is distance in thousands of kilometres and C and CL are common border and common language indicators. The last three control dummies are standard in the trade manufacturing literature and the above specification is likely to be appropriate for services as well. (Head et al. [2009] show that the determinants of services' trade costs are similar to those of manufactured goods). Equation (2.23) is, in effect, the cross-section analogue of (2.22). The only difference is that as I now run the regression in a single year, I have to explicitly account for importer and export dummies and other time-invariant controls rather than have them subsumed in the fixed effect. The estimates are presented in Table 2.5 and fit both expectation and previous literature: being contingent has a negative effect on trade costs, less for services than for goods; distance is not significant in the case of most services; overall, Euro membership reduces trade costs by around 16%, although there is substantial of between sector variation.

Before changing trade costs, I ask what would happen if Greece was forced to run a balanced trade account. That is, I set S_{Greece} to 0 and reduce the trade position of all other countries, using their total trade with Greece as weights, such that $\sum_n S_n = 0$. I do not operate any other changes and I solve for changes equilibrium in using equations (2.9) - (2.13). The overall welfare changes for this counterfactual can be found in column 1 of Panel A in Table 2.6. As Greece runs a deficit, imposing balanced budget would have an income reduction effect, lowering welfare by 1.85%.

The magnitude of the welfare changes is small and in line with that obtained by Dekle et al. [2007] when they performed a similar experiment of shutting down current account imbalances. The reason for this small change is that trade imbalances only make up a fraction of a country's income and a large part of a nation's economy is non-traded. Therefore, prices will adjust roughly in line with the income, attenuating losses. As in the first counterfactual, sectoral interdependencies amplify the effect of welfare changes, but now for the worse: allowing for sectors to be inter-linked more than doubles the losses from trade.

Table 2.5: Effect of Euro membership on trade costs

Sector	Euro Zone	Contingent	Language	Distance
Agriculture, hunting, forestry and fishing	-0.202	-0.747	-0.242	0.0435
	(0.0552)	(0.0751)	(0.133)	(0.0116)
Mining and quarrying	-0.241	-0.965	-0.258	0.0498
	(0.0664)	(0.0914)	(0.156)	(0.0139)
Food , beverages and tobacco	-0.164	-0.735	-0.32	0.0333
	(0.0492)	(0.0669)	(0.119)	(0.0103)
Textiles, textile , leather and footwear	-0.0142	-0.834	-0.496	0.0196
	(0.0846)	(0.119)	(0.24)	(0.0179)
Wood and of wood and cork	-0.128	-0.819	-0.156	0.0262
	(0.049)	(0.0666)	(0.118)	(0.0103)
Pulp, paper, paper , printing and publishing	-0.251	-0.771	-0.0761	0.0105
	(0.0475)	(0.0645)	(0.114)	(0.00998)
Coke, refined petroleum and nuclear fuel	-0.162	-0.997	-0.179	0.0694
	(0.0797)	(0.111)	(0.189)	(0.0168)
Chemicals and chemical	-0.194	-1.052	-0.0422	0.0582
	(0.0814)	(0.113)	(0.216)	(0.0171)
Rubber and plastics	-0.232	-0.804	-0.121	0.0545
	(0.0598)	(0.0813)	(0.15)	(0.0125)
Other non-metallic mineral	-0.165	-0.772	-0.12	0.0395
	(0.0519)	(0.0705)	(0.125)	(0.0109)
Basic metals and fabricated metal	-0.165	-0.779	-0.217	0.019
	(0.0497)	(0.0675)	(0.12)	(0.0104)
Machinery, nec	-0.0785	-0.569	-0.149	0.0196
	(0.0501)	(0.0695)	(0.121)	(0.0105)
Electrical and optical equipment	0.0163	-0.692	-0.199	0.0208
	(0.0575)	(0.0782)	(0.139)	(0.0121)
Transport equipment	-0.201	-0.545	-0.32	0.0735
	(0.07)	(0.0994)	(0.177)	(0.0147)
Manufacturing nec; recycling	-0.0168	-0.717	-0.354	0.0203
	(0.0539)	(0.0732)	(0.13)	(0.0113)

Table 2.5: Effect of Euro membership on trade costs

Sector	Euro Zone	Contingent	Language	Distance
Electricity, gas and water supply	-0.229	-0.408	-0.255	0.0662
	(0.0446)	(0.0619)	(0.108)	(0.00937)
Construction	0.123	-0.577	0.0246	0.0139
	(0.055)	(0.0739)	(0.131)	(0.0114)
Wholesale and retail trade	-0.151	-0.45	-0.0848	0.00579
	(0.0447)	(0.0611)	(0.106)	(0.00926)
Hotels and restaurants	0.0522	-0.511	-0.361	-0.0368
	(0.0756)	(0.104)	(0.182)	(0.0158)
Transport and storage and communication	-0.0726	-0.445	-0.0873	0.0535
	(0.0394)	(0.0536)	(0.095)	(0.00828)
Financial intermediation	-0.287	-0.395	0.0118	0.0587
	(0.0618)	(0.0837)	(0.148)	(0.0129)
Real estate, renting and business activities	-0.17	-0.348	-0.166	0.0296
	(0.0465)	(0.0632)	(0.112)	(0.00977)
Public admin and defence	-0.224	-0.392	0.0561	-0.00923
	(0.0613)	(0.0822)	(0.14)	(0.0126)
Education	-0.13	-0.386	-0.0931	0.000253
	(0.0521)	(0.0707)	(0.121)	(0.0108)
Health and social work	-0.0259	-0.411	-0.00484	-0.0275
	(0.0466)	(0.0646)	(0.11)	(0.00982)
Other community, social and personal services	-0.143	-0.371	-0.136	0.00784
	(0.055)	(0.0752)	(0.131)	(0.0114)

Note: Robust standard errors in brackets, the sector codes correspond to the ones in Table A2.2

Next in building my counterfactual assessment, I simulate a Greek Euro exit. I increase Greece's import and export trade costs with other Eurozone countries by the estimated Eurozone coefficients from column 1 of Table 2.5. The welfare implications for this scenario are displayed in column 2 of Panel A, Table 2.6. Exiting the Euro imposes a further 2% welfare loss on Greece, bringing the total to -3.65%.

The other EU countries register a small welfare loss, as well, as trading with Greece becomes more costly but the changes are negligible, given that Greek goods and services make up a small percentage of their overall balance. The only exception, where losses are sizeable, is Bulgaria, which comes as little surprise given the common border, but even in this case the losses are less than 1%. Comparing columns 1 and 2 of Panel B, it is evident that exiting the Euro would depress both Greek exports and imports.

However, the purpose of a Greek Exit is the issuance of a new currency that would be allowed to depreciate. I consider two plausible values for depreciation: 50% and 75% [Alcidi et al., 2012]. As depreciation acts as an export subsidy and tax on imports, in this counterfactual, I break the symmetry between Greek import and export trade costs, in that I let import costs rise and export costs fall. As my model does not explicitly model exchange rate fluctuations, I have to consider them part of trade costs. In the third paper of this dissertation, I explicitly look into the impact exchange rate have on trade elasticities. For a wide panel of European countries, over 2001-2008, in our preferred specification, the average elasticity of exports to exchange rates is 85%, which I will assume in this paper.

However, in the context of my model and given my calibration this implies that a 50% depreciation would amount to 5% change in trade costs and a 75% depreciation would result only in a 10% change in trade costs. The results for 50% and 75% depreciation can be found in columns 3 and 4 of Panel A, Table 2.6. Faced with higher import, the welfare of Greek households decreases further whereas the other European countries enjoy cheaper imports.

So why would countries choose to depreciate if they made their citizens worse off? Most advocates of a Grexit hope for three effects: re-denominating the Greek debt into a weaker currency and hence 'inflate away' the debt, obtain export-led growth similar to the one experienced by Indonesia, for instance, after the 1997 Asian crisis and internal reforms.

While I have nothing to say on the first effect, Panel B of Table 2.6 shows in the last two columns that depreciation boost exports but the effect is quite limited in scope.

Finally, I ask what would the required changes in productivity be such that they counter the welfare losses suffered by Greece. For the sake of simplicity, I assume that z_{Greece} changes the same proportion for all sectors. Note that in the equilibrium equations, z always enters multiplicatively with τ, so a change in productivity is akin to a change in trade costs. However, there is an additional effect present: not only will a productivity boost make Greek products more competitive internationally, it will also have a positive effect on domestic demand. Productivity gains operate through two channels: they lower the prices of all goods making Greek goods more desirable for both foreigners and Greek manufacturers alike and also lower the price Greek consumers have to pay for goods. In the case of productivity gains, the welfare changes take on an extra term compared to (2.14). Specifically, changes in welfare become

$$\ln \hat{W}_n = -\sum_{j=1}^{J} \frac{\alpha_n^j}{\theta} \ln \hat{\pi}_{jj} - \sum_{j=1}^{J} \frac{\alpha_n^j}{\theta} \frac{1-\beta^j}{\beta^j} \ln \hat{\pi}_{jj} - \sum_{j=1}^{J} \alpha_n^j \frac{1-\beta^j}{\beta^j} \left(\ln \hat{p}_n^j - \sum_{k=1}^{J} \gamma_n^{k,j} \ln \hat{p}_n^k \right) + \sum_{j=1}^{J} \frac{\alpha_n^j}{\beta^j} \ln \hat{z}_n^j \quad (2.24)$$

where the last term compensates the fact that $\ln \hat{\pi}_{nn}$ will rise as Greek consumers move towards cheaper domestic goods.

The productivity gains required can be found in Panel C of Table 2.6 for the four scenarios discussed above. Productivity changes are increasing returns to scale so additional depreciation requires only modest increases in productivity. After the initial loss caused by balanced trade and Euro exit only minor changes in productivity are required to offset welfare losses due to currency depreciation. Nonetheless, even if the required gains in productivity appear to be small, it should be kept in mind that these gains are required to be obtained in all sectors. For instance if large productivity gains are obtained in a sector that is little desired by consumers, (low α), such as mining, this will translate very little into direct consumer gains. Similarly, if that sector is little interlinked with other sectors, the gains that accrue through lower prices will also be minimal as only own sector effects are present.

Table 2.6: Changes in Greek welfare

	Balanced trade	**Euro exit**	**Depreciation**	
			50%	**75%**
Panel A	**Changes in welfare**			
Final goods	-0.76%	-1.19%	-1.23%	-1.23%
Intermediary goods	-1.60%	-2.60%	-2.66%	-2.68%
Prices Effects	0.52%	0.14%	-0.31%	-0.49%
Total Δ Welfare	-1.85%	-3.65%	-4.20%	-4.41%
Panel B	**Changes in imports and exports**			
ΔExports	53.96%	32.68%	35.04%	36.10%
ΔImports	-30.41%	-40.01%	-39.12%	-38.63%
Panel C	**Required productivity changes to offset losses**			
$\Delta\bar{z}_{Greece}$	0.81%	1.61%	1.86%	1.95%

2.5.1 What if Greece Run a Surplus?

Given the considerable debt Greece had amassed, it is unlikely it would have all been forgiven and not be required to be paid back regardless of what course of action Greece took. Moreover, in the case of a messy Euro "divorce", Greece's trade partners would have no incentive to be lenient.

In this section, I run the same set of counterfactual scenarios as above but rather than imposing balanced trade, I investigate the effects of a yearly 5% and 10% trade surplus for Greece. As above, I adjust the trade position of Greece's trading partners proportional to their trade with Greece. The results are summarized in Tables 2.7 and 2.8. The welfare changes are defined relative to the real life case, where Greece is running a double digit deficit.

Columns 1 show the results of Greece running a trade surplus but with no Euro exit. While imports collapse a bit more than in the balanced trade case, the effect on exports is staggering, Greece's exports almost doubling in the case of a 10% trade surplus. Interestingly, the welfare effects are not very large: Greece is less than 1% worse off than in the balanced trade counterfactual. As argued in the previous section, this reflects the fact that I consider the full economy, services included, and European economies are still quite autarchic.

Columns 2 show the impact of Greece leaving the Euro and, predictably, this lowers both export and import volumes and makes Greece much worse off. Columns 3 and 4 consider the same 50% and 75% currency depreciation post-"Grexit". While the results are qualitatively similar with those in Table 2.6, it is interesting to note that if Greece drops the Euro and adopts a new depreciated currency, the welfare losses between balanced trade and surplus are only marginally larger, half a percentage point.

Table 2.7: Changes in Greek welfare in the case of a default and 5 % trade surplus

	5% Surplus	**Euro exit**	**Depreciation**	
			50%	**75%**
Panel A	**Changes in welfare**			
Final goods	-0.92%	-1.34%	-1.37%	-1.38%
Intermediary goods	-1.94%	-2.92%	-2.98%	-2.99%
Prices Effects	0.66%	0.31%	-0.14%	-0.32%
Total Δ Welfare	-2.21%	-3.95%	-4.48%	-4.69%
Panel B	**Changes in imports and exports**			
ΔExports	71.30%	50.35%	52.72%	53.80%
ΔImports	-36.47%	-45.96%	-45.04%	-44.55%
Panel C	**Required productivity changes to offset losses**			
$\Delta \bar{z}_{Greece}$	0.95%	1.75%	1.99%	2.07%

Finally, I consider what productivity gains would offset the negative effects of these trade measures. For a 10% trade surplus with 75% currency depreciation, the necessary productivity boost is 2.18%, compared to 1.95% for the balanced trade case. A 2.18% increase in productivity is not so outlandish, given that the typical TPF growth is around 1% per year [Edwards, 1998]. However, this growth would only offset the losses from trade costs. Furthermore, while the welfare loss in my model appears to be much smaller than the 25%+ decrease in Greek GDP we observed in real life, it must be kept in mind that my results are derived in the best of possible worlds: I make a host of simplifying assumption that are likely to understate the welfare losses. First of all, my model only considers losses due to lower trade resulting from a Grexit and does not say anything about the actual costs of a default. Secondly, labor markets are assumed to be perfectly competitive with no frictions and unemployment. In the model, the adrespectivelyjustment is done solely through a decreases in the real wage but in real life it will also involve the unemployment channel. Thirdly, there is no government in the model to finance the public sector and public services. Faced with a default and inability to meets its social obligations, the welfare consequences are likely to be severe. Finally, the size of currency depreciation I consider is bound to cause large scale inflation, further causing distortions in the economy and lowering the standard of living.

Table 2.8: Changes in Greek welfare in the case of a default and 10 % trade surplus

	10% Surplus	**Euro exit**	**Depreciation**	
			50%	**75%**
Panel A	**Changes in welfare**			
Final goods	-1.07%	-1.48%	-1.50%	-1.51%
Intermediary goods	-2.26%	-3.22%	-3.26%	-3.27%
Prices Effects	0.81%	0.49%	-0.04%	-0.14%
Total Δ Welfare	-2.52%	-4.20%	-4.72%	-4.92%
Panel B	**Changes in imports and exports**			
ΔExports	90.09%	69.55%	71.93%	73.02%
ΔImports	-41.92%	-51.18%	-50.27%	-49.78%
Panel C	**Required productivity changes to offset losses**			
$\Delta \bar{z}_{Greece}$	1.11%	1.85%	2.09%	2.18%

2.6 Conclusion

In this paper I investigated the effect EU has on welfare though the facilitation of trade. I looked at two counterfactual scenarios: 1) what were the welfare effects of EU enlargement in 2004 and 2) what would have happened had Greece exited the Euro in 2009. For both scenarios I used the same underlying multi-sector Ricardian model calibrated to the relevant years.

In the case of EU enlargement, the welfare gains are moderate, below 6%, and new entrants gain more than incumbents several times over. Allowing for sectoral links provides a channel through which additional gains can be measured and in most cases these gains are considerable. The model indicates a clear link between trade openness and welfare gains. While the gains are not spectacular in size, one needs to remember that freer trade was but one of EU enlargement benefits.

In the case of a Greek Euro exit, the welfare losses are between 3.65% and 4.9% depending on the level of currency depreciation considered and whether Greece would need to run a surplus or not. Quantitatively these losses are not excessive, but they are only losses resulting from higher trade costs. While plausible productivity gains could offset these losses, default and Euro exit would have incurred many additional costs, and it is uncertain whether Greece would really be in a better position than it is now.

Bibliography

Alcidi, C., Giovannini, A., and Gros, D. (2012). *'Grexit': Who Would Pay for It?* Centre for European Policy Studies.

Alvarez, F. and Lucas, R. E. (2007). General equilibrium analysis of the eaton–kortum model of international trade. *Journal of monetary Economics*, 54(6):1726–1768.

Arkolakis, C., Costinot, A., and Rodriguez-Clare, A. (2009). New trade models, same old gains? Technical report, National Bureau of Economic Research.

Arkolakis, C., Demidova, S., Klenow, P. J., and Rodriguez-Clare, A. (2008). Endogenous variety and the gains from trade. Technical report, National Bureau of Economic Research.

Bernard, A. B., Eaton, J., Jenson, J. B., and Kortum, S. (2000). Plants and productivity in international trade. Technical report, National Bureau of Economic Research.

Blalock, G. and Gertler, P. J. (2008). Welfare gains from foreign direct investment through technology transfer to local suppliers. *Journal of International Economics*, 74(2):402–421.

Breuss, F. (2001). Macroeconomic effects of eu enlargement for old and new members. Technical report, WIFO.

Bun, M. and Klaassen, F. (2002). Has the euro increased trade? *Available at SSRN 338602*.

Bun, M. J. and Klaassen, F. J. (2007). The euro effect on trade is not as large as commonly thought*. *Oxford Bulletin of Economics and Statistics*, 69(4):473–496.

Burstein, A. and Vogel, J. (2012). Globalization, technology, and the skill premium: A quantitative analysis. Technical Report 16459, National Bureau of Economic Research.

Bussière, M., Fidrmuc, J., and Schnatz, B. (2005). Trade integration of central and eastern european countries: Lessons from a gravity model. Technical Report 545.

Caliendo, L. and Parro, F. (2012). Estimates of the trade and welfare effects of nafta. Technical report, National Bureau of Economic Research.

Casella, A. (1996). Large countries, small countries and the enlargement of trade blocs. *European Economic Review*, 40(2):389–415.

Chen, N. and Novy, D. (2009). International trade integration: a disaggregated approach. Technical report, CESifo working paper.

Costinot, A., Donaldson, D., and Komunjer, I. (2012). What goods do countries trade? a quantitative exploration of ricardo's ideas. *The Review of Economic Studies*, 79(2):581–608.

Dekle, R., Eaton, J., and Kortum, S. (2007). Unbalanced trade. Technical report, National Bureau of Economic Research.

Donaldson, D. (2010). Railroads of the raj: Estimating the impact of transportation infrastructure. Technical report, National Bureau of Economic Research.

Eaton, J. and Kortum, S. (1996). Trade in ideas patenting and productivity in the oecd. *Journal of international Economics*, 40(3):251–278.

Eaton, J. and Kortum, S. (2002). Technology, geography, and trade. *Econometrica*, 70(5):1741–1779.

Eaton, J., Kortum, S., and Kramarz, F. (2011). An anatomy of international trade: Evidence from french firms. *Econometrica*, 79(5):1453–1498.

Edwards, S. (1998). Openness, productivity and growth: what do we really know? *The Economic Journal*, 108(447):383–398.

Feenstra, R. C. (1994). New product varieties and the measurement of international prices. *The American Economic Review*, pages 157–177.

Griffith, R., Redding, S., and Van Reenen, J. (2004). Mapping the two faces of r&d: Productivity growth in a panel of oecd industries. *Review of economics and statistics*, 86(4):883–895.

Head, K., Mayer, T., and Ries, J. (2009). How remote is the offshoring threat? *European Economic Review*, 53(4):429–444.

Head, K. and Ries, J. (2001). Increasing returns versus national product differentiation as an explanation for the pattern of us-canada trade. *American Economic Review*, pages 858–876.

Hornok, C. (2009). Need for speed: The role of timeliness in the trade e ect of eu accession.

Klenow, P. J. and Rodriguez-Clare, A. (1997). Quantifying variety gains from trade liberalization. *University of Chicago*.

Kortum, S. S. (1997). Research, patenting, and technological change. *Econometrica: Journal of the Econometric Society*, pages 1389–1419.

Mohler, L. (2009). Globalization and the gains from variety: The case of a small open economy. Technical report, FIW.

Parro, F. (2013). Capital-skill complementarity and the skill premium in a quantitative model of trade. *American Economic Journal: Macroeconomics*.

Ricardo, D. (1817). *The principles of political economy and taxation*. John Murray.

Roaf, J., Atoyan, R., Joshi, B., and Krogulski, K. (2014). 25 years of transition post-communist europe and the imf. regional economic issues report. *International Monetary Fund, Washington, DC*.

Romalis, J. (2007). Nafta's and cusfta's impact on international trade. *The Review of Economics and Statistics*, 89(3):416–435.

Roubini, N. (2011). Greece should default and abandon the euro. *Financial Times*, 19.

Shackleton, R. (2013). Total factor productivity growth in historical perspective. Technical report, Congressional Budget Office Working Paper 2013-01.

Simonovska, I. and Waugh, M. E. (2011). The elasticity of trade: Estimates and evidence. Technical report, National Bureau of Economic Research.

Timmer, M. P., Ypma, G., and Ark, H. H. (2007). *PPPs for industry output: a new dataset for international comparisons*. University of Groningen, Groningen Growth and Development Centre.

Waugh, M. (2010). International trade and income differences. *The American Economic Review*, 100(5):2093–2124.

10.14754/CEU.2016.08

Chapter 3

Exchange Rate Movements, Firm-level Exports and Heterogeneity

joint with Antoine Berthou[†] and Emmanuel Dhyne[‡]

3.1 Introduction

The large current account imbalances accumulated by European economies before the recent financial crisis have increased their vulnerability to external shocks during the Great Recession. As the process of current account rebalancing requires relative price adjustments in deficit and in surplus economies, the debate regarding the value of the trade elasticities – a key parameter for making any quantitative assessment in macroeconomic models – has regained interest among academics and policy makers.

The elasticity of substitution between domestic and foreign goods used for calibration of macroeconomic models, such as in international business cycle theory, is often between 1 and 1.5 (Bodenstein [2010], Drozd and Nosal [2012]). However, macroeconomic trade elasticities estimated using aggregate trade equations have traditionally produced quite small trade elasticities, often between 0 and 1 (Kenen and Rodrik [1986], Bahmani-Oskooee and Ratha [2008], Goldstein and Kahn [1985], Hooper et al. [2000]) and, often, statistically insignificant. This apparent disconnection between exchange rates movements and aggregate exports has been referred to as the "International Elasticity Puzzle" [Ruhl, 2008].

[†]Banque de France
[‡]National Bank of Belgium

On the other hand, a recent strand of literature, using firm-level data or higher levels of disaggregation, has found much larger trade elasticities (Roberts and Tybout [1997], Goldberg and Tracy [2001]). For instance, Imbs and Méjean [2009] obtain a median value of about 5 for elasticities of substitution using product-level trade data, which implies a price elasticity of demand of about 4 in models with Constant Elasticities of Substitution (CES). These elasticities have been used to quantify the effects of trade openness on aggregate welfare for different classes of trade models [Arkolakis et al., 2009].

In this paper we take a new look at trade elasticities with respect to exchange rates. We build a heterogeneous firms model where firms choose to export and set their price both domestically and abroad in terms of the exchange rate and the number of competing firms. In addition, firms source some of their inputs from abroad. The model delivers sharp predictions regarding the differences in elasticities between firms of varying productivities, between productive and unproductive sectors, between diverse and uniform sectors and between sectors that are reliant on intermediates from abroad and those that are not.

We take the model's predictions to the data using a novel dataset of highly disaggregated firm data for a panel of 11 European economies over 8 years. While we do not have direct access to firm level data, we have numerous statistics for "bins" of firms within a sector, split by productivity or size. To the best of our knowledge, this paper is the first that investigates the role exchange rates play in export elasticities in a disaggregated, multi-country setting. Our empirical investigation provides evidence consistent with the theoretical framework. It emphasizes the heterogeneous response of exports revenues to real effective exchange rates movements, in relation to firms' productivity and size, in the case of 11 European countries. Results confirm that firm-level markups, importer status and sector composition characteristics are important determinants of this heterogeneity.

In particular, we investigate the role firms' productivity and size distributions have within each sector and country in influencing the elasticity of export to exchange rate fluctuations. As our main covariate of interest, we choose the real effective exchange rate (REER) as there is little to no nominal exchange rate movement between European countries. Controlling for factors such as country and sector characteristics that may affect the firm-level exports growth in our sample, the benchmark average elasticity ranges from about 0.4 to 0.9, depending on the specification. However, we find that the reaction of the average firm to REER variations hides substantial heterogeneity within a given sector and country. The elasticity obtained for least productive (smallest) firms is up to 3 times larger than for the most productive (largest) firms. These results are robust to alternative estimation techniques and robustness tests. While the average elasticity obtained is close to the value of trade elasticities used in the macro literature, this weak response of firm-level exports is mostly driven by the subdued reaction of the largest exporters.

We further take advantage of the rich structure of our data and investigate how exchange rates responses vary across sectors. We measure sectot heterogeneity in two distinct modes: first we consider heterogeneity in terms of prices (products), drawing from the approach of Rauch [1999] and second, we consider heterogeneity in terms of productivity, defined as value added per employee. In both approaches, we find that the elasticity of exports to exchange rates is smaller in more diverse sectors. A doubling of productivity would lower exchange rate elasticity by 0.3 and a perfectly differentiated sector would have an exchange rate elasticity almost four times lower than a perfectly homogeneous one.

Finally, we investigate the difference between elasticity for exporters who use intermediate inputs from abroad and those who do not. We find that exporters are able to offset much of impact of a negative exchange rate movement through access to cheaper intermediate goods, resulting in lower elasticities for sectors where two-way traders make up a substantial chunk of exporters. The mediating effect of foreign intermediates continues to hold when accounting for differences in productivity.

The remainder of the paper is organized as follows. Section 2 goes over the relevant literature. Section 3 describes the theoretical model used in guiding our thinking. Section 4 presents the data and the empirical methodology. Section 5 reports the estimation results. In Section 6, we test the robustness of our main result to alternative specifications and controls. Section 7 concludes.

3.2 Related Literature

Our theoretical framework is by no means the only one which can account for the patterns observed in the data. Below we present several alternative models which could generate heterogeneous impacts of exchange rate fluctuations on trade flows. However, it should be noted that such heterogeneous responses are generally inconsistent with recent trade models that feature constant elasticity of substitution, such as Melitz [2003], Chaney [2008].

Robert Dekle, with several co-authors, develop several macro focused papers which attempt to explain the "exchange rate elasticity puzzle" and explores the heterogeneous response of firms to exchange rate depreciations. In Dekle et al. [2009], they develop a simple New Open Economy model, building on Obstfeld et al. [1996]. They assume a continuum of firms, each producing a differentiated product with heterogeneous productivity. As the focus of their paper is empirical, they keep their model simple and solve it as a partial equilibrium only. In their framework the sensitivity of exports to exchange rates is determined by preferences and technology: firms that rely abundantly on imported inputs and have decreasing returns to scale have a lower exchange rate elasticity. At the same time, firms producing in sector with a higher elasticity of substitution between goods face a higher exchange rate elasticity.

In Dekle et al. [2013], they build a dynamic general equilibrium, that generates significant firm level response to exchange rate fluctuations while aggregate quantities don't move much. In their an open real business cycle model, heterogeneous firms face both aggregate and idiosyncratic shocks. Each firm produces a different bundle of goods and productivity is product specific. The extent to which a firm reacts to exchange rate appreciations depends on the productivity of its product mix. All products adjust on the intensive margin, but the size of the adjustment is limited. Low productivity goods, on the other hand adjust on the extensive side as well, generating a much larger elasticity.

Melitz and Ottaviano [2008] build upon the heterogeneous firms framework of Melitz [2003], but consumers have linear quadratic utility over the set of goods, rather than CES. This modification generates endogenous markups that depend on firm productivity. Highly productive firms face a lower demand elasticity and, therefore, are less responsive to exchange rate fluctuations. Following currency depreciation, all exporters increase the prices they charge, but high-productive firms are able to increase their markup more, engaging in more pricing-to-market.

Atkeson and Burstein [2008] propose a model in which heterogeneous firms engage in quantity competition. They build a symmetric two country economy with heterogeneous firms split into sectors. They assume that in each sector, firms produce goods that are imperfect substitutes and there is a small number of firms in each sector. As there are a finite number of firms in each sector, each firm has a non-trivial market share and changes in costs lead to changes in the market share and, in equilibrium, also in markups. These assumptions lead to imperfect pass-through between costs and prices that depends on firm productivity: Firms with a larger market share will have a higher markup than low productivity firms and also engage in more pricing to market.

Amiti and Davis [2012] build on the model of Melitz [2003],allowing firms to choose to import intermediate inputs. The largest exporters are also the largest importers and high productivity firms are able to offset exchange rate fluctuations in their destination market with changes in prices in their inputs, whereas small firms with no imported intermediates have nearly complete pass-through.

Berman et al. [2012] base their empirical approach on a model with distribution costs. They consider heterogeneous firms that export to a number of countries under monopolistic competition. In each country they must pay a fixed sum for distribution, independent of the firm's productivity. Therefore, for high-productivity firms, the producer pricer will form only a small part of the final price faced by consumers. As in the other models summarised in this section, the demand elasticity is decreasing in the exchange rate and in productivity, leading high productivity firms to face a lower demand elasticity that allows them to increase their markup more.

Finally, Rodríguez-López [2011], whose model we start from, builds a dynamic two country open economy setup, incorporating translog preferences. More productive firms are able to charge higher markups. The paper predicts firm level export quantities are elastic with respect to exchange rate movements, however, the elasticity of export values is decreasing in productivity and approaches 0 as productivity approaches inf.

Our work contributes to a burgeoning literature that investigates the macroeconomic consequences of heterogeneity. Recent empirical evidence has shown that exports are extremely concentrated among only few firms (Mayer and Ottaviano [2008], Berthou et al. [2015a]). A recent paper by Gabaix [2009] shows that this very granular distribution of firms' market shares implies that microeconomic shocks affecting few firms can have very large aggregate impacts. In another strand of the literature, Ossa [2012] shows that accounting for heterogeneity across sectors substantially boosts the possible gains from trade.

In parallel, firm-level data have been used in different works to estimate microeconomic trade elasticities. Bas et al. [2015] or Berthou and Fontagne [2015] use French firm-level export data to estimate variable trade cost elasticities. The estimated micro elasticities obtained are quite large and are in line with previous studies using product-level trade data [Imbs and Méjean, 2009]. Other works have rather focused on the effects of real exchange rates variations, and obtained weaker elasticities (see for instance Fitzgerald and Haller [2014], in the case of Ireland). Closely related to our work is the study by Berman et al. [2012], which shows, in the case of France, that more productive firms change their prices more in response to Euro variations, and react less in volume terms. They show that this empirical result can be rationalized in a trade model with CES preferences, if firms incur a fixed distribution cost paid in foreign currency to export in a given destination.

3.3 Theoretical Model

To guide our empirical strategy we build a model with heterogeneous firm and variable markups. Our starting point is the model in Rodríguez-López [2011]. We build a simple extension to it, adding an intermediate goods sector and allowing for firms to source some of their inputs from abroad. While the main variable of interest in the empirical section is the real effective exchange rate, in the theoretical section we use the nominal exchange rate between countries to highlight the transmission mechanism of shocks[1].

Let us consider two symmetric countries: Home and Foreign. In solving the model we will focus on the Home side, and derive Foreign country analogue equations only when necessary. Variables related to the foreign market will be denoted by $\star$ superscript. In each country there are two sectors, a heterogeneous final goods sector and a homogeneous intermediate goods sector, called Manufacturing (related variables will be denoted with m).

The model is a partial equilibrium one, in that wages and consumers' incomes are exogenously set. In addition, the labor market and production are segmented between countries.

3.3.1 Consumers

Households only consume the heterogeneous good. Following Rodríguez-López [2011], Feenstra [2003] and Bergin and Feenstra [2001], we use translog preferences for households. While this preference structure does not have a closed form utility function, a demand system can still be derived.

Let Δ be the set of measure N of goods available at Home coming from both Home and Foreign. The expenditure function for translog preferences is [Diewert, 1974]

$$\ln E = \ln U + \frac{1}{2\gamma N} + + \frac{1}{N} \int_{i \in \Delta} \ln p_i di + \frac{1}{2N} \int_{i \in \Delta} \int_{j \in \Delta} \gamma_{ij} \ln p_i \left(lnp_j - \ln p_i \right) dj di \tag{3.1}$$

where E is the expenditure level required to obtain utility U and p_i is the price of good i; γ is a scalar indicating the degree of differentiation between goods, with a high γ value indicating a low degree of differentiation.

Taking the derivative of the above equation we get s_i, the share of good i in household expenditure

$$s_i = \gamma \ln \frac{\exp\left(\frac{1}{\gamma N} + \overline{\ln p}\right)}{p_i} = \gamma \ln \frac{\widehat{p}}{p_i} \tag{3.2}$$

[1] There is large body of literature identifying a very tight link between nominal and real exchange rate fluctuations: Connolly and Taylor [1976], Vaubel [1978], for instance. Cheung and Sengupta [2013] investigate the impact of both NEER and REER fluctuations on firm level exports for Indian firms and finds numerically similar results for both measures.

where $\widehat{p}$ is the maximum price firms can charge and $\overline{\ln p}$ is the average price in the country. That is, if $p_i > \widehat{p}$, the consumption share of good i is be negative, so in practice it is bound by 0. Households demand for good i is given by

$$q_i = s_i \frac{I}{p_i} \tag{3.3}$$

3.3.2 Firms

3.3.2.1 Intermediate goods

The intermediate sector is perfectly competitive and homogeneous. Firms produce manufacturing goods from labour according to

$$y_m = l^\beta$$

Without loss of generality, we assume $\beta = 1$. Therefore the price of manufacture goods, p_m, will be equal to price of labor, W. Furthermore, without loss of generality, we assume the intermediate good is freely traded across countries.

3.3.2.2 Final goods

In the final goods sector, production is set in a standard Melitz framework: There is a continuum of firms producing differentiated products, that are heterogeneous in their productivity. Entry is unrestricted but there is a fixed cost associated with firm entry, $f_E \times W$. Firms know their productivity level, ϕ_i, only upon entry and low-productivity firms will exit the market immediately if their productivity is below a certain threshold to be detailed later. The output of a firm i is

$$q_i = \phi_i \left(m + \alpha m^\star\right) \tag{3.4}$$

where m and $m^\star$ and manufacturing goods from Home and Foreign, respectively and $\alpha < 1$ is a fixed share. Production is realized according to a fixed recipe, in a Leontief fashion, so firms cannot substitute between domestic and foreign intermediates. The main advantage of this specification is that any changes in the exchange rate will not make the cost of supplying intermediates so onerous that firms decide to exit the market. Using more sophisticated production function, that allow firms to choose the source of intermediates, such as Cobb-Douglas or CES, would leave main conclusions of the model intact. Howver, implementing them would require bounds on either the production function parameters or the range of exchange rate movements to ensure firms are not over-reliant on imported inputs and a currency depreciation does not inhibit exports. One obvious unrealistic implication of the current Leontief modelling choice is that all firms use Foreign inputs when in reality this may not be the case. Allowing firms to explicitly choose between domestic and foreign inputs, possibly depending on their productivity, could allow corner solutions where a subset of firms uses only domestic or only foreign inputs. Exploring these possibilities goes beyond the scope of this paper.

Under the chosen specification the cost to produce one unit of output is:

$$c = p_m + \varepsilon \alpha p_m^{\star}$$

where ε is the exchange rate, defined such that an increase implies depreciation of the Home currency. As the model is set in partial equilibrium, demand is fixed and firm i maximizes its profits by choosing only the price it charges:

$$\max_{p_i} \pi_i = p_i q_i - c q_i \tag{3.5}$$

subject to supply equalling demand from (3.3). Solving the above maximization problem leads to the first order condition

$$mc_i \left(1 + \ln \frac{\widehat{p}}{p_i}\right) = p_i \tag{3.6}$$

where $mc_i = \frac{c}{\phi_i}$. While there is no apparent explicit solution to p_i, Rodríguez-López [2011] shows that the optimal price can be rewritten using the W Lambert function

$$p_i = \Omega\left(\frac{\widehat{p}}{mc_i} e\right) mc_i \tag{3.7}$$

where Ω is the W Lambert function. (3.7) can be further re-arranged so that the price is given by the constant marginal cost and the markups:

$$p_i = (1 + \mu_i)\, mc_i \tag{3.8}$$

where

$$\mu_i = \frac{p_i - mc_i}{mc_i} = \Omega\left(\frac{\widehat{p}}{mc_i} e\right) - 1 \tag{3.9}$$

is the markup for firm i. Given the properties of the Lambert function, the markup is decreasing in marginal costs, reaching 0 when the marginal cost equals the limitation price $\hat{p}$. One other useful results that we'll be using in solving the model is

$$s_i = \gamma \mu_i \tag{3.10}$$

In order to sell abroad, firms need to pay iceberg trade costs, $\tau > 1$. As markets are segmented, firms choose different prices and different markups between the Home and Foreign markets. Specifically, prices depend on markups, which in turn are a function of trade costs, exchange rates and the number of goods in each market. Substituting these insights into (3.8) and (3.9), we get that a firm with productivity ϕ that operates both in the Home and the Foreign market will charge the following prices:

$$\begin{aligned} p_D(\phi) &= (1 + \mu_D(\phi))\, \tfrac{c(\varepsilon)}{\phi} \\ p_X(\phi) &= (1 + \mu_x(\phi))\, \tfrac{\tau c(\varepsilon)}{\varepsilon \phi} \end{aligned} \tag{3.11}$$

Markups are given by

$$\begin{aligned} \mu_D(\phi) &= \Omega\left(\tfrac{\widehat{p}}{\frac{c}{\phi}} e\right) - 1 \\ \mu_X(\phi) &= \Omega\left(\tfrac{\widehat{p^\star}}{\frac{\tau c}{\varepsilon \phi}} e\right) - 1 \end{aligned} \tag{3.12}$$

Plugging in the optimal price in the profit maximization equation, (3.5), we obtain the profits for the domestic and export markets:

$$\begin{aligned} \pi_D(\phi) &= \gamma \tfrac{I \mu_D(\phi)^2}{(1+\mu_D(\phi))} \\ \pi_X(\phi) &= \gamma \tfrac{I^\star \mu_X(\phi)^2}{(1+\mu_X(\phi))} \end{aligned} \tag{3.13}$$

The two profit equations identical from a functional point of view, as all information on exchange rates, market conditions and trade costs is contained within the markups. Combining demand equations (3.3) with the optimal price, (3.11), we get the following supply equations:

$$\begin{aligned} y_D(\phi) &= \tfrac{\mu_D(\phi)}{1+\mu_D(\phi)}\tfrac{\gamma I\phi}{c} \\ y_X(\phi) &= \tfrac{\mu_X(\phi)}{1+\mu_X(\phi)}\tfrac{\varepsilon\gamma I^{\star}\phi}{c\tau} \end{aligned} \tag{3.14}$$

3.3.3 Cutoffs

There is a natural sorting in the model: The least productive firms will have prices higher than the maximal price and, as there is no demand for their products at that price, will exit the market immediately; the next more productive ones will sell in the domestic market only; the most productive ones will sell both at home and abroad. Demand/Supply is equal to 0, when markups are equal to 0, i.e. $\widehat{p} = \frac{c}{\phi}$, domestically, and $\widehat{p^{\star}} = \frac{c\tau}{\phi\varepsilon}$ abroad, so the cutoffs for domestic and export markets are:

$$\phi_D = \frac{c}{\widehat{p}} \tag{3.15}$$

$$\phi_X = \frac{c\tau}{\widehat{p^{\star}}\varepsilon} \tag{3.16}$$

We assume the countries are similar and trade costs high enough that $\phi_X > \phi_D$. For Foreign firms the cutoffs are analogously obtained:

$$\phi_D^{\star} = \frac{c^{\star}}{\widehat{p^{\star}}} \tag{3.17}$$

$$\phi_X^{\star} = \frac{c^{\star}\varepsilon\tau}{\widehat{p}} \tag{3.18}$$

Using the above four equations, we can rewrite the exporters' cut-offs in terms of the domestic conditions for Home and Foreign:

$$\begin{aligned} \phi_X^{\star} &= \tfrac{c^{\star}\varepsilon\tau}{\widehat{p}} = \varepsilon\tau\tfrac{c^{\star}}{c}\phi_D \\ \phi_X &= \tfrac{c\tau}{\widehat{p^{\star}}\varepsilon} = \varepsilon\tau\tfrac{c}{c^{\star}}\phi_D^{\star} \end{aligned} \tag{3.19}$$

As in most Melitz-type models, we assume the distribution is Pareto distributed on the interval $[\phi_{min}, \infty)$, $\phi_{min} > 0$. The cumulative productivity distribution is given by $G(\phi) = 1 - \left(\frac{\phi_{min}}{\phi}\right)^k$, where k is the parameter governing the productivity distribution, a higher k implying less heterogeneity. The use of the Pareto distribution leads to several analytical implications that will be of use in solving the model and deriving its predictions.

For a given market M, where market means Home or Foreign, the density of firms that sell in that market is

$$g(\phi|\phi > \phi_D) = \frac{g(\phi)}{1 - G(\phi_D)} \tag{3.20}$$

As the truncation of a Pareto distribution is a Pareto distribution itself, the average productivity of firms for market M:

$$\overline{\phi^M} = \frac{k}{k-1}\phi^M \tag{3.21}$$

The average markup for a market M is constant and only depends on the productivity distribution parameter

$$\mu_X^\star = \mu_D = \overline{\mu(k)}^{2} \tag{3.22}$$

One other useful results is that the number of goods in each country is constant and equal to $1\big/\gamma\overline{\mu(k)}$. However, the composition of goods, domestic or foreign, will vary. Let N_P and $N_P^\star$ be the number of potential firms in each country. The number of domestic and exporting firms can be derived using the cutoffs

$$\begin{aligned} N_D &= (1 - G(\phi_D))N_P \\ N_X &= (1 - G(\phi_X))N_P \\ N_D^\star &= (1 - G(\phi_D))N_P^\star \\ N_X^\star &= (1 - G(\phi_X))N_P^\star \end{aligned} \tag{3.23}$$

This forms a system of equation from which closed form solution for N_p and $N_P^\star$ can be obtained.

$$\begin{aligned} N_P &= \tfrac{1}{\gamma\overline{\mu(k)}\phi_{min}^k}\left[\tfrac{\tau^{2k}\phi_D^k - \phi_X^k}{\tau^{2k}-1}\right] \\ N_p^\star &= \tfrac{1}{\gamma\overline{\mu(k)}\phi_{min}^k}\left[\tfrac{\tau^{2k}\phi_D^{\star k} - \phi_X^{\star k}}{\tau^{2k}-1}\right] \end{aligned} \tag{3.24}$$

There is unbound entry in each country. Firms pay an entry cost $f_E W$ and will continue to enter until expected profits are equal to the entry costs. Each period firms risk a death

[2] $\overline{\mu(k)} = \int\limits_1^\infty \frac{\Omega(xe)-1}{x^{k+1}}dx$

shock that strikes with probability δ. As more firms enter the market, profitability is lowered until expected profits are

$$\overline{\pi} = \frac{f_E W}{\delta} \tag{3.25}$$

Expected profits are the sum in domestic currency of domestic profits and exporting profits in the local currency

$$\overline{\pi} = \overline{\pi_D} + \varepsilon \overline{\pi_X} \tag{3.26}$$

where

$$\begin{aligned} \bar{\pi}_D &= \tfrac{\psi I}{(\phi_D)^k} \\ \bar{\pi}_X &= \tfrac{\psi I^\star}{(\phi_X)^k} \\ \psi &= \tfrac{\gamma \mu(k) \phi_{min}^k}{k+1} \end{aligned} \tag{3.27}$$

3.3.4 Model Solution

All model equations above depend only on parameters and the productivity cutoffs. In order to fully solve the model, explicit solutions for the cutoffs are needed. They can be easily derived as follows

$$\begin{aligned} \phi_D &= \tfrac{\Psi_D}{\tau} \left[\tfrac{\tau^{2k}-1}{\tau^k - (\rho\varepsilon)^{k+1}} \right]^{\frac{1}{k}} \\ \phi_X &= \tfrac{\Psi_X}{\tau \varepsilon \rho^{\frac{k+1}{k}}} \left[\tfrac{\tau^{2k}-1}{\tau^k - \frac{1}{(\rho\varepsilon)^{k+1}}} \right]^{\frac{1}{k}} \\ \phi_D^\star &= \tfrac{\Psi_D^\star}{\tau} \left[\tfrac{\tau^{2k}-1}{\tau^k - \frac{1}{(\rho\varepsilon)^{k+1}}} \right]^{\frac{1}{k}} \\ \phi_X^\star &= \tfrac{\Psi_X^\star}{\tau} \rho^{\frac{k+1}{k}} \varepsilon \left[\tfrac{\tau^{2k}-1}{\tau^k - (\rho\varepsilon)^{k+1}} \right]^{\frac{1}{k}} \end{aligned} \tag{3.28}$$

where

$$\begin{aligned} \rho &= \left(\tfrac{f_E^\star W^\star}{f_E W} \right)^{\frac{1}{k+1}} \left(\tfrac{c^\star}{c} \right)^{\frac{k}{k+1}} \\ \Psi_D &= \left(\tfrac{\psi I}{\delta f_E W} \right)^{\frac{1}{k}} \\ \Psi_D^\star &= \left(\tfrac{\psi I^\star}{\delta f_E W} \right)^{\frac{1}{k}} \\ \Psi_X &= \left(\tfrac{\psi I^\star}{\delta f_E W^\star} \right)^{\frac{1}{k}} \Psi_X^\star = \left(\tfrac{\psi I}{\delta f_E W^\star} \right)^{\frac{1}{k}} \end{aligned} \tag{3.29}$$

Note that the asymmetry between Home and Foreign cutoffs stems from the definition of the exchange rate. For the remainder of the paper I will assume perfect symmetry between countries, i.e. $W = W^{\star}$ and $f_E = f_E^{\star}$.

3.3.5 Exchange Rate Movements

The main question this paper aims to answer is "How does the elasticity of exchange rates vary according to sector characteristics and to firm productivity?". As everything in the model can be rewritten in terms of cut-offs, obtaining the elasticity of cutoffs to exchange rates is a helpful first step.

Proposition 1:

- *The domestic cutoff elasticity with respect to exchange rate movements is positive and monotonically increasing and is given by:*

$$\xi_{\phi_D,\varepsilon} = \frac{\partial \ln \phi_D}{\partial \ln \varepsilon} = \frac{k+1}{k} \frac{\varepsilon^{k+1}\rho^{k+1}}{\tau^k - (\rho\varepsilon)^{k+1}} \left[1 - \frac{k}{k+1}\varpi\right] > 0$$

where

$$0 \leqslant \varpi = \frac{\alpha + 2\alpha^2\varepsilon + \alpha\varepsilon^2}{\varepsilon + \alpha\varepsilon^2 + \alpha + \alpha^2\varepsilon} \leqslant 1$$

The above proposition has several important implications. First of all, currency depreciation raises the expected profits of firms through the profits they will realize in the abroad market and also puts Home domestic firms at a comparative advantage with Foreign firms. As expected profits rise, more firms attempt to enter the Home market. However, for the free entry condition to hold, expected domestic profits must fall, leading to a higher barrier of entry to the domestic market. Second, the ϖ terms acts as a break, lowering the impact of exchange rate movements on the cutoff. In the appendix we show that ϖ is increasing in α, so the larger the dependence on Foreing intermediates the less meaningful the effect of exchange rate movements is as firms can offset shocks. Note that if firms do not use any Foreign intermediate inputs, $\alpha = 0$, the penalty term is 0, and the elasticity is the same as in Rodríguez-López [2011]. Conversely, if $\alpha = 1$, $\varpi = 1$ and the elasticity is at its minimum $\frac{1}{k}\frac{\varepsilon^{k+1}\rho^{k+1}}{\tau^k-(\rho\varepsilon)^{k+1}}$.

Similarly, the foreing cutoff elasticity is

$$\xi_{\phi_D^\star,\varepsilon} = \frac{\partial \ln \phi_D^\star}{\partial \ln \varepsilon} = -\frac{k+1}{k\rho} \frac{(\rho\varepsilon)^{-(k+1)}}{\tau^k - (\rho\varepsilon)^{-(k+1)}} \left[1 - \frac{k}{k+1}\varpi\right] < 0$$

Proposition 2:

- *The export cutoff elasticity with respect to exchange rate movements is negative and is given by:*

$$\xi_{\phi_X,\varepsilon} = -\frac{k+1}{k\rho} \frac{(\rho\varepsilon)^{-(k+1)}}{\tau^k - (\rho\varepsilon)^{-(k+1)}} \left[1 - \frac{k}{k+1}\varpi\right] - 1 + \left(\frac{\alpha}{\varepsilon+\alpha} + \frac{\alpha\varepsilon}{1+\alpha\varepsilon}\right)$$

where the penalty term is

$$0 \leq \frac{\alpha}{\varepsilon+\alpha} + \frac{\alpha\varepsilon}{1+\alpha\varepsilon} \leq 1$$

As with domestic elasticities, allowing for imported intermediates leads to a shrinkage towards zero of the elasticities. When $\alpha = 0$, both the penalty term and ϖ are 0 leading to the classic result of Rodríguez-López [2011], $\xi_{\phi_X,\varepsilon} = \xi_{\phi_D^\star,\varepsilon} - 1$. Conversely, if $\alpha = 1$, firms use only Foreign goods as intermediates, $\xi_{\phi_X,\varepsilon} = \xi_{\phi_D^\star,\varepsilon}$.

Proposition 3:

- *The elasticity of export values with respect to the exchange rate is positive, and is equal to*

$$\xi_{V,\varepsilon} = -\Omega'\left(\frac{\phi}{\phi_X}e\right)\frac{\phi}{\phi_X}\frac{e}{\Omega\left(\frac{\phi}{\phi_X}e\right) - 1}\xi_{\phi_X,\varepsilon} > 0 \tag{3.30}$$

One interesting implication of proposition 3 is that the export elasticity for the average firm will be the same regardless of γ. The productivity of the average firm is $\overline{\phi_X} = \frac{k}{k+1}\phi_X$. As γ only influences the elasticity through the cutoffs in $\Omega\left(\frac{\phi}{\phi_X}e\right)$, it ends up not influencing the elasticity at all for the average firm. This leads to a serious warning to consider in empirical work: Even if on average the sectors appear to have the same elasticity, there are important differences in the response of firms within sectors.

Proposition 4:

- *The elasticity of export values with respect to the exchange rate is decreasing in firm productivity.*

The elasticity of export values can be represented as markups divided by a polynomial of markups, $\xi_{V,\varepsilon} = -\frac{\mu(\phi)+1}{\mu(\phi)^2+2\mu(\phi)}\xi_{\phi_X,\varepsilon}$. As more productive firms charge a higher markup, it is straightforward to see that in the limit, the elasticity goes to 0 for infinitely productive firms and to $-\infty$ for $\phi = \phi_X$. In the appendix we show the formal proof.

Proposition 5:

- *Sectors that are more differentiated will have a lower elasticity of exports: i.e. sectors with lower γ will have lower elasticity.*

Again, to build intuition for this result it helps to represent the elasticity in terms of markups. Firms set their markup as a function of the maximal price they can charge in a market. If the sector is highly diverse in terms of products, the maximal price will be higher and markups will be consequently higher. Therefore, the elasticity of export values is a decreasing function in markups and it will be lower if diversity is high.

Proposition 6:

- *The exchange rate elasticity of exports is decreasing in the share of intermediate goods used.*

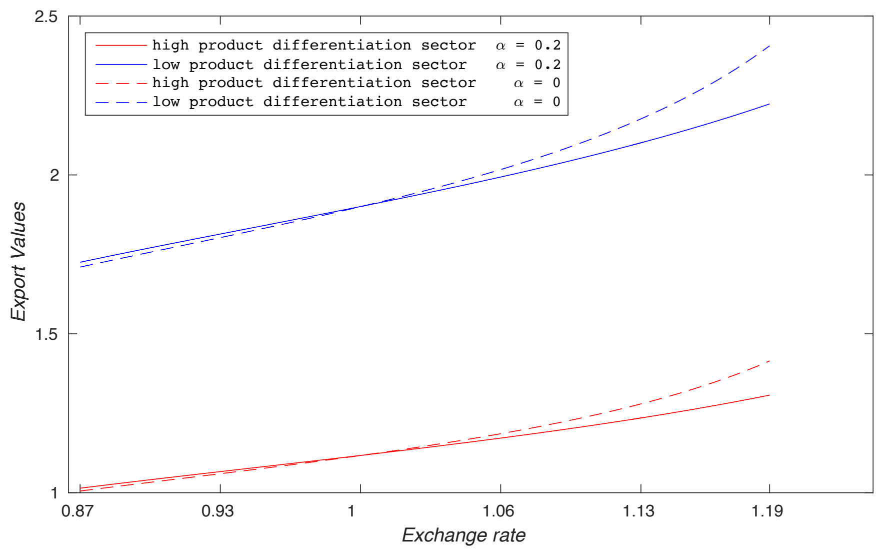
The export value elasticity to exchange rates is decreasing in the export cutoff elasticity, which in turn is increasing in the share of Foreign goods. If a country is highly dependent on Foreign goods, the impact of exchange rate movements on the export cutoff will be minimal as loses on the export market are offset by access to cheaper inputs.

The following figures provide a visual summary of the model's main predictions. Besides the above 6 propositions, there is another important implication that, unfortunately is too complicated to show analytically, but can easily be show to hold through computer simulations.

- *More heterogeneity implies a lower elasticity.*

There are two sources of heterogeneity in the model, γ, governing product variety, and k, governing productivity dispersion. Figure 3.1 shows how total exports vary with the exchange rate depending on product variety, γ, and it is obvious that the elasticity is lower in sectors with more product heterogeneity. Similarly, Figure 3.2 shows how the elasticities differ for varying productivity levels, assuming two different values of γ.

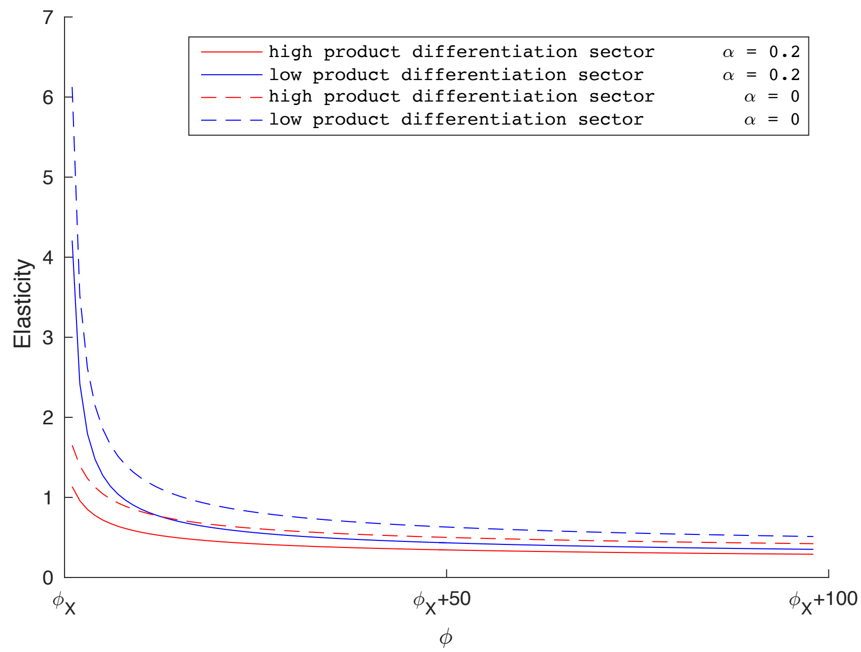
Figure 3.1: Total export values with respect to exchange rates



Simulation for symmetric countries with $I = W = 1$, $f_E = 0.2$, $\delta = 0.1$, $\tau = 1.4$, $k = 4$, $\boldsymbol{\gamma^1 = 2}$, $\boldsymbol{\gamma^2 = 34}$

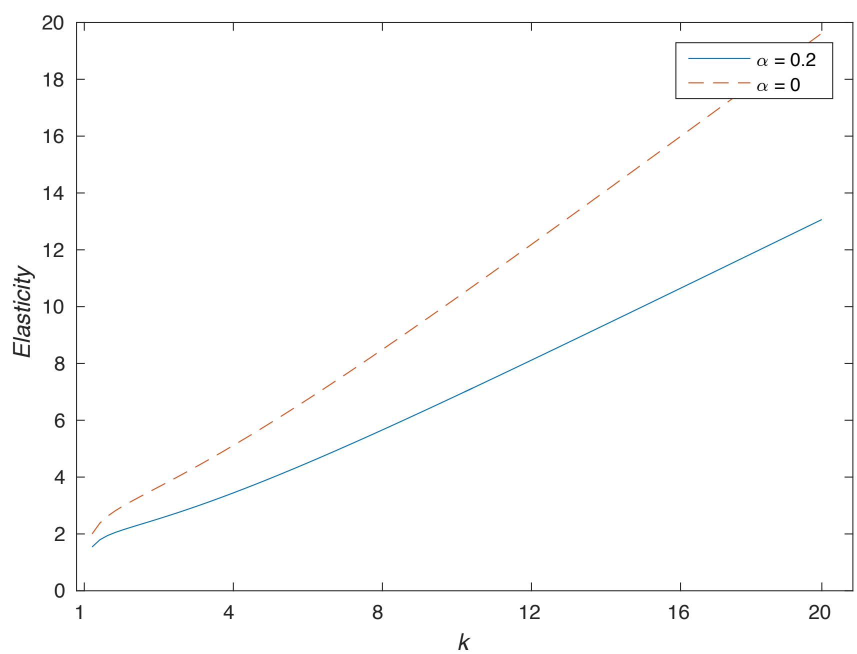
In addition, the elasticity of exports will be lower if k is lower, i.e. the productivity distribution is flat and narrow. As productivity is drawn from a Pareto distribution, a lower k implies both a higher average productivity and more heterogeneity. Figure 3.3 plots how the elasticity of exports with respect to the exchange rate changes for various values of k, showing a monotonic and near linear relationship.

Figure 3.2: Exchange rate elasticity of export values for varying levels of productivity



Simulation for symmetric countries with $I = W = 1$, $f_E = 0.2$, $\varepsilon = 1.1$, $\delta = 0.1$, $\tau = 1.4$, $k = 4$, $\boldsymbol{\gamma^1 = 2}$, $\boldsymbol{\gamma^2 = 34}$

Figure 3.3: Export values' exchange rate elasticity for the average exporter as a function of k



Simulation for symmetric countries with $I = W = 1$, $f_E = 0.2$, $\varepsilon = 1.1$, $\delta = 0.1$, $\tau = 1.4$, $\gamma = 34$

In all figures, each line is drawn under two alternative shares of intermediate input goods. Solid lines represent the elasticities assuming 20% of intermediate goods are imported and dashed lines show the model implications assuming autarchic production. As detailed in Proposition 6, an increase in dependence on Foreign goods lowers the elasticity.

Proposition 3 - 6 offer testable implications that will be empirically examined in the next sections.

3.4 Data and Empirical Strategy

3.4.1 Data

In order to test the model's predictions we need three types of data: disaggregated exports and productivity, real effective exchange rate (REER) and aggregate trade flows. Disaggregated data is drawn from the dataset produced by CompNet, a network consisting of the Competitiveness Research Network at the European Central Bank and most Central Banks in the European Union. As the network has prepared several descriptive and methodological papers on the creation and structure of the database[3], we will only give a brief overview of the data here.

The data is collected as part of a distributed code approach using balance sheet data from 21 European countries. As firm-level data are typically confidential and their usage is restricted to one country analysis, in order to be able to work with multiple countries, outside of specific and narrow purposes, one typically has to use aggregate data. CompNet partially bypasses these restriction by aggregating firms into productivity bins within sectors and provides a staggering number of statistics on firm level information for a large set EU countries, albeit aggregated at a granular sector level (2 digit NACE2)[4].

In this paper, we use firms' total yearly exports as our main variable of interest and productivity data (both labor productivity and estimated TFP[5]). The data is available

[3]See Lopez-Garcia et al. [2015] for a general description and Berthou et al. [2015b] for a description of the trade variables within the dataset.

[4]Special care was devoted to harmonizing definitions of variables, the outlier treatment and the use of deflators across countries and different national definitions.

[5]TFP is estimated at the firm level during the data collection phase of Compnet from the residual of

for 11 countries in 22 manufacturing sectors. In each sector, we use average export value and the average growth rate (in delta logs) of exports for exporters with more than 20 employees, broken down by their productivity and size deciles. Size is defined as the number of employees, and productivity is defined as value added per employee. The deciles are redefined every years so the top 10% of firms will not be the same every year, for instance. For this paper, though, we aggregate the deciles and perform the analysis at the quartile level. That is, we have the average delta log growth rate of export revenues for the 25% least productive firms in a sector, for the next 25% productive firms and so on[6]. Summary statistics for the growth rate of exports by country and productivity/size class are available in Table 3.1. In order not to have our results too strongly influenced by the recent financial crisis and associated trade collapse, we restrict our sample to the years 2001-2008.

Table 3.1: Descriptive statistics: average delta log exports by country and quartiles

Country	Productivity quartile				Size quartile			
	1	2	3	4	1	2	3	4
Belgium	0.062	0.056	0.018	-0.043	0.033	0.033	0.035	-0.001
Estonia	0.196	0.150	0.074	-0.163	0.187	0.149	0.099	-0.189
Finland	0.092	0.086	0.025	-0.027	0.078	0.079	0.098	-0.035
France	0.076	0.058	0.027	-0.039	0.052	0.057	0.052	-0.045
Hungary	0.116	0.088	0.070	0.022	0.108	0.074	0.074	0.022
Italy	0.102	0.070	0.044	-0.022	0.081	0.081	0.052	-0.017
Lithuania	0.187	0.147	0.036	-0.076	0.155	0.100	0.037	-0.089
Poland	0.193	0.171	0.085	-0.007	0.180	0.184	0.116	-0.036
Portugal	0.128	0.104	0.068	-0.009	0.089	0.079	0.078	-0.030
Slovakia	0.180	0.155	0.134	0.011	0.163	0.139	0.133	0.015
Slovenia	0.131	0.111	0.054	0.001	0.084	0.101	0.078	0.056

Note: The cells represent the averages of each quartile across sectors and years

One possible reason for exchange rate heterogeneity is the fact that some firms are also importers and can hedge the losses they may incur on the export side with access to cheaper

fitted Cobb-Douglas function on Real Value Added. The methodology is a modification of Wooldridge [2009] as proposed in Galuscak et al. [2011]. See Lopez-Garcia et al. [2015] for details on the exact implementation for the database in question.

[6]Keeping the data structured in the initial deciles does not alter the results in any meaningful way, but makes them harder to follow due to excessive granularity.

inputs and vice-versa. In order to test this possibility, we also examine how the pattern of importers among exporting firms affects estimated elasticities. As part of the data collection exercise, CompNet also documented the share of two-way traders in each bin for all sectors, countries and years. Table 3.2 shows summary statistics on the distribution of importers across sectors. A cursory look over the table reveals that some sector, such as chemical production or computer and optics, are more likely than others to be import oriented whereas other sectors are inherently domestically focused, such as food products. Nonetheless, looking at dispersion, there are important differences between countries and productivity classes. However, in all sectors that are bins where all exporters are importers and also where all exporters source only domestic inputs.

REER data are obtained from the Bruegel REER database [Darvas, 2012]. Two different estimates are available: one based on Consumer Price Indices (CPI) and one based on unit labor costs (ULC). CPI based REER are annual and computed using a broad index of 172 trading partners. ULC based REER are calculated against 30 trading partners for manufacturing sectors only. As ULC exchange rate data is at a quarterly frequency in the Bruegel database, we use only the first quarter data of each year to compute the yearly REER growth rate. We will use both measures, in turn, in order to check the sensitivity of our results to measurement issues. However, we will be giving more credence to the ULC estimates as they are based only on manufacturing sectors and are more closely related to the notion of productivity which we explore.

We need to control for changes in total foreign demand. To do this, we follow Berman et al. [2015] and construct demand shifters based on aggregated trade flows at the sector level. We define the demand shifters as $D_{ikt} = \sum_j \frac{V_{ijkt}}{V_{ikt}} M_{jkt}$, where V_{ijkt} are bilateral exports from country i to country j in sector k at time t, V_{ikt} are total export of country i in sector k and M_{jkt} are total imports of country j in sector k. Trade data is obtained from the BACI dataset [Gaulier and Zignago, 2010], aggregated in NACE2 two digits sector level, for all counties in the world, not just the ones in our sample. Table 3.3 shows summary statistics by country for the main variables in our specification.

Table 3.2: Distribution of the share of importers by sector

Sector	Min	25%	50%	75%	Max	Mean	SD
Food products	0%	12.9%	31.8%	56.2%	100%	35.2%	25.1%
Beverages	0%	33.3%	54.3%	68.9%	100%	50.1%	26.3%
Textiles	0%	46.4%	62.8%	78.6%	100%	59.8%	27.2%
Wearing apparel	0%	17.4%	41.2%	74.4%	100%	45.3%	31.4%
Leather and related products	0%	20.2%	52.6%	75.9%	100%	49.3%	31.1%
Wood and of products of wood and cork, except furniture	0%	24.3%	41.9%	61.7%	100%	43.3%	24.9%
Paper and paper products	0%	43.5%	65.0%	80.0%	100%	60.2%	27.8%
Printing and reproduction of recorded media	0%	14.8%	27.3%	44.0%	100%	30.2%	20.2%
Chemicals and chemical products	0%	68.8%	83.3%	93.8%	100%	75.0%	27.0%
Basic pharmaceutical products and pharmaceutical preparations	0%	68.3%	75.9%	85.6%	100%	73.9%	19.9%
Rubber and plastic products	0%	50.4%	71.8%	87.2%	100%	65.9%	27.3%
Other non-metallic mineral products	0%	26.8%	39.8%	50.4%	100%	39.9%	23.2%
Basic metals	0%	54.3%	74.7%	85.7%	100%	67.5%	25.8%
Fabricated metal products, except machinery and equipment	0%	26.0%	39.3%	61.8%	100%	43.0%	23.5%
Computer, electronic and optical products	0%	56.5%	76.1%	88.4%	100%	69.1%	27.9%
Electrical equipment	0%	48.5%	69.5%	86.2%	100%	64.5%	27.3%
Machinery and equipment	0%	49.3%	70.7%	86.1%	100%	64.9%	26.2%
Motor vehicles, trailers and semitrailers	0%	52.7%	72.9%	84.8%	100%	66.1%	26.8%
Other transport equipment	0%	39.8%	57.7%	72.6%	100%	55.4%	21.1%
Furniture	0%	33.0%	52.4%	70.1%	100%	51.4%	26.2%
Other manufacturing	0%	50.0%	69.6%	80.4%	100%	63.9%	26.9%
Repair and installation of machinery and equipment	0%	11.0%	22.8%	42.9%	100%	27.2%	21.5%
Overall	0%	31.3%	56.6%	77.5%	100%	53.8%	29.4%

Table 3.3: Descriptive statistics: real effective exchange rate, exports and demand

	REER CPI-based (delta log)	REER ULC-based (delta log)	Exports value (delta log)	Foreign demand (delta log)
Belgium	0.019	0.017	0.028	0.043
	(0.019)	(0.013)	(0.231)	(0.050)
Estonia	0.034	0.073	0.090	0.045
	(0.020)	(0.046)	(0.391)	(0.057)
Finland	0.011	0.015	0.050	0.042
	(0.026)	(0.026)	(0.265)	(0.052)
France	0.018	0.020	0.033	0.042
	(0.023)	(0.021)	(0.162)	(0.051)
Hungary	0.037	0.030	0.084	0.053
	(0.054)	(0.059)	(0.220)	(0.044)
Italy	0.021	0.032	0.050	0.042
	(0.025)	(0.020)	(0.129)	(0.050)
Lithuania	0.022	0.063	0.100	0.039
	(0.028)	(0.031)	(0.433)	(0.054)
Poland	0.049	0.068	0.115	0.058
	(0.031)	(0.055)	(0.230)	(0.049)
Portugal	0.011	0.010	0.075	0.048
	(0.002)	(0.007)	(0.226)	(0.051)
Slovakia	0.074	0.050	0.125	0.040
	(0.035)	(0.032)	(0.325)	(0.053)
Slovenia	0.013	0.012	0.082	0.041
	(0.017)	(0.013)	(0.271)	(0.054)
Total	0.027	0.031	0.065	0.044
	(0.034)	(0.037)	(0.252)	(0.051)

One prediction of our model is that elasticity will differ across sectors, according on their level of product differentiation. To test this hypothesis we construct an index of differentiation based on Rauch [1999], that will proxy for γ. In his paper, goods are classified in three categories: those traded on organized exchanges, differentiated products and goods that, although not traded on exchanges, still have a reference price.

However, he defines his differentiation measure for SITC sector classification, whereas the data used in this paper is NACE2. As we could not find a direct conversion table between

SITC and NACE2, we used a series of correspondence tables, namely SITC $\longrightarrow$ HS2 $\longrightarrow$ ISIC Rev 3 $\longrightarrow$ ISIC Rev 3.1 $\longrightarrow$ ISIC Rev 4 $\longrightarrow$ NACE 2. A well known fact of using conversion tables is that there is not a 1-to-1 matching of sectors between various classifications: some sectors get split into several sectors whereas others get merged. In order to bypass this inconvenience, we redefine Rauch's original trinomial differentiation measure as follows: we recode all sectors as 1 for fully differentiated, -1 for those traded on exchanges and 0 for reference priced. This way, when converting from one sector classification to another and a resulting sector happens to be the merger of two different sectors we simply take the average of the original sectors. In the end, we obtain a continuous index of differentiation ranging from -1 (homogeneous) to 1 (fully differentiated) for 4-digit NACE2 industries.

As our export and productivity data is at the 2-digit NACE2 level we have to aggregate the 4-digit differentiation index. We do this by averaging the 4 digit sub-sector Rauch measures, using the share of exports of each 4-digit industry in the 2-digit one as weights. For robustness, we use two sets of weights: country specific and EU wide, where EU refers just to the countries in our sample. Unfortunately, due to the imperfect matching between classification tables, we were unable to obtain differentiation indices for all sectors. Note that the differentiation index is time invariant. Overall, the aggregation index makes intuitive sense: manufacturing of furniture is more differentiated than manufacturing of basic wood, and manufacturing of fabricated metal more differentiated than that of basic metal, for instance. Table 3.4 shows the differentiation index's values for all countries and sectors.

Table 3.4: Descriptive statistics: values of Rauch differentiation index

Sector	*Belgium*	*Estonia*	*Finland*	*France*	*Hungary*	*Italy*	*Lithuania*	*Poland*	*Portugal*	*Slovakia*	*Slovenia*	*Average*
Food products	0.19	0.26	0.20	0.13	0.06	0.24	0.18	0.21	0.15	0.16	0.07	0.16
Beverages	0.15			0.49	0.36	0.61	0.30	0.11	0.58	0.09		0.49
Textiles	0.76	0.73	0.84	0.75	0.81	0.61	0.60	0.85	0.61	0.78	0.74	0.70
Wearing apparel	0.63	0.79	0.64	0.66	0.70	0.60	0.71	0.78	0.49	0.67	0.75	0.64
Leather and related products				0.88	0.72	0.79		0.81	0.55	0.67		0.77
Wood and of products of wood and cork, except furniture	0.51	0.81	0.73	0.58	0.71	0.81	0.84	0.64	0.78	0.77	0.72	0.70
Paper and paper products	0.23		0.03	0.21	0.27	0.33	0.24	0.24	0.09	0.19	0.16	0.17
Printing and reproduction of recorded media												
Chemicals and chemical products	0.69		0.68	0.78	0.72	0.74		0.76	0.68	0.56	0.71	0.73
Basic pharmaceutical products and pharmaceutical preparations	0.59			0.59	0.59	0.59		0.59	0.59			0.59
Rubber and plastic products	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Other non-metallic mineral products	0.63	0.47	0.72	0.74	0.72	0.69	0.62	0.71	0.72	0.48	0.73	0.70
Basic metals	0.55	0.58	0.51	0.53	0.34	0.59		0.37	0.52	0.66		0.54
Fabricated metal products, except machinery and equipment	0.98	0.99	0.97	0.96	0.98	0.96	0.98	0.97	0.96	0.95	0.98	0.97
Computer, electronic and optical products	0.99		1.00	0.99	1.00	0.98	0.99	1.00	0.99	1.00	0.99	0.99
Electrical equipment	0.92		0.99	0.97	0.98	0.98		0.96	0.97	1.00	0.96	0.97
Machinery and equipment	0.96		0.90	0.97	0.97	0.96	0.98	0.97	0.97	0.97	0.97	0.96
Motor vehicles, trailers and semitrailers	0.98		0.96	0.99	0.98	0.98		0.98	0.99	0.94	0.97	0.98
Other transport equipment			0.87	0.94		0.90		0.97	0.95			0.93
Furniture												
Other manufacturing	0.77		0.88	0.88	0.91	0.82	0.94	0.93	0.94			0.85
Repair and installation of machinery and equipment	1.00		1.00	1.00		1.00	1.00	1.00	1.00	1.00		1.00

3.4.2 Empirical Methodology

In our empirical specification, we estimate the impact of REER variations on exports starting from the following basic specification:

$$\Delta \ln V_{fikt} = \beta \Delta \ln REER_{it} + \gamma \Delta \ln D_{ikt} + \mathbf{C}_{fikt}\Omega' + \lambda + \varepsilon_{fikt} \tag{3.31}$$

where V_{fikt} are the average exports revenue of exporting firms in productivity category f operating in country i, sector k and year t; $REER_{it}$ is the real effective exchange rates of country i; D_{ikt} is the foreign demand shifter, constructed as described above,; $\mathbf{C}_{fikt}$ is a vector of controls: GDP growth rate and average TFP growth rate; λ is a vector of category, country, sector and year fixed effects, respectively; ε_{fikt} is an error term clustered by country, year and sector.

In order to test the heterogeneous response across sectors we amend equation (3.31) by including the Rauch Differentiation index.

$$\Delta \ln V_{fikt} = \beta \Delta \ln REER_{it} + \delta \Delta \ln REER_{it} \times R_{ik} + \gamma \Delta \ln D_{ikt} + \mathbf{C}_{fikt}\Omega' + \lambda + \varepsilon_{fijt} \tag{3.32}$$

where R_{ik} is the Rauch differentiation index for country i and sector k. To ensure the robustness of our finding we will also run equation (3.32) using the average R_{ik} across countries.

The structure of the CompNet data allows us to go further than this and explore the heterogeneous effect of exchange rate fluctuations in terms of firm productivity as well. We define four dummies, Q_f, one for each category, and interact them with the REER variable in order to obtain class specific elasticity estimates.

$$\Delta \ln V_{fikt} = \sum_{z=1}^{4} \beta_z \Delta \ln REER_{it} \times Q_z + \gamma \Delta \ln D_{ikt} + \mathbf{C}_{fikt}\Omega' + \lambda + \varepsilon_{fikt} \tag{3.33}$$

In an alternative specification we concentrate on the relative effects of REER variations and define dummies only for the least productive categories, looking at their extra elasticity relative to the more productive firms' category

$$\Delta \ln V_{fikt} = \sum_{z=1}^{3} \beta_z \Delta \ln REER_{it} \times Q_z + \gamma \Delta \ln D_{ikt} + \mathbf{C}_{fikt}\Omega' + \lambda + \varepsilon_{fikt} \tag{3.34}$$

Finally, to test the role of imported inputs have in determining the exchange rate elasticity we run modified versions of (3.31) and (3.33) where we interacts the time-averaged importer share in each productivity bin with the REER

$$\Delta \ln V_{fikt} = \beta \Delta \ln REER_{it} + \delta \Delta \ln REER_{it} \times \overline{\text{twoway}_{fik}} + \gamma \Delta \ln D_{ikt} + \mathbf{C}_{fikt}\Omega' + \boldsymbol{\lambda} + \varepsilon_{fijt}$$

$$\Delta \ln V_{fikt} = \sum_{z=1}^{4} \beta_z \Delta \ln REER_{it} \times Q_z + \delta \Delta \ln REER_{it} \times \overline{\text{twoway}_{fik}} + \gamma \Delta \ln D_{ikt} + \mathbf{C}_{fikt}\Omega' + \boldsymbol{\lambda} + \varepsilon_{fikt} \tag{3.35}$$

While our main focus is on the effect of REER fluctuations on productivity deciles, as a robustness check we also look at the effect by size quartiles.

3.5 Estimation Results

3.5.1 Baseline Estimates

Our first step is to run some basic specification to make sure our data and methods pass first scrutiny, that is, to see if a basic specification gives results in line with those in the broader literature.

Table 3.5 shows the baseline estimates, derived from equation (3.31). We find that an increase in foreign demand boosts export revenues, as does an increase in TFP; GDP per capita does not have any significant effect on export revenue growth rates, although the sign indicates converge between poorer and richer countries. The elasticity estimates, although have the expected sign, are not significant when we control for TFP.

In addition to being marginally significant, the estimates are on the lower end of the literature. As exchange rates are volatile and export contracts are negotiated in advance, it may take time for firms to respond to competitiveness changes. In order to smooth out exchange rate fluctuations and to account for the lagged response of exports to exchange

Table 3.5: Real effective exchange rate elasticity: CPI-based

Dep. var.	$\Delta \ln export_{fikt}$					
$\Delta \ln reer_{it}$	0.390**	0.368*	0.305			
	(0.174)	(0.190)	(0.195)			
$\Delta \ln reer_{it/t-1}$				0.926**	0.759	0.727
				(0.415)	(0.485)	(0.481)
$\Delta \ln demand_{ikt}$	0.290***	0.291***	0.313***	0.341***	0.341***	0.342***
	(0.075)	(0.075)	(0.086)	(0.094)	(0.094)	(0.096)
$\ln GDP\ per\ cap_{it-1}$		-0.02	-0.034		-0.071	-0.098
		(0.083)	(0.087)		(0.109)	(0.108)
$\Delta \ln TFP_{fikt}$			0.115***			0.104***
			(0.029)			(0.030)
Observations	8800	8800	7767	7364	7364	6,999
R-squared	0.129	0.129	0.131	0.128	0.128	0.135
Fixed effects	sector, country, year and productivity class					

Standard errors clustered by country, year and sector. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

rate movements, we adjust our specification by using the average effective exchange rate movements between t and $t-1$ as a regressor. In this specification, which we will prefer in all subsequent regressions, the estimated elasticities are more than double in size, around 0.75. However, statistical significance is still elusive.

Table 3.6 contains the same regressions as Table 3.5, but using the ULC based REER as the independent variable. Overall, the results are quite similar to those in Table 3.5, the key difference being that now the elasticity estimates are significant when controlling for covariates. The estimates are also somewhat bigger: 0.56 for contemporaneous exchange rate movement and above 0.8 when using lagged changes in REER.

Table 3.6: Real effective exchange rate elasticity: ULC-based

Dep. var.	$\Delta \ln export_{fikt}$					
$\Delta \ln reer_{it}$	0.458***	0.574***	0.556***			
	(0.121)	(0.103)	(0.106)			
$\Delta \ln reer_{it/t-1}$				0.839**	0.807*	0.857**
				(0.365)	(0.432)	(0.433)
$\Delta \ln demand_{ikt}$	0.290***	0.575***	0.558***	0.335***	0.335***	0.336***
	(0.076)	(0.070)	(0.076)	(0.093)	(0.093)	(0.095)
$\ln GDP\ per\ cap_{it-1}$		0.019	0.033		-0.015	-0.025
		(0.055)	(0.059)		(0.107)	(0.110)
$\Delta \ln TFP_{fikt}$			0.117***			0.103***
			(0.029)			(0.030)
Observations	8800	8800	7767	7364	7364	6,999
R-squared	0.13	0.12	0.124	0.128	0.128	0.135
Fixed effects	sector, country, year and productivity class					

Standard errors clustered by country, year and sector. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

3.5.2 Between Sector Differences

Our second sensibility check is whether more productive sectors have lower elasticities. This is both a prediction of our model, corollary to Proposition 6, and an established fact in the literature [Berman et al., 2012]. Indeed, as can be seen in column 2 of Table 3.7, the results hold in our data as well: a doubling of productivity lowers the exchange rate elasticity by 0.3. These results also suggest that poorer Eastern European countries have much higher exchange rate elasticities than their Western counterparts. This is a finding echoed elsewhere in the literature: ECFIN et al. [2014] find that the export elasticity of Southern Europe countries is much higher than that of the Northern ones.

Another prediction of our model is that more differentiated sectors in term of products also have lower elasticities. The results of equation (3.32) are presented in Table 3.8. We find that for ULC-bases real effective exchange rates, there is a very strong link between the degree of differentiation and the export elasticity. The first row indicates the elasticity for a sector with moderate differentiation. For a completely homogeneous sector the exchange

Table 3.7: Real effective exchange rate elasticity: productivity differences

Dep. var.	$\Delta \ln export_{fikt}$	
	CPI-based REER	ULC-based REER
$\Delta \ln reer_{it/t-1}$	0.863*	1.601**
	(0.511)	(0.622)
$\Delta \ln reer_{it/t-1} \times \ln \, lprod_{fikt-1}$	-0.018	-0.317**
	(0.131)	(0.158)
$\ln \, lprod_{fikt-1}$	0.018*	0.005
	(0.009)	(0.010)
$\Delta \ln demand_{ikt}$	0.334***	0.336***
	(0.091)	(0.092)
$\ln GDP \; per \; cap_{it-1}$	-0.078	-0.031
	(0.111)	(0.103)
Observations	7636	7,636
R-squared	0.127	0.127
Fixed effects	sector, country, year and productivity class	

Standard errors clustered by country, year and sector. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

rate elasticity would be the first row plus the second one, around 2.7, while for a completely differentiated sector it would 0.7.

This estimated elasticity for fully differentiated sectors is quite close to the baseline estimates in Table 3.6 , which corroborates Table 3.4, as most sectors in our sample are quite diverse, as would be expected from manufacturing at this level of aggregation. We re-run this specification using the EU-average differentiation measure and the results are nearly identical. We do not show them here in order to conserve space. One interesting aspect of both Tables 3.7 and 3.8 is that, although the baseline elasticity is both statistically significant and around the expected value, the impact of heterogeneity is not significant for CPI based REER.

Table 3.8: Real effective exchange rate elasticity: product differentiation

Dep. var.	$\Delta \ln export_{fikt}$			
	CPI-based REER		ULC-based REER	
$\Delta \ln reer_{it/t-1}$	1.165*	1.107*	1.799***	1.698***
	(0.613)	(0.614)	(0.593)	(0.617)
$\Delta \ln reer_{it/t-1} \times$ Rauch Diff	-0.471	-0.411	-1.000**	-0.939**
	(0.410)	(0.416)	(0.403)	(0.420)
$\Delta \ln demand_{ikt}$	0.703***	0.707***	0.705***	0.705***
	(0.076)	(0.079)	(0.076)	(0.079)
$\ln GDP\ per\ cap_{it-1}$	-0.024	-0.024	0.064	0.057
	(0.112)	(0.114)	(0.110)	(0.116)
$\Delta \ln TFP_{fikt}$		0.113***		0.111***
		(0.031)		(0.031)
Observations	6941	6598	6941	6,598
R-squared	0.103	0.109	0.105	0.111
Fixed effects	country, year and productivity class			

Standard errors clustered by country, year and sector. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

3.5.3 Productivity Differences

We turn our attention to the heterogeneous response of firms, according on their productivity. Table 3.9 shows the results for both CPI and REER elasticities for firm quartiles. Columns 1 and 4 replicate the results in Tables 3.5 and 3.6, respectively. Columns 2 and 5 show the results of equation (3.33), which give us 4 elasticities, one for each productivity quartile. While not strictly monotonic, less productive firms have higher exchange rate elasticities than their more productive counterparts: For CPI based REERs, the bottom 25% firms have an elasticity close to 1 while for the top 25% it is 0.66. For ULC based REER, the respective figures are 1.42 and 0.5, an almost threefold difference.

Finally, Columns 3 and 6 show the results of equation (3.34), where we set the top productive quartile as the reference category. This specification allows us to see how much additional elasticity less productive firms have and whether this difference is statistically significant. For CPI based REER there isn't a very strong difference between productivity categories although the difference between the top and bottom quartiles is marginally significant at 10% confidence level. However, in the case of ULC based REER, there is a significant and substantial difference between the top category and the bottom two quartiles. Overall, our results suggest that while heterogeneity in REER elasticity exists and it is substantial, it is far from being a linear function of productivity. Rather, there is a considerable difference between the least productive firms and the rest. This echoes the predictions of our theoretical model, as shown in Figure 3.2, where the elasticity has a very steep slope for low productivity exporters.

Table 3.9: Real effective exchange rate elasticity: productivity interactions

Dep. var.	$\Delta \ln export_{fikt}$					
	CPI-based REER			ULC-based REER		
$\Delta \ln reer_{it/t-1}$	0.727			0.857**		
	(0.481)			(0.433)		
$\Delta \ln reer_{it/t-1} \times Q1 - prod_{fikt}$		1.049**	0.556*		1.422***	1.105***
		(0.534)	(0.320)		(0.533)	(0.412)
$\Delta \ln reer_{it/t-1} \times Q2 - prod_{fikt}$		0.803	0.322		1.044**	0.724**
		(0.525)	(0.279)		(0.473)	(0.300)
$\Delta \ln reer_{it/t-1} \times Q3 - prod_{fikt}$		0.599	0.123		0.584	0.265
		(0.501)	(0.274)		(0.468)	(0.301)
$\Delta \ln reer_{it/t-1} \times Q4 - prod_{fikt}$		0.668			0.556	
		(0.488)			(0.476)	
$\Delta \ln demand_{ikt}$	0.342***	0.341***	0.340***	0.336***	0.333***	0.335***
	(0.096)	(0.096)	(0.096)	(0.095)	(0.095)	(0.095)
$\ln GDP\ per\ cap_{it-1}$	-0.098	-0.092	-0.162*	-0.025	-0.023	-0.097
	(0.108)	(0.108)	(0.096)	(0.110)	(0.110)	(0.095)
$\Delta \ln TFP_{fikt}$	0.104***	0.100***	0.100***	0.103***	0.091***	0.090***
	(0.030)	(0.030)	(0.030)	(0.030)	(0.029)	(0.029)
Observations	6999	6999	6999	6999	6999	6,999
R-squared	0.135	0.135	0.135	0.135	0.136	0.136
Fixed effects	sector, country, year and productivity class					

Standard errors clustered by country, year and sector. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

3.5.4 Two-way Traders

One prediction of the theoretical model is that a larger dependence on imported inputs will lead to a lower exchange rate elasticity. While we do not have data on the share of imported intermediates firms use, we can indirectly test this prediction by looking at the difference in elasticity between firms which use intermediate inputs and firms which do not. Specifically, we look at the share of exporters who are using imported goods in each country-sector-bin tuple. We run equation (3.35) where we interact the change in exchange rates and the average share of importers across years in each bin[7]. This allows us to investigate the differences in elasticities between sectors which are rich in importers and sectors which are not.

Table 3.10 summarizes this set of results. As earlier, the CPI based results don't say much, as most coefficients as statistically indistinguishable from zero. The ULC based ones, however, reveal that the share of importers among exporters plays an important part in determining the magnitude of the exchange rate elasticity. Column 4 indicates that were all of a sector's exporters also importers, the exchange rate elasticity would be in effect zero. We continue by controlling for bin specific elasticities. For comparison, column 5 replicates column 5 from Table 3.9, where we do not control for two-way traders. In column 6 we add the two-way share interaction term which is significant at the 10% level. One interesting effect is that taking importers into account raises the estimated elasticities for all productivity bins. More so, while elasticities maintain their inverse relationship to productivity, the difference between productivity classes diminishes and the elasticity for the most productive firms becomes substantially larger and statistically significant indicating that accounting for imports explains a great deal of exchange rate heterogeneity.

[7]When the share of two-way traders is missing we assume it is 0. However, due to confidentiality policy when the data was collected, the number of twoway traders in some bins is not available even if it is non-zero. In order to minimize the need for imputation and maximize coverage we choose to use the time-averaged share of twoway traders as a covariate rather than the lagged or contemporeneous share. Doing the latter would have either considerably reduced the sample or resulted in a large number of imputations.

Table 3.10: Real effective exchange rate elasticity: twoway traders

Dep. var.	$\Delta \ln export_{fikt}$					
	CPI-based REER			ULC-based REER		
$\Delta \ln reer_{it/t-1}$	0.718			1.411***		
	(0.539)			(0.493)		
$\Delta \ln reer_{it/t-1} \times \overline{twoway}_{fik}$	0.03		0.295	-1.328**		-1.019*
	(0.591)		(0.624)	(0.603)		(0.608)
$\Delta \ln reer_{it/t-1} \times Q1 - prod_{fikt}$		1.049**	0.995*		1.422***	1.728***
		(0.534)	(0.563)		(0.533)	(0.567)
$\Delta \ln reer_{it/t-1} \times Q2 - prod_{fikt}$		0.803	0.731		1.044**	1.423***
		(0.525)	(0.572)		(0.473)	(0.519)
$\Delta \ln reer_{it/t-1} \times Q3 - prod_{fikt}$		0.599	0.507		0.584	1.042*
		(0.501)	(0.569)		(0.468)	(0.535)
$\Delta \ln reer_{it/t-1} \times Q4 - prod_{fikt}$		0.668	0.561		0.556	1.088**
		(0.488)	(0.564)		(0.476)	(0.537)
$\Delta \ln demand_{ikt}$	0.343***	0.341***	0.344***	0.327***	0.333***	0.327***
	(0.096)	(0.096)	(0.096)	(0.095)	(0.095)	(0.095)
$\ln GDP\ per\ cap_{it-1}$	-0.097	-0.092	-0.081	-0.043	-0.023	-0.037
	(0.105)	(0.108)	(0.105)	(0.110)	(0.110)	(0.110)
$\Delta \ln TFP_{fikt}$	0.104***	0.100***	0.100***	0.098***	0.091***	0.090***
	(0.030)	(0.030)	(0.030)	(0.030)	(0.029)	(0.029)
Observations	6999	6999	6999	6999	6999	6,999
R-squared	0.135	0.135	0.135	0.136	0.136	0.137
Fixed effects	sector, country, year and productivity class					

Standard errors clustered by country, year and sector. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

3.6 Robustness

In this section we carry out three robustness checks: whether there is a difference in elasticity between Euro and non-Euro countries, whether there are sample issues affecting our estimates and whether we obtain similar results when looking at elasticity heterogeneity by size category rather than productivity.

3.6.1 Euro and non-Euro Countries

In order to check for the effect of the Euro, we define a dummy that takes the value 1 for countries that used the Euro in a particular year. We interact this dummy with the real exchange rate and add it as a covariate to equations (3.31) and (3.33). Table 3.11 shows the results for both CPI and ULC based REERs. The elasticity estimates, both the average ones and the quartile specific ones, are slightly higher than in our baseline specification whereas the Euro interaction one is substantially large but statistically insignificant.

Table 3.11: Robustness: different elasticity for Euro countries

Dep. var.	$\Delta \ln export_{fikt}$			
	CPI-based REER		ULC-based REER	
$\Delta \ln reer_{it/t-1}$	0.724		0.959**	
		(0.486)		(0.476)
$\Delta \ln reer_{it/t-1} \times Q1 - prod_{fikt}$		1.187**		1.648***
		(0.534)		(0.570)
$\Delta \ln reer_{it/t-1} \times Q2 - prod_{fikt}$		0.805		1.189**
		(0.531)		(0.519)
$\Delta \ln reer_{it/t-1} \times Q3 - prod_{fikt}$		0.556		0.629
		(0.504)		(0.503)
$\Delta \ln reer_{it/t-1} \times Q4 - prod_{fikt}$		0.644		0.554
		(0.496)		(0.516)
$\Delta \ln reer_{it/t-1} \times Euro_{it}$	-0.338	-0.352	-0.774	-0.780
	(0.448)	(0.448)	(0.490)	(0.492)
$\Delta \ln demand_{ikt}$	0.340***	0.339***	0.333***	0.333***
	(0.093)	(0.093)	(0.092)	(0.092)
Euro$_{it}$	0.068**	0.068**	0.054*	0.054*
	(0.031)	(0.031)	(0.031)	(0.031)
$\ln GDP\ per\ cap_{it-1}$	-0.142	-0.136	-0.098	-0.096
	(0.120)	(0.121)	(0.111)	(0.111)
Observations	7364	7364	7364	7,364
R-squared	0.129	0.13	0.13	0.132
Fixed effects	sector-country, year and productivity class			

Standard errors clustered by country, year and sector. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

3.6.2 Sensitivity Checks

In order to assess the validity of our results we run several additional regressions to ensure that our findings are not driven by various sample or specification idiosyncrasies. First, we consider an alternative specification which includes country-sector fixed effects rather than country and sector fixed effects. Even in this circumstance, when all our identification comes from time and between categories differences, the results in Table 3.12 are broadly the same as those in Table 3.9.

Table 3.12: Real effective exchange rate elasticity: country-sector fixed effects

Dep. var.	$\Delta \ln export_{fikt}$					
REER var.	CPI-based REER			ULC-based REER		
$\Delta \ln reer_{it/t-1}$	0.699			0.790**		
	(0.435)			(0.385)		
$\Delta \ln reer_{it/t-1} \times Q1 - prod_{fikt}$		1.042**	0.553*		1.391***	1.111***
		(0.493)	(0.312)		(0.487)	(0.402)
$\Delta \ln reer_{it/t-1} \times Q2 - prod_{fikt}$		0.755	0.279		0.943**	0.661**
		(0.484)	(0.267)		(0.428)	(0.289)
$\Delta \ln reer_{it/t-1} \times Q3 - prod_{fikt}$		0.564	0.093		0.524	0.241
		(0.451)	(0.259)		(0.426)	(0.288)
$\Delta \ln reer_{it/t-1} \times Q4 - prod_{fikt}$			0.663			0.491
			(0.450)			(0.441)
$\Delta \ln demand_{ikt}$	0.328***	0.326***	0.325***	0.321***	0.319***	0.321***
	(0.092)	(0.092)	(0.091)	(0.090)	(0.090)	(0.090)
$\ln GDP\ per\ cap_{it-1}$	-0.124	-0.119	-0.189*	-0.061	-0.059	-0.125
	(0.108)	(0.109)	(0.098)	(0.108)	(0.109)	(0.098)
$\Delta \ln TFP_{fikt}$	0.097***	0.093***	0.093***	0.097***	0.084***	0.083***
	(0.032)	(0.032)	(0.031)	(0.032)	(0.031)	(0.031)
Observations	6999	6999	6999	6999	6999	6,999
R-squared	0.165	0.166	0.165	0.165	0.167	0.166
Fixed effects	sector, country, year and productivity class					

Standard errors clustered by country, year and sector. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

Another source of uncertainty in our results lies in the way we split our sample in quartiles. The original CompNet data had statistics on productivity deciles that we pooled into quartiles as such: $Cat\ 1 = \{1, 2\}$; $Cat\ 2 = \{3, 4, 5\}$; $Cat\ 3 = \{6, 7, 8\}$; $Cat\ 4 = \{, 9, 10\}$. We consider an alternative classification for productivity categories: $Cat\ 1 = \{1, 2, 3\}$; $Cat\ 2 = \{4, 5\}$; $Cat\ 3 = \{6, 7\}$; $Cat\ 4 = \{8, 9, 10\}$ and re-estimate the equations behind Table 3.9. The results are shown in Table 3.13 and the differences are minimal.

Finally, we consider how sensitive our findings are to sample composition. In order to check this, we remove a sector from a country and re-run equations (3.31), (3.33) and (3.34). We save the results and then, from the original sample, we remove the next sector from

Table 3.13: Real effective exchange rate elasticity: alternative productivity thresholds

Dep. var.	$\Delta \ln export_{fikt}$					
	CPI-based REER			ULC-based REER		
$\Delta \ln reer_{it/t-1}$	0.727			0.857**		
	(0.481)			(0.433)		
$\Delta \ln reer_{it/t-1} \times Q1 - prod_{fikt}$		1.070**	0.503**		1.299***	0.971***
		(0.498)	(0.231)		(0.485)	(0.334)
$\Delta \ln reer_{it/t-1} \times Q2 - prod_{fikt}$		0.658	0.105		1.047**	0.720**
		(0.564)	(0.294)		(0.508)	(0.315)
$\Delta \ln reer_{it/t-1} \times Q3 - prod_{fikt}$		0.529	0.022		0.721	0.391
		(0.520)	(0.285)		(0.522)	(0.359)
$\Delta \ln reer_{it/t-1} \times Q4 - prod_{fikt}$		0.693			0.486	
		(0.481)			(0.450)	
$\Delta \ln demand_{ikt}$	0.342***	0.341***	0.340***	0.336***	0.333***	0.335***
	(0.096)	(0.096)	(0.096)	(0.095)	(0.095)	(0.095)
$\ln GDP\ per\ cap_{it-1}$	-0.098	-0.092	-0.173*	-0.025	-0.023	-0.099
	(0.108)	(0.108)	(0.094)	(0.110)	(0.110)	(0.093)
$\Delta \ln TFP_{fikt}$	0.104***	0.099***	0.099***	0.103***	0.092***	0.090***
	(0.030)	(0.030)	(0.030)	(0.030)	(0.029)	(0.029)
Observations	6999	6999	6999	6999	6999	6,999
R-squared	0.135	0.135	0.135	0.135	0.136	0.136
Fixed effects	sector, country, year and productivity class					

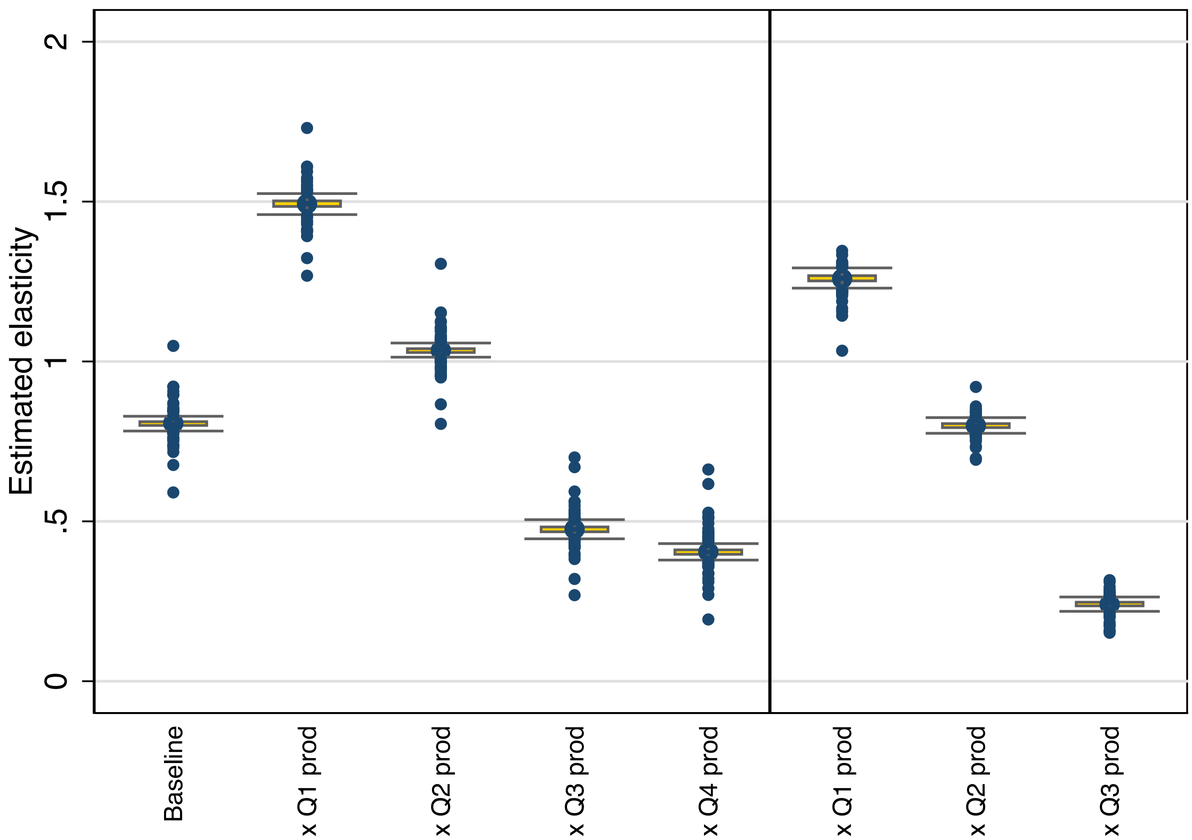
Standard errors clustered by country, year and sector. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

the same country. Afterwards we move on to the next country. Figure 3.4 summarizes the outcome of this exercise. The first column, Baseline, shows a boxplot with the 95% range of estimates in the case where we don't consider within sector heterogeneity. The range of estimates is quite tight, although there a few influential outliers. The next four columns show the coefficients coming out of equation (3.33) under alternative samples. The bulk of the estimates fall in a very tight band, but there are some sectors which have oversized influence on the estimates, typically sectors with few firms in small countries. The final three columns show the estimates from equation (3.34) and the same comments apply. Unsurprisingly, outliers appear to have the greatest effect on lower productivity bins.

3.6.3 Splitting the Firms by Size

Finally, we look at how our results change when we split firms by size rather than by productivity. Table 3.14 replicates the results in Table 3.9, just that now our dependent

Figure 3.4: Robustness to sample composition



variable will be exports by firms in a given **size** quartile in country i, sector k and at time t. Columns 1 and 4 show the results for CPI and ULC based REERs, without taking into account any heterogeneity in elasticity. The estimates are very similar to the productivity ones, although slightly lower. Columns 2 and 5 show the estimates for the four size quartiles. It appears that the response of firms to exchange rate movements is lower in terms of size than productivity: The ratio of elasticities between the smallest and largest firms is the same as the one between the least and top productive ones but the difference is smaller in absolute terms. The largest firms appear insensitive to real exchange rate changes. The lower and more homogeneous elasticity estimates make sense as, while there is a correlation between size and productivity, there are likely to be many large inefficient firms and many niche champions.

Table 3.14: Real effective exchange rate elasticity: size interactions

Dep. var.	$\Delta \ln export_{fikt}$					
REER var.	CPI-based REER			ULC-based REER		
$\Delta \ln reer_{it/t-1}$	0.21			0.546**		
	(0.611)			(0.267)		
$\Delta \ln reer_{it/t-1} \times Q1 - size_{fikt}$		0.387	0.331		0.870*	0.736*
		(0.673)	(0.462)		(0.505)	(0.427)
$\Delta \ln reer_{it/t-1} \times Q2 - size_{fikt}$		0.199	0.145		0.826***	0.696***
		(0.669)	(0.340)		(0.308)	(0.257)
$\Delta \ln reer_{it/t-1} \times Q3 - size_{fikt}$		0.284	0.232		0.402	0.270
		(0.636)	(0.292)		(0.290)	(0.194)
$\Delta \ln reer_{it/t-1} \times Q4 - size_{fikt}$		0.072			0.222	
		(0.606)			(0.304)	
$\Delta \ln demand_{ikt}$	0.336***	0.336***	0.336***	0.332***	0.332***	0.333***
	(0.109)	(0.109)	(0.109)	(0.109)	(0.109)	(0.109)
$\ln GDP\ per\ cap_{it-1}$	-0.13	-0.127	-0.135	-0.055	-0.054	-0.083
	(0.114)	(0.114)	(0.092)	(0.085)	(0.087)	(0.079)
$\Delta \ln TFP_{fikt}$	0.189***	0.188***	0.188***	0.188***	0.182***	0.182***
	(0.035)	(0.036)	(0.036)	(0.035)	(0.035)	(0.035)
Observations	6176	6176	6176	6176	6176	6,176
R-squared	0.12	0.12	0.12	0.12	0.121	0.121
Fixed effects	sector, country, year and productivity class					

Standard errors clustered by country, year and sector. Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

3.7 Conclusion

In this paper we looked at the impact of exchange rate movements on exporter behaviour, with a particular focus on heterogeneity. Our results confirm that firm-size or productivity heterogeneity is an important factor explaining the discrepancy between micro and macro elasticities. We found that the impact of REER variations on firm-level export revenues range from 0.66 to about 1. However, the elasticity of exports varies across sectors, more productive and more differentiated sectors having lower elasticities. We further found the reaction of large/highly productive firms to be much weaker, around 3 times in size, than that of small/unproductive firms. We also looked at the role imported inputs play in elasticity differences and found that accounting for foreign inputs explains a substantial part of export heterogeneity.

Overall, our paper contributes to the explanation of the "International Elasticity Puzzle", although there still many questions left to answer. There could be different mechanisms through which productive firms mitigate the effects of exchange rate shocks. Firms could absorb internal shocks through *internal* finance by lowering profits and markups or they could absorb external shocks through *external* finance by adjusting their financial position. Furthermore, there could be other types of distortions influencing heterogeneity in elasticities such as labor marker frictions, resource mis-allocation, cross-sector elasticities of substitution or imperfect financial markets. We relegate these possibilities to future research.

Bibliography

Amiti, M. and Davis, D. R. (2012). Trade, firms, and wages: Theory and evidence. *The Review of economic studies*, 79(1):1–36.

Arkolakis, C., Costinot, A., and Rodriguez-Clare, A. (2009). New trade models, same old gains? Technical report, National Bureau of Economic Research.

Atkeson, A. and Burstein, A. (2008). Pricing-to-market, trade costs, and international relative prices. *The American Economic Review*, 98(5):1998–2031.

Bahmani-Oskooee, M. and Ratha, A. (2008). Exchange rate sensitivity of us bilateral trade flows. *Economic Systems*, 32(2):129–141.

Bas, M., Mayer, T., and Thoenig, M. (2015). From micro to macro: Demand, supply, and heterogeneity in the trade elasticity.

Bergin, P. R. and Feenstra, R. C. (2001). Pricing-to-market, staggered contracts, and real exchange rate persistence. *Journal of international Economics*, 54(2):333–359.

Berman, N., Berthou, A., and Héricourt, J. (2015). Export dynamics and sales at home. *Journal of International Economics*, 96(2):298–310.

Berman, N., Martin, P., and Mayer, T. (2012). How do different exporters react to exchange rate changes? *The Quarterly Journal of Economics*, 127(1):437–492.

Berthou, A., Dhyne, E., Bugamelli, M., Cazacu, A.-M., Demian, C.-V., Harasztosi, P., Lalinsky, T., Meriküll, J., Oropallo, F., Soares, A. C., et al. (2015a). Assessing european firms' exports and productivity distributions: The compnet trade module. Technical report.

Berthou, A., Dhyne, E., Cazacu, A., Chiriacescu, B., Merikyll, J., Demian, V., Harasztosi, P., Opromolla, L., Lalinsky, T., Tello, P., Bugamelli, M., and Oropallo, F. (2015b). New evidence on european exporters. *ECB Working Paper series*.

Berthou, A. and Fontagne, L. (2015). Variable trade costs, composition effects, and the intensive margin of trade.

Bodenstein, M. (2010). Trade elasticity of substitution and equilibrium dynamics. *Journal of Economic Theory*, 145(3):1033–1059.

Chaney, T. (2008). Distorted gravity: the intensive and extensive margins of international trade. *The American Economic Review*, 98(4):1707–1721.

Cheung, Y.-W. and Sengupta, R. (2013). Impact of exchange rate movements on exports: an analysis of indian non-financial sector firms. *Journal of International Money and Finance*, 39:231–245.

Connolly, M. and Taylor, D. (1976). Adjustment to devaluation with money and nontraded goods. *Journal of International Economics*, 6(3):289–298.

Darvas, Z. (2012). Real effective exchange rates for 178 countries: A new database.

Dekle, R., Jeong, H., and Kiyotaki, N. (2013). Dynamics of firms and trade in general equilibrium. *KDI School of Pub Policy & Management Paper*, (13-06).

Dekle, R., Jeong, H., Ryoo, H., et al. (2009). A re-examination of the exchange rate disconnect puzzle: Evidence from firm level data. *University of Sourthern California mimeo*.

Diewert, W. E. (1974). Applications of duality theory.

Drozd, L. A. and Nosal, J. B. (2012). Understanding international prices: Customers as capital. *The American Economic Review*, 102(1):364–395.

ECFIN, for Economic, D. G., and Commission, F. A. E. (2014). Quarterly report on the euro area. *Journal of International Money and Finance*, 13.

Feenstra, R. C. (2003). A homothetic utility function for monopolistic competition models, without constant price elasticity. *Economics Letters*, 78(1):79–86.

Fitzgerald, D. and Haller, S. (2014). Pricing-to-market: evidence from plant-level prices. *The Review of Economic Studies*, 81(2):761–786.

Gabaix, X. (2009). The granular origins of aggregate fluctuations. Technical report, National Bureau of Economic Research.

Galuscak, K., Lizal, L., et al. (2011). The impact of capital measurement error correction on firm-level production function estimation. Technical report.

Gaulier, G. and Zignago, S. (2010). Baci: International trade database at the product-level. the 1994-2007 version. Technical report.

Goldberg, L. and Tracy, J. (2001). Exchange rates and wages. Technical report, National Bureau of Economic Research.

Goldstein, M. and Kahn, H. (1985). Income and price effects in foreign trade. *Handbook of International Economimcs*, 2:1041–1105.

Hooper, P., Johnson, K., and Marquez, J. (2000). Trade elasticities for the g-7 countries.

Imbs, J. M. and Méjean, I. (2009). Elasticity optimism. *IMF Working Papers*, pages 1–45.

Kenen, P. B. and Rodrik, D. (1986). Measuring and analyzing the effects of short-term volatility in real exchange rates. *The Review of Economics and Statistics*, pages 311–315.

Lopez-Garcia, P., di Mauro, F., and the CompNet Task Force (2015). Assessing european competitiveness: the new compnet microbased database. *ECB Working Paper series*, (1764).

Mayer, T. and Ottaviano, G. I. (2008). The happy few: The internationalisation of european firms. *Intereconomics*, 43(3):135–148.

Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica*, 71(6):1695–1725.

Melitz, M. J. and Ottaviano, G. I. (2008). Market size, trade, and productivity. *The review of economic studies*, 75(1):295–316.

Obstfeld, M., Rogoff, K. S., and Wren-lewis, S. (1996). *Foundations of international macroeconomics*, volume 30. MIT press Cambridge, MA.

Ossa, R. (2012). Why trade matters after all. Technical report, National Bureau of Economic Research.

Rauch, J. E. (1999). Networks versus markets in international trade. *Journal of international Economics*, 48(1):7–35.

Roberts, M. J. and Tybout, J. R. (1997). The decision to export in colombia: an empirical model of entry with sunk costs. *The American Economic Review*, pages 545–564.

Rodríguez-López, J. A. (2011). Prices and exchange rates: A theory of disconnect. *The Review of Economic Studies*, page rdq031.

Ruhl, K. J. (2008). The international elasticity puzzle. *unpublished paper, NYU.*

Vaubel, R. (1978). Real exchange-rate changes in the european community: A new approach to the determination of optimum currency areas. *Journal of International Economics*, 8(2):319–339.

Wooldridge, J. M. (2009). On estimating firm-level production functions using proxy variables to control for unobservables. *Economics Letters*, 104(3):112–114.

Appendix to Chapter 1

A1.1 Gini coefficients and estimated productivities

Table A1.1: Gini indices and estimated productivities

Country	Gini	$\left(\frac{\lambda^a_{US}}{\lambda^a_i}\right)^{\theta^a}$	$\left(\frac{\lambda^m_{US}}{\lambda^m_i}\right)^{\theta^m}$	$\left(\frac{\lambda^k_{US}}{\lambda^k_i}\right)^{\theta^k}$
Albania	0.330	1.214	3.593	10.113
Argentina	0.493	0.879	2.479	9.215
Armenia	0.362	1.203	4.821	16.207
Australia	0.352	0.439	0.532	1.033
Austria	0.291	0.347	0.491	0.786
Azerbaijan	0.365	1.052	5.160	19.731
Bahrain	0.390	0.423	1.528	3.283
Bangladesh	0.332	2.214	7.703	44.878
Belgium	0.330	0.461	1.068	0.905
Bolivia	0.578	0.638	3.552	21.529
Botswana	0.610	1.433	2.437	5.985
Brazil	0.574	1.155	2.367	5.533
Bulgaria	0.292	0.987	3.827	9.067
Cambodia	0.418	2.837	13.098	61.880
Canada	0.326	0.554	0.597	1.102
Chile	0.518	0.832	2.391	7.883
China	0.425	1.713	4.542	9.321
Colombia	0.561	1.311	3.485	12.664
Croatia	0.290	0.691	1.446	3.493
Cyprus	0.290	0.480	1.060	2.764
Czech Republic	0.268	0.576	1.539	2.349
Denmark	0.232	0.382	0.294	0.534
Ecuador	0.541	0.849	3.728	16.618

Table A1.1: Gini indices and estimated productivities

Country	Gini	$\left(\frac{\lambda^a_{US}}{\lambda^a_i}\right)^{\theta^a}$	$\left(\frac{\lambda^m_{US}}{\lambda^m_i}\right)^{\theta^m}$	$\left(\frac{\lambda^k_{US}}{\lambda^k_i}\right)^{\theta^k}$
Estonia	0.360	0.905	1.833	4.496
Ethiopia	0.298	1.455	11.815	70.435
Finland	0.254	0.385	0.520	0.699
France	0.288	0.388	0.505	0.598
Georgia	0.410	0.568	3.661	20.088
Germany	0.285	0.396	0.459	0.636
Ghana	0.428	3.696	10.430	34.511
Greece	0.321	0.429	1.065	1.570
Hungary	0.300	0.676	1.436	3.311
Iceland	0.257	0.371	0.568	1.102
India	0.334	1.364	4.988	15.621
Indonesia	0.340	1.096	2.820	15.143
Ireland	0.343	0.380	0.341	0.718
Israel	0.392	0.620	1.165	2.001
Italy	0.352	0.443	0.618	0.830
Japan	0.231	0.580	0.651	0.511
Jordan	0.377	1.034	5.166	19.348
Kazakhstan	0.308	0.739	2.235	9.012
Kenya	0.477	2.669	9.955	33.305
Korea	0.306	1.021	2.172	1.611
Latvia	0.357	0.750	2.357	7.352
Lithuania	0.358	0.688	2.284	5.662
Malta	0.280	0.464	1.246	3.277
Mauritius	0.370	0.930	2.749	6.914
Mexico	0.461	0.692	1.490	3.530
Namibia	0.639	1.866	4.205	13.134
Netherlands	0.284	0.298	0.538	0.705
New Zealand	0.335	0.695	1.162	2.092
Niger	0.439	4.550	14.586	80.236
Norway	0.276	0.348	0.379	0.598
Pakistan	0.312	1.708	5.420	27.353
Peru	0.511	1.097	3.345	10.160
Philippines	0.440	1.008	4.322	18.947
Poland	0.349	0.757	1.591	3.791

Table A1.1: Gini indices and estimated productivities

Country	Gini	$\left(\frac{\lambda_{US}^a}{\lambda_i^a}\right)^{\theta^a}$	$\left(\frac{\lambda_{US}^m}{\lambda_i^m}\right)^{\theta^m}$	$\left(\frac{\lambda_{US}^k}{\lambda_i^k}\right)^{\theta^k}$
Portugal	0.385	0.595	1.157	2.144
Qatar	0.411	0.247	0.674	1.466
Romania	0.316	0.932	2.423	6.687
Russian Federation	0.375	0.123	0.521	3.867
Senegal	0.392	2.769	7.751	27.397
Serbia	0.334	1.242	3.865	12.686
Slovak Republic	0.298	0.540	1.390	3.103
Slovenia	0.311	0.476	1.264	2.179
South Africa	0.674	1.544	3.052	8.411
Spain	0.321	0.480	0.728	1.054
Sri Lanka	0.403	1.141	5.066	26.696
Sweden	0.234	0.313	0.380	0.575
Switzerland	0.276	0.377	0.414	0.575
Syrian Arab Republic	0.358	1.192	5.164	26.465
Tanzania	0.376	3.550	11.127	40.002
Thailand	0.423	1.256	4.245	9.629
Togo	0.344	3.876	12.692	45.612
Turkey	0.426	0.863	2.054	3.576
Uganda	0.457	2.629	10.687	37.408
Ukraine	0.282	0.736	3.311	15.381
United Kingdom	0.331	0.345	0.371	0.625
United States	0.380	1.000	1.000	1.000
Venezuela, RB	0.495	1.056	2.476	7.084
Zambia	0.580	3.456	8.409	29.910

Source: World Bank and author's own calculations

A1.2 Derivation of w^s in simplified model

From the expenditure equations

$$\begin{aligned} DX^a + \mathrm{I}^a & \quad (1-\alpha)\left(DX^a + \mathrm{E}^a\right) + (1-\beta)\left(w^s s + w^u(1-s)\right)L \\ DX^k + \mathrm{I}^k &= \gamma^{k,k}\left(DX^k + \mathrm{E}^k\right) + \gamma^{k,f} DX^f \\ DX^f & \quad \beta\left(w^s s + (1-s)w^u\right)L_i \end{aligned}$$

I can get explicit values for the domestic expenditures

$$
\begin{aligned}
&DX^a = DX^a - \alpha DX^a + (1-\alpha)\,\mathrm{E}^a + (1-\beta)\left(w^s s + w^u(1-s)\right)L - \mathrm{I}^a \\
&DX^a = \tfrac{(1-\alpha)\mathrm{E}^a + (1-\beta)(w^s s + w^u(1-s))L - \mathrm{Is}^a}{\alpha} \\
&DX^k(1-\gamma^{k,k}) + \mathrm{I}^k = \gamma^{k,k}\mathrm{E}^k + \gamma^{k,f}\beta\left(w^s s + (1-s)w^u\right)L \\
&DX^k = \tfrac{\gamma^{k,k}\mathrm{E}^k - I^k + \gamma^{k,f}\beta(w^s s + (1-s)w^u)L}{1-\gamma^{k,k}}
\end{aligned}
$$

Plugging the values of DX back into the skilled wage equation

Separating the domestic from trade related terms

$$
\begin{aligned}
w^s sL = {} & \gamma^{s,a}\left(\tfrac{\mathrm{E}^a - \mathrm{I}^a + (1-\beta)(w^s s + w^u(1-s))L}{\alpha}\right) \\
& + \gamma^{s,k}\left(\tfrac{E^k - I^k + \gamma^{k,f}\beta(w^s s + (1-s)w^u)L}{1-\gamma^{k,k}}\right) + \gamma^{s,f}\beta\left(w^s s + (1-s)w^u\right)L
\end{aligned}
$$

Finally, by collecting the w^s terms, I get a closed form solution

$$
w^s = \frac{1}{sL}\frac{\frac{\gamma^{s,a}}{\alpha}\left(\mathrm{E}^a - \mathrm{I}^a\right) + \frac{\gamma^{s,k}}{1-\gamma^{k,k}}\left(E^k - I^k\right)}{1-\left((1-\beta)\frac{\gamma^{s,a}}{\alpha} + \beta\frac{\gamma^{s,k}}{1-\gamma^{k,k}}\right)} + \frac{1-s}{s}\left[\frac{(1-\beta)\frac{\gamma^{s,a}}{\alpha} + \beta\frac{\gamma^{s,k}}{1-\gamma^{k,k}}}{1-\left((1-\beta)\frac{\gamma^{s,a}}{\alpha} + \beta\frac{\gamma^{s,k}}{1-\gamma^{k,k}}\right)}\right]
$$

And after a bit of rearranging

$$
\begin{aligned}
w^s &= \tfrac{1-s}{s}\tfrac{(1-\beta)\frac{\gamma^{s,a}}{\alpha} + \beta\frac{\gamma^{s,k}}{1-\gamma^{k,k}}}{1-\left((1-\beta)\frac{\gamma^{s,a}}{\alpha} + \beta\frac{\gamma^{s,k}}{1-\gamma^{k,k}}\right)} + \tfrac{1}{s}\tfrac{\frac{\gamma^{s,a}}{\alpha}\left(\frac{\mathrm{E}^a - \mathrm{I}^a}{L}\right) + \frac{\gamma^{s,k}}{1-\gamma^{k,k}}\left(\frac{E^k - I^k}{L}\right)}{1-\left((1-\beta)\frac{\gamma^{s,a}}{\alpha} + \beta\frac{\gamma^{s,k}}{1-\gamma^{k,k}}\right)} \\
w^s &= \tfrac{1-s}{s}\tfrac{(1-\beta)\frac{\gamma^{s,a}}{\alpha} + \beta\frac{\gamma^{s,k}}{\gamma^{s,k} + \gamma^{u,k}}}{1-\left((1-\beta)\frac{\gamma^{s,a}}{\alpha} + \beta\frac{\gamma^{s,k}}{\gamma^{s,k} + \gamma^{u,k}}\right)} + \tfrac{1}{s}\tfrac{\frac{\gamma^{s,a}}{\alpha}\left(\frac{NX^a}{L}\right) + \frac{\gamma^{s,k}}{\gamma^{s,k} + \gamma^{u,k}}\left(\frac{NX^k}{L}\right)}{1-\left((1-\beta)\frac{\gamma^{s,a}}{\alpha} + \beta\frac{\gamma^{s,k}}{\gamma^{s,k} + \gamma^{u,k}}\right)}
\end{aligned}
$$

A1.3 Derivations of propositions in Section 1.5

Proposition 1

The only influence capital goods have on the share of value added going to unskilled labour is through the price of the skilled labor-capital bundle. Using the chain rule $\frac{\partial \gamma^{u,j}}{\partial p^k} = \frac{\partial \gamma^{u,j}}{\partial p^{\chi,j}}\frac{\partial p^{\chi,j}}{\partial p^k}$, both of which are trivially positive.

$$\frac{\partial \gamma_i^{u,j}}{\partial p_i^{\chi,j}} = \frac{\alpha(1-\delta)\delta\vartheta\left(p_i^{\chi,j}\right)^{\frac{\vartheta}{\vartheta-1}-1}(w_i^u)^{\frac{\vartheta}{\vartheta-1}}}{(1-\vartheta)\left((1-\delta)\left(p_i^{\chi,j}\right)^{\frac{\vartheta}{\vartheta-1}}+\delta(w_i^u)^{\frac{\vartheta}{\vartheta-1}}\right)^2} > 0$$

$$\frac{\partial p_i^{\chi,j}}{\partial p_i^k} = \left(1-H_i^j\right)\left(p_i^{\chi,j}\right)^{\frac{1}{\rho-1}1}\left(p_i^k\right)^{\frac{\rho}{\rho-1}+1} > 0$$

Proposition 2

$$\frac{\partial \gamma_i^{s,j}}{\partial p_i^{k,j}} = \frac{1}{\rho}\frac{\alpha H^2(1-\rho-)w_i^s\left(\frac{w_i^s}{p_i^k}\right)^{-1/\rho}\left(\delta\left(\frac{w_i^u}{p_i^{\chi,j}}\right)^{\frac{\vartheta}{\vartheta-1}}+1-\delta\right)}{(1-H)\left(p_i^k\right)^2\left(\frac{H\left(w_i^s\right)\left(\frac{w_i^s}{p_i^k}\right)^{-1/\rho}}{(1-\mathrm{H})p_i^k}+1\right)^2\left(\frac{\delta\left(\frac{w_i^u}{p_i^{\chi,j}}\right)^{\frac{\vartheta}{\vartheta-1}}}{\delta-1}-1\right)^2} +$$

$$\frac{1}{\vartheta-1}\frac{\alpha H\delta(1-H)\vartheta\left(p_i^k\right)^{\frac{\rho}{\rho-1}+1}\left(\frac{Hw_i^s\left(\frac{w_i^s}{p_i^k}\right)^{-1/\rho}}{(1-\mathrm{H})p_i^k}+1\right)\left(\frac{w_i^u}{p_i^{\chi,j}}\right)^{\frac{\vartheta}{\vartheta-1}}}{\left(p_i^{\chi,j}\right)^{\frac{\rho}{\rho-1}}\left(p_i^k\right)^2\left(\frac{H\left(w_i^s\right)\left(\frac{w_i^s}{p_i^k}\right)^{-1/\rho}}{(1-H)p_i^k}+1\right)^2\left(\frac{\delta\left(\frac{w_i^u}{p_i^{\chi,j}}\right)^{\frac{\vartheta}{\vartheta-1}}}{\delta-1}-1\right)^2} < 0$$

As unskilled labour is substitutable to skilled labor, $\rho < 0$. All terms of the first fraction are postive with the exception of ρ in the denominator. In the second fraction, all terms are positive except for the leading $\vartheta - 1$ which is negative because $\vartheta < 1$.

Proposition 3

$$\frac{\partial \gamma_i^{s,j}}{\partial w_i^u} = -\frac{\vartheta}{\vartheta-1}\frac{\alpha_i^j\delta H_i^j\left(\frac{w_i^u}{p_i^{\chi,j}}\right)^{\frac{\vartheta}{\vartheta-1}-1}}{p_i^{\chi,j}\left(\frac{H_i^j\left(\frac{w_i^s}{p_i^k}\right)^{\frac{\rho}{\rho-1}}}{1-H_i^j}+1\right)\left(\frac{\delta\left(\frac{w_i^u}{p_i^{\chi,j}}\right)^{\frac{\vartheta}{\vartheta-1}}}{1-\delta}+1\right)^2} > 0$$

$$\frac{\partial \gamma_i^{s,j}}{\partial w_i^s} = \frac{\vartheta}{\vartheta - 1} \frac{\alpha \delta H^2 \left(w_i^u\right)^{\frac{\vartheta}{\vartheta-1}} \left(w_i^s\right)^{\frac{1}{\rho}} \left(p_i^{\chi,j}\right)^{\frac{\vartheta-\rho}{\rho-1}\frac{1}{\vartheta}}}{\left(\frac{H\left(\frac{w_i^s}{p_i^k}\right)^{\frac{\rho}{\rho-1}}}{1-H}+1\right)\left(\frac{\delta\left(\frac{w_i^u}{p_i^{\chi,j}}\right)^{\frac{\vartheta}{\vartheta-1}}}{1-\delta}+1\right)^2} - \frac{\rho}{\rho-1} \frac{\alpha(1-\delta)H^2\left(w_i^s\right)^{\frac{1}{\rho-1}} p_i^{k,j-\frac{\rho}{\rho-1}}}{(1-H)\left(\frac{H\left(\frac{w_i^s}{p_i^k}\right)^{\frac{\rho}{\rho-1}}}{1-H}+1\right)^2\left(\frac{\delta\left(\frac{w_i^u}{p_i^{\chi,j}}\right)^{\frac{\vartheta}{\vartheta-1}}}{1-\delta}+1\right)} < 0$$

The derivative of the value added share going to skilled workers is positive as all terms are positive except for the first fraction. Checking the sign of the second equation, complicated as it may look, is straightforward. As $\rho < 0$ the second term is positive as all multiplication terms are positive. In the first term, all multiplication terms are positive except for $\frac{\vartheta}{\vartheta-1}$, making the term negative. Therefore, the first derivative is negative.

Appendix to Chapter 2

A2.1 Alternative values of θ

A large part of this paper was devoted to estimating a reliable θ so the natural question to ask is: Does it really matter? The answer is strongly yes. Table A2.1 details the welfare gains under various values for the dispersion of productivity. When looking at these results, one needs to keep in mind that they are based on ad-hoc values and nothing in the model or the data indicates the underlying parametrization is sensible. Rather, the following should be viewed as a purely numerical exercise on the features of the model. Column (1) reproduces the main results in Table 2.4.

Column (2) shows the gains were θ equal to 12, which is about the upper bound of the estimates in the literature. The gains from trade are larger for all countries, especially for incumbents. The reason for this is that as θ increases the technological differences between countries matter less and the change in trade costs has a stronger effect on welfare. Furthermore, as comparative advantage is estompated, the relative disadvantage new EU members have compared to old countries disappears.

Unlike Caliendo and Parro (2012), I assume a common value for θ across sectors, so it is only natural that I look at the effects of this assumption. As I classify sectors the same as them, I can just plug in their values of θ and rerun the model. In order to separate the level effects and the heterogeneity effects of θ I run two specifications: using Caliendo and Parro's sector specific estimates and using a common value, averaging their estimat4es across sectors. The results are in columns (3) and (4) of A2.1. While there are obvious numerical differences between the last two columns they are not significant. Overall, it appears that while the absolute value of θ matters, whether it is heterogeneous across sectors matters little.

Welfare gains are monotonically increasing in the value of θ. That may seem puzzling as from (2.14) it seems obvious that a higher value of the dispersion parameter leads to lower welfare gains and the claim in Simonovska and Waugh (2011) that lower θ should increase the gains from trade. However, θ also plays a part in dictating how large $\ln \hat{\pi}_{nn}$ will be. That is, if θ is small, there is a lot of variability across countries, amplifying their comparative advantage. Therefore, a change in trade costs won't likely change the cheapest source for a good.

Table A2.1: Welfare gains under different assumptions

	Original Estimate	θ=12	Heterogeneous θ	$\theta = 9.04$
Austria	0.84	1.80	1.53	1.35
Belgium	0.32	0.93	0.75	0.64
Czech Republic	4.34	5.46	4.83	4.87
Denmark	0.33	0.95	0.68	0.63
Estonia	5.35	6.84	5.86	5.77
Finland	0.54	1.57	1.20	1.05
France	0.27	0.91	0.70	0.57
Germany	0.68	1.62	1.22	1.16
Great Britain	0.25	0.87	0.64	0.53
Greece	0.17	0.67	0.50	0.39
Hungary	5.62	6.32	5.79	5.81
Ireland	0.14	0.57	0.42	0.31
Italy	0.18	0.61	0.43	0.36
Latvia	3.38	4.58	3.99	4.06
Lithuania	4.55	5.63	5.73	5.04
The Netherlands	0.33	1.03	0.71	0.64
Poland	3.18	4.65	4.20	4.05
Portugal	0.07	0.30	0.23	0.18
Slovakia	5.30	7.23	6.50	6.41
Slovenia	4.42	5.76	4.95	5.15
Spain	0.14	0.47	0.34	0.28
Sweden	0.58	1.50	1.17	1.05
ROW	0.03	0.08	0.08	0.06
Correlation with original estimate		99.4	99.5	99.7

A2.2 Additional tables

Table A2.2: Sector classification along with NACE code and share in overall trade

Sector	**Code**	Trade share
Agriculture, hunting, forestry and fishing	AtB	3.03%
Mining and quarrying	C	4.52%
Food , beverages and tobacco	15t16	7.17%
Textiles, textile , leather and footwear	17t19	6.13%
Wood and of wood and cork	20	0.71%
Pulp, paper, paper , printing and publishing	21t22	3.74%
Coke, refined petroleum and nuclear fuel	23	2.86%
Chemicals and chemical	24	12.52%
Rubber and plastics	25	2.36%
Other non-metallic mineral	26	0.82%
Basic metals and fabricated metal	27t28	4.77%
Machinery, nec	29	3.46%
Electrical and optical equipment	30t33	8.27%
Transport equipment	34t35	10.15%
Manufacturing nec; recycling	36t37	2.40%
Electricity, gas and water supply	E	0.72%
Construction	F	0.41%
Wholesale and retail trade	G	2.94%
Hotels and restaurants	H	0.68%
Transport and storage and communication	I	8.11%
Financial intermediation	J	3.58%
Real estate, renting and business activities	K	8.76%
Public admin and defence;	L	0.28%
Education	M	0.16%
Health and social work	N	0.06%
Other community, social and personal services	O	1.36%

 10.14754/CEU.2016.08

Table A2.3: Countries used in the two counterfactuals

	First Counterfactual	**Second Counterfactual**
Austria	•	•
Belgium	•	•
Bulgaria	○	•
Czech Republic	•	•
Denmark	•	•
Estonia	•	•
Finland	•	•
France	•	•
Germany	•	•
Great Britain	•	•
Greece	•	•
Hungary	•	•
Ireland	•	•
Italy	•	•
Latvia	•	•
Lithuania	•	•
The Netherlands	•	•
Poland	•	•
Portugal	•	•
Romania	○	•
Slovakia	•	•
Slovenia	•	•
Spain	•	•
Sweden	•	•
ROW	•	•

Note: underlined countries are new members in the 2004 wave

A2.3 Household income

In this section, I prove that the trade deficit is a component of household income, $I = w_n L_n - S_n$. The demand equations and the balanced budget equations become:

$$\begin{aligned} X_n^j &= \sum_{k=1}^{J} \left[\gamma_n^{k,j} \left(1-\beta^k\right) \sum_{i=1}^{N} \pi_{in}^k X_i^k \right] + \alpha_n^j I \\ \sum_{j=1}^{J} X_n^j + S_n &= \sum_{j=1}^{J} \sum_{i=1}^{N} \pi_{in}^j X_i^j \end{aligned} \tag{A2.1}$$

where HI is household income. Summing over the expense equation, I get

$$\sum_{j=1}^{J} X_n^j = \sum_{j=1}^{J} \left[\sum_{k=1}^{J} \gamma_n^{k,j} \left(1-\beta^k\right) \sum_{i=1}^{N} \pi_{in}^k X_i^k \right] + I$$

Using the fact that $\sum_k \gamma_n^{k,j} = 1$ and the commutative properties of addition I get:

$$\begin{aligned} \sum_{j=1}^{J} X_n^j &= \sum_{k=1}^{J} \left[\sum_{j=1}^{J} \left(1-\beta^k\right) \gamma_n^{k,j} \sum_{i=1}^{N} \pi_{in}^k X_i^k \right] + I \\ \sum_{j=1}^{J} X_n^j &= \sum_{k=1}^{J} \left[\sum_{i=1}^{N} \left(1-\beta^k\right) \pi_{in}^k X_i^k \sum_{j=1}^{J} \gamma_n^{k,j} \right] + I \\ \sum_{j=1}^{J} X_n^j &= \sum_{k=1}^{J} \sum_{i=1}^{N} \left(1-\beta^k\right) \pi_{in}^k X_i^k + I \end{aligned}$$

I substitute in total output from the balanced trade condition

$$\sum_{j=1}^{J} \sum_{i=1}^{N} \pi_{in}^j X_i^j - S_n = \sum_{k=1}^{J} \sum_{i=1}^{N} \left(1-\beta^k\right) \pi_{in}^k X_i^k + I$$

This implies that

$$\sum_{j=1}^{J} \beta^j \sum_{i=1}^{N} \pi_{in}^j X_i^j - S_n = I$$

The inner sum of the first time on the left hand side is total output of industry j. As I assume constant returns to scale, $\beta^j y^j$ is the payment to labour in that sector. As wages are constant across sectors, summing up, the left hand side summation is $w_n L_n$. QED ∎

Appendix to Chapter 3

A3.1 Additional tables

Table A3.1: Sectors covered

NACE code	Manufacturing Sector
10	Food products
11	Beverages
13	Textiles
14	Wearing apparel
15	Leather and related products
16	Wood and of products of wood and cork, except furniture
17	Paper and paper products
18	Printing and reproduction of recorded media
19	Chemicals and chemical products
20	Basic pharmaceutical products and pharmaceutical preparations
21	Rubber and plastic products
22	Other non-metallic mineral products
23	Basic metals
24	Fabricated metal products, except machinery and equipment
25	Computer, electronic and optical products
26	Electrical equipment
27	Machinery and equipment
28	Motor vehicles, trailers and semitrailers
29	Other transport equipment
30	Furniture
31	Other manufacturing
32	Repair and installation of machinery and equipment

A3.2 Proof of Propositions

Proof of Proposition 1:

Taking log of the domestic cut-off

$$\ln \phi_D = \ln \frac{\Psi_D}{\tau} + \frac{1}{k}\left[\ln\left(\tau^{2k}-1\right) - \ln\left(\tau^k - (\rho\varepsilon)^{k+1}\right)\right] = \ln \frac{\Psi_D}{\tau} + \frac{1}{k}\ln\left(\tau^{2k}-1\right) - \frac{1}{k}\ln\left(\tau^k - (\rho\varepsilon)^{k+1}\right)$$

we get that the elasticity is

$$\frac{\partial \ln \phi_D}{\partial \ln \varepsilon} = \frac{k+1}{k}\frac{(\rho\varepsilon)^{k+1}}{\tau^k - (\rho\varepsilon)^{k+1}} + \frac{k+1}{k}\frac{\varepsilon^{k+1}\rho^k}{\tau^k - (\rho\varepsilon)^{k+1}}\frac{\partial \rho}{\partial \ln \varepsilon}$$

We know that

$$\rho = \left(\frac{c^\star}{c}\right)^{\frac{k}{k+1}}$$

Under symmetry this becomes

$$\rho = \left(1+\alpha\varepsilon^{-1}\right)^{\frac{k}{k+1}}(1+\alpha\varepsilon)^{-\frac{k}{k+1}}$$

Let $x = \ln \varepsilon$. Then

$$\frac{\partial\rho}{\partial x} = -\frac{k}{k+1}(1+\alpha e^{-x})^{\frac{k}{k+1}-1}(1+\alpha e^{x})^{-\frac{k}{k+1}}\alpha e^{-x} - \frac{k}{k+1}(1+\alpha e^{-x})^{\frac{k}{k+1}}(1+\alpha e^{x})^{-\frac{k}{k+1}-1}\alpha e^{x} =$$

$$\frac{\partial\rho}{\partial x} = -\frac{k}{k+1}\alpha\left[\frac{(1+\alpha e^{-x})^{\frac{k}{k+1}}}{(1+\alpha e^{-x})}(1+\alpha e^{x})^{-\frac{k}{k+1}}e^{-x} + \frac{(1+\alpha e^{-x})^{\frac{k}{k+1}}(1+\alpha e^{x})^{-\frac{k}{k+1}}}{(1+\alpha e^{x})}e^{x}\right]$$

$$\frac{\partial\rho}{\partial x} = -\frac{k}{k+1}\alpha(1+\alpha e^{-x})^{\frac{k}{k+1}}(1+\alpha e^{x})^{-\frac{k}{k+1}}\left[\frac{e^{-x}}{(1+\alpha e^{-x})} + \frac{e^{x}}{(1+\alpha e^{x})}\right]$$

Plugging ε back in

$$\frac{\partial\rho}{\partial x} = -\frac{k}{k+1}\alpha(1+\tfrac{\alpha}{\varepsilon})^{\frac{k}{k+1}}(1+\alpha\varepsilon)^{-\frac{k}{k+1}}\left[\frac{\frac{1}{\varepsilon}}{(1+\frac{\alpha}{\varepsilon})} + \frac{\varepsilon}{(1+\alpha\varepsilon)}\right]$$

$$\frac{\partial\rho}{\partial x} = -\frac{k}{k+1}\alpha\rho\left[\frac{1+\alpha\varepsilon+\varepsilon^2+\alpha\varepsilon}{\varepsilon+\alpha\varepsilon^2+\alpha+\alpha^2\varepsilon}\right]$$

$$\frac{\partial\rho}{\partial x} = -\frac{k}{k+1}\rho\left[\frac{\alpha+2\alpha^2\varepsilon+\alpha\varepsilon^2}{\varepsilon+\alpha\varepsilon^2+\alpha+\alpha^2\varepsilon}\right]$$

So the derivative becomes

$$\frac{\partial \ln\phi_D}{\partial\ln\varepsilon} = \frac{k+1}{k}\frac{(\rho\varepsilon)^{k+1}}{\tau^k-(\rho\varepsilon)^{k+1}} + \frac{k+1}{k}\frac{\varepsilon^{k+1}\rho^k}{\tau^k-(\rho\varepsilon)^{k+1}}\frac{\partial\rho}{\partial\ln\varepsilon} = \frac{k+1}{k}\frac{\varepsilon^{k+1}\rho^k}{\tau^k-(\rho\varepsilon)^{k+1}}\left[\rho - \frac{k}{k+1}\rho\left[\frac{1+2\alpha\varepsilon+\varepsilon^2}{\varepsilon+\alpha\varepsilon^2+\alpha+\alpha^2\varepsilon}\right]\right]$$

$$\frac{\partial \ln\phi_D}{\partial\ln\varepsilon} = \frac{k+1}{k}\frac{\varepsilon^{k+1}\rho^{k+1}}{\tau^k-(\rho\varepsilon)^{k+1}}\left[1 - \frac{k}{k+1}\left[\frac{\alpha+2\alpha^2\varepsilon+\alpha\varepsilon^2}{\varepsilon+\alpha\varepsilon^2+\alpha+\alpha^2\varepsilon}\right]\right]$$

Looking at the term in the inner parenthesis, we can rearrange it such that

$$\frac{\alpha+2\alpha^2\varepsilon+\alpha\varepsilon^2}{\varepsilon+\alpha\varepsilon^2+\alpha+\alpha^2\varepsilon}=\frac{\varepsilon-\varepsilon+\alpha\varepsilon^2+\alpha+\alpha^2\varepsilon+\alpha^2\varepsilon}{\varepsilon+\alpha\varepsilon^2+\alpha+\alpha^2\varepsilon}=\frac{\varepsilon+\alpha\varepsilon^2+\alpha+\alpha^2\varepsilon+\alpha^2\varepsilon-\varepsilon}{\varepsilon+\alpha\varepsilon^2+\alpha+\alpha^2\varepsilon}=$$

$$\frac{\alpha+2\alpha^2\varepsilon+\alpha\varepsilon^2}{\varepsilon+\alpha\varepsilon^2+\alpha+\alpha^2\varepsilon}=1-\frac{\varepsilon\left(1-\alpha^2\right)}{\varepsilon+\alpha\varepsilon^2+\alpha+\alpha^2\varepsilon}$$

This implies that ϖ is always smaller than one and the exchange rate elasticity is always positive.

Proof of Proposition 2:

We start by taking logs of the export cutoff elasticity

$$\ln\phi_X=\ln\frac{\Psi_X}{\tau}+\frac{1}{k}\ln\left(\tau^{2k}-1\right)-\frac{1}{k}\ln\left(\tau^k-(\rho\varepsilon)^{-k-1}\right)-\ln\varepsilon-\frac{k+1}{k}\ln\rho=\ln\phi_{D^\star}-\ln\varepsilon-\frac{k+1}{k}\ln\rho$$

Therefore the exchange rate elasticity is

$$\xi_{\phi_X,\varepsilon}=\xi_{\phi_{D^\star},\varepsilon}-1-\frac{\partial\ln\rho}{\partial\ln\varepsilon}$$

where

$$\frac{\partial\ln\rho}{\partial\ln\varepsilon}=-\frac{k}{k+1}\left[\frac{\alpha}{\varepsilon+\alpha}+\frac{\alpha\varepsilon}{1+\alpha\varepsilon}\right]$$

Let x denote the term in paranthesis. As

$$\frac{\partial x}{\partial\alpha}=\frac{\varepsilon\left(1+4\varepsilon\alpha+\alpha^2+\varepsilon^2\left(1+\alpha^2\right)\right)}{(\varepsilon+\alpha)^2(1+\varepsilon\alpha)^2}>0$$

$\frac{\partial\ln\rho}{\partial\ln\varepsilon}$ is at its maximum at $\alpha=1$. Therefore in the case when firms source all their inputs from abroad $1-\left(\frac{\alpha\varepsilon^{-1}}{1+\alpha\varepsilon^{-1}}+\frac{\alpha\varepsilon}{1+\alpha\varepsilon}\right)=1-\frac{1}{\varepsilon+1}-\frac{\varepsilon}{1+\varepsilon}=0$ and at worst $\xi_{\phi_X,\varepsilon}=\xi_{\phi_{D^\star},\varepsilon}$. Therefore the export cutoff elasticity is always negative.

Proof of Proposition 3:

The value of exports for a firm of productivity ϕ is given by:

$$\begin{aligned} y_X(\phi) &= \tfrac{\mu_X(\phi)}{1+\mu_X(\phi)} \tfrac{\varepsilon\gamma I^\star \phi}{c\tau} \\ p_X(\phi) &= (1+\mu_x(\phi)) \tfrac{\tau c}{\varepsilon\phi} \\ V = p_X(\phi) y_X(\phi) &= (1+\mu_X(\phi)) \tfrac{\tau c}{\varepsilon\phi} \tfrac{\mu_X(\phi)}{1+\mu_X(\phi)} \tfrac{\varepsilon\gamma I^\star \phi}{c\tau} = \mu_X(\phi)\gamma I^\star \end{aligned} \tag{A3.1}$$

Taking logs it is clear that The elasticity of export with respect to the exchange rate is:

$$\begin{aligned} \ln V_X &= \ln \mu_X(\phi) + \ln \gamma I^\star \\ \xi_{V_X,\varepsilon} &= \tfrac{\partial \ln V_X}{\partial \ln \varepsilon} = \tfrac{\partial \mu_X(\phi)}{\partial \ln \varepsilon} \end{aligned} \tag{A3.2}$$

$$\begin{aligned} \mu_X(\phi) &= \Omega\left(\tfrac{\phi}{\phi_X} e\right) - 1 \\ \tfrac{\partial \mu_X(\phi)}{\partial \varepsilon} \tfrac{\varepsilon}{\mu_X(\phi)} &= \tfrac{\partial\left(\Omega\left(\frac{\phi}{\phi_X}e\right)-1\right)}{\partial\varepsilon} \tfrac{\varepsilon}{\Omega\left(\frac{\phi}{\phi_X}e\right)-1} = -\Omega'\left(\tfrac{\phi}{\phi_X}e\right) \tfrac{\phi}{\phi^2{}_X} e \tfrac{\varepsilon}{\Omega\left(\frac{\phi}{\phi_X}e\right)-1} \tfrac{\partial\phi_X}{\partial\varepsilon} \\ \tfrac{\partial \mu_X(\phi)}{\partial \varepsilon} \tfrac{\varepsilon}{\mu_X(\phi)} &= -\Omega'\left(\tfrac{\phi}{\phi_X}e\right) \tfrac{\phi}{\phi_X} \tfrac{e}{\Omega\left(\frac{\phi}{\phi_X}e\right)-1} \tfrac{\partial\phi_X}{\partial\varepsilon} \tfrac{\varepsilon}{\phi_X} = -\Omega'\left(\tfrac{\phi}{\phi_X}e\right) \tfrac{\phi}{\phi_X} \tfrac{e}{\Omega\left(\frac{\phi}{\phi_X}e\right)-1} \xi_{\phi_X,\varepsilon} > 0 \end{aligned} \tag{A3.3}$$

Proof of Proposition 4:

Using the fact that $\Omega\prime(x) = \frac{\Omega(x)}{x[1+\Omega(x)]}$, the elasticity of exports to exchange rates can be rewritten as

$$\begin{aligned} \xi_{V,\varepsilon} &= -\Omega'\left(\tfrac{\phi}{\phi_X}e\right) \tfrac{\phi}{\phi_X} \tfrac{e}{\Omega\left(\frac{\phi}{\phi_X}e\right)-1} \xi_{\phi_X,\varepsilon} = \\ &-\tfrac{\Omega\left(\frac{\phi}{\phi_X}e\right)}{\left(\frac{\phi}{\phi_X}e\right)\left[1+\Omega\left(\frac{\phi}{\phi_X}e\right)\right]} \tfrac{\phi}{\phi_X} \tfrac{e}{\Omega\left(\frac{\phi}{\phi_X}e\right)-1} \xi_{\phi_X,\varepsilon} = \\ &\tfrac{-\Omega\left(\frac{\phi}{\phi_X}e\right)}{\left[\Omega\left(\frac{\phi}{\phi_X}e\right)-1\right]\left[\Omega\left(\frac{\phi}{\phi_X}e\right)+1\right]} \xi_{\phi_X,\varepsilon} \end{aligned} \tag{A3.4}$$

Rather than taking the derivative of the elasticity with respect to ϕ, we take the derivate of the log of the elasticity, using the fact that the logarithm is a monotonically increasing function.

$$\ln \xi_{V,\varepsilon} = \ln \Omega\left(\frac{\phi}{\phi_X}e\right) - \ln\left[\Omega\left(\frac{\phi}{\phi_X}e\right) - 1\right] - \ln\left[\Omega\left(\frac{\phi}{\phi_X}e\right) + 1\right] - \ln \xi_{\phi_X,\varepsilon} \tag{A3.5}$$

As the last term does not depend on ϕ, taking the derivative yields

$$\begin{gathered}\frac{\partial \ln \xi_{V,\varepsilon}}{\partial \phi} = \frac{1}{\Omega\left(\frac{\phi}{\phi_X}e\right)} \frac{\Omega\left(\frac{\phi}{\phi_X}e\right)}{\frac{\phi}{\phi_X}e\left[1+\Omega\left(\frac{\phi}{\phi_X}e\right)\right]} \frac{e}{\phi_X} - \frac{1}{\Omega\left(\frac{\phi}{\phi_X}e\right)-1} \frac{\Omega\left(\frac{\phi}{\phi_X}e\right)}{\frac{\phi}{\phi_X}e\left[1+\Omega\left(\frac{\phi}{\phi_X}e\right)\right]} \frac{e}{\phi_X} - \frac{1}{\Omega\left(\frac{\phi}{\phi_X}e\right)+1} \frac{\Omega\left(\frac{\phi}{\phi_X}e\right)}{\frac{\phi}{\phi_X}e\left[1+\Omega\left(\frac{\phi}{\phi_X}e\right)\right]} \frac{e}{\phi_X} \approx \\ \frac{\partial \ln \xi_{V,\varepsilon}}{\partial \phi} = \frac{1}{1+\Omega\left(\frac{\phi}{\phi_X}e\right)} - \frac{\Omega\left(\frac{\phi}{\phi_X}e\right)}{\Omega\left(\frac{\phi}{\phi_X}e\right)-1} \frac{1}{\left[1+\Omega\left(\frac{\phi}{\phi_X}e\right)\right]} - \frac{\Omega\left(\frac{\phi}{\phi_X}e\right)}{\Omega\left(\frac{\phi}{\phi_X}e\right)+1} \frac{1}{\left[1+\Omega\left(\frac{\phi}{\phi_X}e\right)\right]}\end{gathered} \tag{A3.6}$$

where $\approx$ indicates that we have simplified by $\frac{e}{\phi_X}$, a positive constant, on the right hand side. Grouping the first two terms gives us:

$$\begin{gathered}\frac{\partial \ln \xi_{V,\varepsilon}}{\partial \phi} = \frac{1}{1+\Omega\left(\frac{\phi}{\phi_X}e\right)} \left[1 - \frac{\Omega\left(\frac{\phi}{\phi_X}e\right)}{\Omega\left(\frac{\phi}{\phi_X}e\right)-1}\right] - \frac{\Omega\left(\frac{\phi}{\phi_X}e\right)}{\left[1+\Omega\left(\frac{\phi}{\phi_X}e\right)\right]^2} \approx \\ \frac{\partial \ln \xi_{V,\varepsilon}}{\partial \phi} = \frac{1}{1+\Omega\left(\frac{\phi}{\phi_X}e\right)} \left[-\frac{1}{\Omega\left(\frac{\phi}{\phi_X}e\right)-1}\right] - \frac{\Omega\left(\frac{\phi}{\phi_X}e\right)}{\left[1+\Omega\left(\frac{\phi}{\phi_X}e\right)\right]^2} = \\ \frac{\partial \ln \xi_{V,\varepsilon}}{\partial \phi} = -\frac{1}{\Omega\left(\frac{\phi}{\phi_X}e\right)^2-1} - \frac{\Omega\left(\frac{\phi}{\phi_X}e\right)}{\left[1+\Omega\left(\frac{\phi}{\phi_X}e\right)\right]^2}\end{gathered} \tag{A3.7}$$

Where we know from the proof of Proposition 3 that the first fraction is positive and all the terms of the second one are positive, hence the elasticity is negative. Alternatively we can substitute in the definition of the markup and we get:

$$\frac{\partial \ln \xi_{V,\varepsilon}}{\partial \phi} = -\frac{1}{\mu_X(\phi)\left[\mu_X(\phi)+2\right]} - \frac{\mu_X(\phi)+1}{\left[\mu_X(\phi)+2\right]^2} = -\left[\frac{2+\mu_X(\phi)^2+2\mu_X(\phi)}{\mu_X(\phi)\left[\mu_X(\phi)+2\right]}\right] = -\frac{1+(\mu_X(\phi)+1)^2}{\mu_X(\phi)\left[\mu_X(\phi)+2\right]}$$

Proof of Proposition 5:

Again we take the derivative of the log of elasticity. After a little algebraic manipulation we get the following results

$$\begin{gathered}\frac{\partial \ln \xi_{V,\varepsilon}}{\partial \psi} = \frac{1}{\Omega\left(\frac{\phi}{\phi_X}e\right)} \frac{\Omega\left(\frac{\phi}{\phi_X}e\right)}{\frac{\phi}{\phi_X}e\left[1+\Omega\left(\frac{\phi}{\phi_X}e\right)\right]} \frac{-\phi e}{\phi_X} \frac{\partial \phi_X}{\partial \psi} - \frac{1}{\Omega\left(\frac{\phi}{\phi_X}e\right)-1} \frac{\Omega\left(\frac{\phi}{\phi_X}e\right)}{\frac{\phi}{\phi_X}e\left[1+\Omega\left(\frac{\phi}{\phi_X}e\right)\right]} \frac{-\phi e}{\phi_X} \frac{\partial \phi_X}{\partial \psi} - \\ \frac{1}{\Omega\left(\frac{\phi}{\phi_X}e\right)+1} \frac{\Omega\left(\frac{\phi}{\phi_X}e\right)}{\frac{\phi}{\phi_X}e\left[1+\Omega\left(\frac{\phi}{\phi_X}e\right)\right]} \frac{-\phi e}{\phi_X} \frac{\partial \phi_X}{\partial \psi}\end{gathered} \tag{A3.8}$$

Using the results in Proposition 4, this simplifies to

$$\frac{\partial \ln \xi_{V,\varepsilon}}{\partial \gamma} = -\frac{\partial \ln \xi_{V,\varepsilon}}{\partial \phi} \phi \frac{\partial \phi_X}{\partial \gamma} \tag{A3.9}$$

As $\frac{\partial \ln \xi_{V,\varepsilon}}{\partial \phi}$ is negative, we just need to show that

$$\frac{\partial \phi_X}{\partial \gamma}$$

is positive. Note from (3.28) that ϕ_X only depends on γ through Ψ_X and, from (3.29) follows that

$$\frac{\partial \Psi_X}{\partial \gamma} = \frac{\partial \psi_X}{\partial \gamma} > 1 \tag{A3.10}$$