Entrepreneurial risk and diversification through trade

Working Papers 2017

Federico Esposito

BANCO DE PORTUGAL
EUROSYSTEM

14

14

Entrepreneurial risk and diversification through trade

Working Papers 2017

Federico Esposito

July 2017

Please address correspondence to
Banco de Portugal, Economics and Research Department
Av. Almirante Reis 71, 1150-012 Lisboa, Portugal
T +351 213 130 000 | estudos@bportugal.pt

BANCO DE PORTUGAL
EUROSYSTEM

Lisbon, 2017 • www.bportugal.pt

WORKING PAPERS | Lisbon 2017 • Banco de Portugal Av. Almirante Reis, 71 | 1150-012 Lisboa • www.bportugal.pt •
Edition Economics and Research Department • ISBN 978-989-678-538-3 (online) • ISSN 2182-0422 (online)

Entrepreneurial Risk and Diversification through Trade

Federico Esposito
Tufts University

July 2017

Abstract
Demand shocks have been shown to be an important determinant of firm sales' variation across different markets. The key insight of this paper is that, in presence of incomplete financial markets, firms can reduce demand risk through geographical diversification. I first develop a general equilibrium trade model with monopolistic competition, characterized by stochastic demand and risk-averse entrepreneurs, who exploit the imperfect correlation of demand across countries to lower the variance of their total sales. Despite its complexity, I provide a novel analytical characterization of the firm's problem and show that both entry and trade flows to a market are affected by its risk-return profile, which in turn depends on the multilateral covariance of the country's demand with all other markets. Moreover, I show that welfare gains from trade can be significantly higher than the gains predicted by standard models which neglect firm level risk. After a trade liberalization, risk-averse firms boost exports to countries that offer better diversification benefits. Hence, in these markets foreign competition becomes stronger, lowering the price level more. Therefore, countries with better risk-return profiles gain more from international trade, while riskier markets reap lower gains. I then use data on Portuguese firm-level international trade flows, from 1995 to 2005, to provide evidence that exporters behave in a way consistent with my model's predictions. Finally, policy counterfactuals reveal that, for the median country in the sample, the risk diversification channel increases welfare gains from trade by 15% relative to traditional models with risk neutrality.

Acknowledgements: I am extremely grateful to my advisor Costas Arkolakis, and to Lorenzo Caliendo, Samuel Kortum and Peter Schott for their continue guidance as part of my dissertation committee at Yale University. I thank the hospitality of the Economic and Research Department of Banco de Portugal, where part of this research was conducted. I have benefited from discussions with Treb Allen, Mary Amiti, Pol Antras, David Atkin, Andrew Bernard, Kirill Borusyak, Arnaud Costinot, Penny Goldberg, Gene Grossman, Tim Kehoe, Giovanni Maggi, Marc Melitz, Monica Morlacco, Peter Neary, Luca Opromolla, Emanuel Ornelas, Eunhee Lee, Michael Peters, Tommaso Porzio, Steve Redding, Joe Shapiro, Robert Staiger, James Tybout as well as seminar participants at Yale University, Tufts University, Federal Reserve Board, University of Florida, Yale SOM, Bank of Italy, SUNY Albany, SED 2016, World Bank, AEA Meetings 2017, EEA Conference 2017, University of Naples - CSEF, Rocky Mountains Empirical Trade Conference 2017, N.A. Econometric Society Meetings 2017, SAET Conference 2017. Finally, I thank Siyuan He and Guangbin Hong for excellent research assistance. All errors are my own.

E-mail: federico.esposito@tufts.edu

1. Introduction

Recent advancements in trade theory have highlighted how various economic channels – market structure, firm-level heterogeneity, multiple sectors, intermediate goods – affect the size of the welfare gains from trade (see Costinot and Rodriguez-Clare (2013) for an overview). The trade literature, however, has so far overlooked an important welfare benefit that international trade could bring in: risk diversification.

This paper argues that international trade is an opportunity for firms not only to increase their scale, as in Krugman (1980) and Melitz (2003), but also to diversify their demand risk. In presence of incomplete financial markets, selling to destinations with imperfectly correlated demand can hedge firms against idiosyncratic shocks hitting sales, in the spirit of classical portfolio theory (Markowitz (1952) and Sharpe (1964)).

The paper shows that the benefits of international trade may go even beyond the reduction in the variance of firms' profits. When trade barriers go down, firms export more to countries which are a good hedge against demand risk, i.e. markets with either a stable demand or whose demand is negatively correlated with the other countries. In such markets, this increases competition among firms, which in turn lowers prices and leads to higher welfare gains from trade. In contrast, markets with a worse risk-return profile reap lower gains from trade, because the pro-competitive effect is weaker. Once I calibrate the model, I find that risk diversification channel increases, for the median country, welfare gains from trade by 15% relative to standard trade models.

In the first tier of my analysis, I develop a general equilibrium trade model with monopolistic competition, as in Melitz (2003), and Pareto distributed firms' productivities, as in Chaney (2008). The model is characterized by two novel elements. First, consumers have a Constant Elasticity of Substitution utility over a continuum of varieties, and demand is subject to country-variety random shocks. In addition, for each variety these demand shocks are imperfectly correlated across countries. Second, firms are owned by risk-averse entrepreneurs. This assumption reflects the evidence, discussed in Section 2, that most firms across several countries are owned by entrepreneurs whose wealth is not perfectly diversified and whose main source of income are their firm's profits, therefore exposing their income to demand fluctuations. In addition, even for multinational and public listed firms, whose ownership is not as concentrated as for small firms, stock-based compensation exposes their managers to firm-specific risk. Thus, in making economic decisions such as investment and production, managers reasonably attempt to minimize their risk exposure (see Ross (2004), Parrino *et al.* (2005) and Panousi and Papanikolaou (2012)).[1]

The entrepreneurs' problem consists of two stages. In the first stage, the entrepreneurs know only the moments of the demand shocks but not their realization. Firms make an irreversible investment: they choose in which countries to operate, and in these markets perform costly marketing and distributional activities. After the investment in marketing costs, firms learn the realized demand. Then, after uncertainty is resolved, entrepreneurs finally produce, using a production function linear in labor.

The fact that demand is correlated across countries implies that, in the first stage, entrepreneurs face a combinatorial problem. Indeed, both the extensive margin (whether to export to a market) and the intensive margin (how much to export) decisions are interdependent across markets: any decision taken in a market affects the outcome in the others. Then, for a given number of potential countries N, the choice set includes 2^N elements, and computing the indirect utility function corresponding to each of its elements would be computationally unfeasible.[2]

I deal with this computational challenge by assuming that firms send costly ads in each country where they want to sell. These activities allow firms to reach a fraction n of the consumers in each location, as in Arkolakis (2010). This implies that the firm's choice variable becomes continuous rather than discrete, and thus firms simultaneously choose *where to sell* (depending on whether n is optimally zero or positive) and *how much to sell* (firms can choose to sell to some or all consumers). In addition, the concavity of the firm's objective function, arising from the mean-variance specification, implies that the optimal solution is unique.[3]

Therefore, the firm's extensive and intensive margin decisions are not taken market by market, but rather performing a *global* diversification strategy. Entrepreneurs trade off the expected global profits with their variance, the exact slope being governed by the risk aversion, along the lines of the "portfolio analysis" pioneered by Markowitz (1952) and Sharpe (1964). This stands in sharp contrast to standard trade models, such as Melitz (2003),

1. I assume that financial markets are absent. This assumption captures in an extreme way the incompleteness of financial markets. Shutting down financial markets therefore allows to focus only on international trade as a mechanism firms can use to stabilize their sales. See also Riaño (2011) and Limão and Maggi (2013).

2. Other works in trade, such as Antras *et al.* (2014), Blaum *et al.* (2015), de Gortari *et al.* (2016) and Morales *et al.* (2014), deal with similar combinatorial problems, but in different contexts.

3. The presence of bounds on n (it cannot be negative and larger than 1) implies that the firm's problem cannot be solved analytically, as in standard portfolio theory. However, the concavity of the objective function implies that, numerically, the firm's problem can be solved using standard methods, such as the active set method, employed in quadratic programming. This is way faster than evaluating all the possible combinations of extensive/intensive margin decisions.

Chaney (2008) and Helpman *et al.* (2008), where the decision to sell in one destination is independent from the export decisions in other markets.

The model implies that both the probability of entering a market and the intensity of trade flows are increasing in the market's "Diversification Index". This variable measures the diversification benefits that a market can provide to firms exporting there. If demand in a country is relatively stable and negatively/mildly correlated with demand in the other countries, then firms optimally choose, *ceteribus paribus*, to export more there to hedge their business risk.[4] Therefore, my model suggests that neither the demand volatility in a market, nor the bilateral covariance of demand with the domestic market, are sufficient to predict the direction of trade. Instead, what determines trade patterns is the multilateral covariance: how much demand in a market co-varies with demand in other countries.

Furthermore, in a two-country version of the model, I show that the welfare gains from international trade are increasing in the Diversification Index. The intuition is simple: if the Diversification Index is high, firms can hedge their domestic demand risk by exporting to the foreign country. This implies tougher competition among firms, which in general equilibrium leads to lower prices and higher welfare gains.[5] Therefore, not only firms are able to lower the volatility of their profits by diversifying their sales abroad, but their risk-hedging behavior has a "pro-competitive" effect on welfare.

In the second tier of my analysis, I rely on a panel dataset of Portuguese manufacturing firms' exports, from 1995 to 2005, to test the model's predictions and to calibrate the model. Portugal is a small and export-intensive country, being at the 72nd percentile worldwide for exports per capita, and therefore can be considered a good laboratory to analyze the implications of my model. Furthermore, 70% of Portuguese exporters in 2005 were small firms, i.e. companies with less than 50 employees, for which the exposure to demand risk is likely to be a first-order concern.

I first estimate the cross-country covariance matrix of demand, Σ. Given the static nature of the model, Σ can be interpreted as a *long-run* covariance matrix that firms take as given when they choose their risk diversification strategy. Therefore, I estimate it by using variation in firm-level exports to each destination over the years 1995-2004.[6]

4. It is worth noting that the Diversification Index nests as special case the classical Sharpe Ratio proposed by Sharpe (1966). In fact, in the limit case in which all demand correlations are zero, the Diversification Index equals the simple ratio between mean and variance, similarly to the Sharpe Ratio.

5. In my model, total welfare is the sum of workers' welfare, which is simply the real wage, and entrepreneurs' welfare, which depends also on the variance of real profits.

6. I consider only sales of "established" firm-destination pairs, i.e. exporters selling to a certain market for at least 5 years. In this way, my estimates capture only the long run covariance of demand, rather than picking also some short-run noise due to the firms' demand learning process (see Albornoz *et al.* (2012), Berman *et al.* (2015b) and Conconi *et al.* (2016)).

From the estimated covariance matrix, I compute the Diversification Index, the country-level measure of diversification benefits. I then test the prediction that the firms' probability of entry and trade flows to a market are increasing in the market's Diversification Index, using the Portuguese firm-level trade data for 2005. The findings confirm that, controlling for several destination characteristics and "standard" gravity variables, e.g. bilateral distance and tariffs, firms are more likely to enter in countries with a high Diversification Index, i.e. markets that provide good diversification benefits. Moreover, conditional on entering a destination, firms export more to countries where they can better hedge their demand risk.

In the second part of the empirical analysis, I calibrate the parameters of the model, which I augment with i) a non-tradeable sector; ii) intermediate inputs and iii) exogenous trade deficits, similarly to Caliendo and Parro (2014) and Arkolakis *et al.* (2015). I calibrate the firms' risk aversion by matching the observed (positive) gradient of the relationship between the mean and the variance of firms' profits, as suggested by the firm's first order conditions. The reasoning is straightforward: if firms are risk-averse, they want to be compensated for taking additional risk, and thus higher sales variance must be associated with higher expected revenues. Interestingly, the results suggest that a modest amount of risk aversion is sufficient to rationalize the magnitudes in the data. Lastly, I calibrate the remaining parameters, such as marketing and iceberg trade costs, with the Simulated Method of Moments, as in Eaton *et al.* (2011).[7]

Armed with the calibrated model, I quantify the risk diversification benefits of international trade. Specifically, I follow Arkolakis *et al.* (2012) (ACR henceforth) and Costinot and Rodriguez-Clare (2013) and compute the welfare gains of going from autarky, i.e. a world where trade costs are infinitely high, to the observed trade equilibrium in 2005. My results illustrate that countries with a higher Diversification Index tend to benefit more from opening up to trade, consistent with the theoretical results. The rationale is that firms exploit the trade liberalization not only to expand their sales abroad, but also to diversify their demand risk. Having access to foreign markets not only allows firms to lower the total variability of profits, but it also implies more trade flows toward markets that provide better diversification benefits, i.e. countries with a high Diversification Index. Consequently, the increase in foreign competition is stronger in these countries, thereby lowering more prices.[8]

7. In particular, I match the observed i) bilateral manufacturing trade shares; ii) normalized number of Portuguese exporters to each destination; iii) mean and dispersion of export shares.

8. These findings are robust to the specification used for the entrepreneurs' utility. In particular, I show that having a decreasing rather than constant absolute risk aversion does not affect substantially the welfare results.

In addition, I compare the gains in my model with those predicted by traditional trade models that neglect risk, such as the class of models considered in ACR.[9] My results show that gains from trade are, for the median country, 15% higher than in ACR. Therefore, the "pro-competitive" effect of the firms' risk diversification behavior is also quantitatively relevant. However, while safer countries reap higher welfare gains than in ACR, markets with a worse risk-return profile have lower gains than in ACR, because the pro-competitive effect from foreign firms is weaker.

The result that, in presence of uncertainty, some countries do not gain much, and could potentially lose, from international trade is reminiscent of the finding in Newbery and Stiglitz (1984). In their simple model with two sectors (one safe and one risky) and two countries, when there is free trade consumers are insured from the variance but prices go up because production shifts toward the safe good, which can make countries worse off, rather than better off. A similar mechanism is at play in my model: although the variance of real profits goes down, which makes firms better off, in risky countries softer competition from abroad could raise prices, thus lowering welfare.

This paper relates to the growing literature studying the importance of second order moments for international trade.[10] Allen and Atkin (2016) use a portfolio approach to study the crop choice of Indian farmers under uncertainty. They show that greater trade openness increases farmers' revenues volatility, leading farmers to switch to safer crops, which in turn increases their welfare. Similarly, in my model a trade liberalization induces firms to export more to less risky countries, which increases welfare gains through a general equilibrium force. Fillat and Garetto (2015) argue that multinational firms, due to the large sunk costs of accessing foreign markets, are the most exposed to foreign demand risk, and therefore are riskier than firms selling domestically, especially in presence of persistent disaster risk. While they focus on the link between a company's international status and its stock return, I argue that international trade provides relevant risk diversification benefits to exporters, especially small and medium ones. De Sousa *et al.* (2015) use a partial equilibrium model with risk averse firms to rationalize the empirical finding that volatility and skewness of demand affect the firms' exporting decision. My contribution relative to these papers is, first, to establish that the multilateral covariance of demand is a key driver of trade patterns, and then quantify the welfare benefits of risk diversification, by means of a novel general equilibrium framework.[11]

9. These include the models in Krugman (1980), Eaton and Kortum (2002), Melitz (2003), and Chaney (2008).

10. For earlier contributions, see Helpman and Razin (1978), Kihlstrom and Laffont (1979), Eaton and Grossman (1985) and Maloney and Azevedo (1995).

11. Other recent works exploring the link between uncertainty and trade are Rob and Vettas (2003), Riaño (2011), Nguyen (2012), Impullitti *et al.* (2013), Vannoorenberghe (2012), Ramondo

This paper contributes to the literature that models exporters' behavior. Previous models of firms' export decision have studied a binary exporting decision (Roberts and Tybout (1997); Das *et al.* (2007)) or have assumed that exporters make independent entry decisions for each destination market (Helpman *et al.* (2008); Arkolakis (2010); Eaton *et al.* (2011)). In contrast, in my model entry in a given market depends on the global diversification strategy of the firm and, despite the analytical complexity of the firm's problem, I characterize both the extensive and intensive margin decisions.[12] Another trade model where the entry decision is interrelated across markets is Morales *et al.* (2015), in which the firm's export decision depends on its previous export history.

My paper also complements the strand of literature that studies the connection between openness to trade and macroeconomic volatility. Di Giovanni *et al.* (2014) investigate how idiosyncratic shocks to large firms directly contribute to aggregate volatility, through input-output linkages across the economy. Caselli *et al.* (2012) show that openness to international trade can lower GDP volatility by reducing exposure to domestic shocks. My paper, in contrast, investigates the implications of demand risk for firms' behavior on international markets and its effect on aggregate welfare.

Finally, my paper connects to the literature that studies the implications of incomplete financial markets for entrepreneurial risk and firms' behavior and performance. Herranz *et al.* (2015) show, using data on ownership of US small firms, that entrepreneurs are risk-averse and hedge business risk by adjusting the firm's capital structure and scale of production. Other notable contributions to this literature are Heaton and Lucas (2000), Roussanov (2010), Luo *et al.* (2010), Chen *et al.* (2010) and Hoffmann (2014).

The remainder of the paper is organized as follows. Section 2 presents some stylized facts that corroborate the main assumptions of the model, presented in Section 3. In Section 4, I estimate the model and empirically test its implications. In Section 5, I perform the counterfactual exercise, while Section 6 concludes.

2. Motivating evidence

Compared to standard trade models, such as Melitz (2003), the main novelty of my framework is that entrepreneurs are risk averse. There is recent evidence supporting this assumption. Cucculelli *et al.* (2012) survey several

et al. (2013), Vannoorenberghe *et al.* (2014), Novy and Taylor (2014), Handley and Limao (2015), Gervais (2016).

12. Heiland (2016) and De Sousa *et al.* (2015) also feature risk averse exporters, but the extensive margin decision is not modeled.

Italian entrepreneurs in the manufacturing sector and show that 76.4% of interviewed decision makers are risk averse. Interestingly, larger firms tend to be managed by decision makers with lower risk aversion.[13] A survey promoted by the consulting firm Capgemini reveals that, among 300 managers/CEO of leading companies across several countries, 40% of them believes that market/demand volatility is the most important challenge for their firm.[14] Further evidence that entrepreneurs display a risk-averse behavior has been recently provided, in different contexts, by Herranz *et al.* (2015), De Sousa *et al.* (2015) and Allen and Atkin (2016).

It is important to note that risk aversion is a factor affecting the behavior of large firms and multinationals as well, not just small-medium enterprises. Indeed, risk aversion arises if corporate management seeks to avoid default risk and the costs of financial distress, where these costs rise with the variability of the net cash flows of the firm (see Froot *et al.* (1993) and Allayannis *et al.* (2008)). Moreover, stock-based compensation exposes managers to firm-specific risk (see Petersen and Thiagarajan (2000), Ross (2004), Parrino *et al.* (2005) and Panousi and Papanikolaou (2012)). Thus, in making economic decisions such as investment and production, managers reasonably attempt to minimize their risk exposure.

Two objections could be raised to the risk aversion assumption. The first is that entrepreneurs could invest their wealth across several assets, diversifying away business risk. In reality, however, the majority of firms around the globe are controlled by *imperfectly diversified* owners. Using a dataset about ownership of 162,688 firms in 34 European countries, Lyandres *et al.* (2013) show that entrepreneurs' holdings are far from being well-diversified. The median entrepreneur in their sample owns shares of only two firms, and the Herfindhal Index of his holdings is 0.67, a number indicating high concentration of wealth. According to the Survey of Small Business Firms (2003), a large fraction of US small firms' owners invest substantial personal net-worth in their firms: half of them have 20% or more of their net worth invested in one firm, and 87% of them work at their company.[15] Moreover, Moskowitz and Vissing-Jorgensen (2002) estimate that US households with entrepreneurial equity invest on average more than 70 percent of their private holdings in a single private company in which they have an active management interest. Similar evidence that most of companies are controlled

13. I will take into account for differences in risk aversion across firms in an extension of the model.

14. This survey was conducted in 2011 among 300 companies across the globe. The survey can be found at: https://www.capgemini-consulting.com/resource-file-access/resource/pdf/The_2011_Global_Supply_Chain_Agenda.pdf.

15. This Survey, administered by Federal Reserve System and the U.S. Small Business Administration, is a cross sectional stratified random sample of about 4,000 non-farm, non-financial, non-real estate small businesses that represent about 5 million firms.

by imperfectly diversified owners has been provided by Benartzi and Thaler (2001), Agnew *et al.* (2003), Heaton and Lucas (2000), Faccio *et al.* (2011) and Herranz *et al.* (2013).

The second objection that could be raised is that firms can hedge demand risk on financial and credit markets. However, often small firms (which account for the vast majority of existing firms) have a limited access to capital markets (see Gertler and Gilchrist (1994), Hoffmann and Shcherbakova-Stewen (2011)), and even large firms under-invest in financial instruments (see Guay and Kothari (2003)) and, when they do, such instruments often do not successfully reduce risks (see Hentschel and Kothari (2001)). In addition, notice that financial derivatives can be used to hedge interest rate, exchange rate, and commodity price risks, rather than demand risk, which is the focus of this paper.

The model also features country-variety demand shocks. Recent empirical evidence has shown that demand shocks explain a large fraction of the total variation of firm sales. Hottman *et al.* (2015) have shown that 50-70 percent of the variance in firm sales can be attributed to differences in firm appeal. Eaton *et al.* (2011) and Kramarz *et al.* (2014) with French data and Munch and Nguyen (2014) with Danish data have instead estimated that firm-destination idiosyncratic shocks drive around 40-45% percent of sales variation. Di Giovanni *et al.* (2014) show that firm-specific components account for the vast majority of the variation in sales growth rates across firms, the remaining being sectoral and aggregate shocks. In addition, about half of the variation in the firm-specific component is explained by variation in that component across destinations. Recent contributions also include Bricongne *et al.* (2012), Nguyen (2012), Munch and Nguyen (2014), Berman *et al.* (2015a) and Armenter and Koren (2015).

The insight of this paper is that risk averse entrepreneurs optimally hedge these idiosyncratic demand shocks by exporting to markets with *imperfectly correlated* shocks. In the following section I describe the theoretical framework, where I introduce entrepreneurs' risk aversion and correlated demand shocks in a general equilibrium trade model, and show their implications trade patterns and welfare gains from trade.

3. A trade model with risk-averse entrepreneurs

I consider a static trade model with N asymmetric countries. The importing market is denoted by j, and the exporting market by i, where $i, j = 1, ..., N$. Each country j is populated by a continuum of workers of measure $\tilde{L}_j$, and a continuum of *risk-averse* entrepreneurs of measure M_j. Each entrepreneur owns a non-transferable technology to produce, with productivity z, a differentiated variety under monopolistic competition, as in Melitz (2003) and Chaney (2008). The productivity z is drawn from a known distribution, independently across countries and firms, and its realization is known by the entrepreneurs at the time of production. Since there is a one-to-one mapping from the productivity z to the variety produced, throughout the rest of the paper I will always use z to identify both. Finally, I assume that financial markets are absent.[16]

3.1. Consumption side

Both workers and entrepreneurs have access to a potentially different set of goods Ω_{ij}. Each agent v in country j chooses consumption by maximizing a CES aggregator of a continuum number of varieties, indexed with z:

$$\max U_j(v) = \left(\sum_i \int_{\Omega_{ij}} \alpha_j(z)^{\frac{1}{\sigma}} q_j(z,v)^{\frac{\sigma-1}{\sigma}} dz \right)^{\frac{\sigma}{\sigma-1}} \tag{1}$$

$$\text{s.to} \sum_i \int_{\Omega_{ij}} p_j(z) q_j(z,v) dz \leq y(v) \tag{2}$$

where $y(v)$ is agent v's income, and $\sigma > 1$ is the elasticity of substitution across varieties. Although the consumption decision, given income $y(v)$, is the same for workers and entrepreneurs, their incomes differ. In particular, workers earn labor income by working (inelastically) for the entrepreneurs. I assume that there is perfect and frictionless mobility of workers across firms, and therefore they *all* earn the same *non-stochastic* wage w. In contrast, entrepreneurs' only source of income are the profits they reap from operating their firm. Entrepreneurs, therefore, own a technology to maximize their income, but they incur in business risk, as it will be clearer in the next subsection.

The term $\alpha_j(z)$ reflects an exogenous demand shock specific to good z in market j, similarly to Eaton *et al.* (2011), Crozet *et al.* (2012) and Di Giovanni *et al.* (2014). This is the only source of uncertainty in the economy, and it can reflect shocks to tastes, climatic conditions, consumers confidence, regulation, firm reputation, etc. Define $\alpha(z) \equiv \alpha_1(z), ...\alpha_N(z)$ to be the vector of realizations of the demand shock for variety z. I assume that:

Assumption 1. $\alpha(z) \sim G(\bar{\alpha}, \Sigma)$, i.i.d. across z

16. This assumption captures in an extreme way the incompleteness of financial markets. Even if there were some financial assets available in the economy, as long as capital markets are incomplete firms would always be subject to a certain degree of demand risk. Shutting down financial markets therefore allows to focus only on international trade as a mechanism firms can use to stabilize their sales. See also Riaño (2011) and Limão and Maggi (2013).

Assumption 1 states that the demand shocks are drawn, independently across varieties, from a multivariate distribution characterized by an N-dimensional vector of means $\bar{\alpha}$ and an $N \times N$ variance-covariance matrix Σ. Given the interpretation of $\alpha_j(z)$ as a consumption shifter, I assume that the distribution has support over $\mathbb{R}^+$.

Few comments are in order. First, I assume that the demand shocks are country-variety specific. Therefore I am ruling out, for tractability, any aggregate shock that would affect the demand for all varieties in a destination. Second, for simplicity I assume that the moments of the shocks are the same for all varieties, but it would be fairly easy to extend the model to have $G(\bar{\alpha}, \Sigma)$ varying across sectors.

The maximization problem implies that the agent v's demand for variety z is:

$$q_{ij}(z, v) = \alpha_j(z) \frac{p_{ij}(z)^{-\sigma}}{P_j^{1-\sigma}} y_j(v), \tag{3}$$

where $p_{ij}(z)$ is the price of variety z produced in i and sold in j, and P_j is the standard Dixit-Stiglitz price index.

3.2. *Production side*

Entrepreneurs are the only owners and managers of their firms, and their only source of income are their firm's profits. Alternatively, one can think of them as the majority shareholders of their firm, with complete power over the firm's production choices. This assumption captures, in an extreme way, the evidence shown earlier that the majority of firms around the globe feature a concentrated ownership. They choose how to operate their firm z in country i by maximizing the following indirect utility in real income:

$$\max V\left(\frac{y_i(z)}{P_i}\right) = E\left(\frac{y_i(z)}{P_i}\right) - \frac{\gamma}{2} Var\left(\frac{y_i(z)}{P_i}\right), \tag{4}$$

where $y_i(z)$ equals net profits. The mean-variance specification above can be derived assuming that the entrepreneurs maximize the expectation of a CARA utility in real income.[17] The CARA utility has been widely used in the portfolio allocation literature (see, for example, Markowitz (1952), Sharpe (1964) and Ingersoll (1987)), and has the advantage of having a *constant* absolute risk aversion, given by the parameter $\gamma > 0$, which gives a lot of tractability to the model. One shortcoming of the CARA utility is that the absolute risk aversion

17. If the entrepreneurs have a CARA utility with parameter γ, a second-order Taylor approximation of the expected utility leads to the expression in 4 (see Eeckhoudt *et al.* (2005) and De Sousa *et al.* (2015) for a standard proof). If the demand shocks are normally distributed, the expression in 4 is exact (see Ingersoll (1987)). Maloney and Azevedo (1995) also assume that firms maximize a CARA utility.

is independent from wealth. In the Appendix I consider a variation of the model where the entrepreneurs maximize a CRRA utility, which features a decreasing absolute risk aversion, and show that the overall implications do not change substantially.

The production problem consists of two stages. In the first, firms know only the distribution of the demand shocks, $G(\alpha)$, but not their realization. Under uncertainty about future demand, firms make an irreversible investment: they choose in which countries to operate, and in these markets perform costly marketing and distributional activities. After the investment in marketing costs, firms learn the realized demand. Then, entrepreneurs produce using a production function linear in labor, and allocate their real income to different consumption goods, according to the sub-utility function in (1).

I assume that the first stage decision cannot be changed after the demand is observed. This assumption captures the idea that marketing activities present irreversibilities that make reallocation costly after the shocks are realized.[18] An alternative interpretation of this irreversibility is that firms sign contracts with buyers before the actual demand is known, and the contracts cannot be renegotiated.

The fact that demand is correlated across countries implies that, in the first stage, entrepreneurs face a combinatorial problem. Indeed, both the extensive margin (whether to export to a market) and the intensive margin (how much to export) decisions are intertwined across markets: any decision taken in a market affects the outcome in the others. Then, for a given number of potential countries N, the choice set includes 2^N elements, and computing the indirect utility function corresponding to each of its elements would be computationally unfeasible.[19]

I deal with such computational challenge by assuming that firms send costly ads in each country where they want to sell. These activities allow firms to reach a fraction $n_{ij}(z)$ of consumers in location j, as in Arkolakis (2010). This implies that the firm's choice variable is continuous rather than discrete, and thus firms simultaneously choose *where to sell* (if $n_{ij}(z)$ is optimally zero, firm z does not sell in country j) and *how much to sell* (firms can choose to sell to some or all consumers). In addition, the concavity of the firm's objective function, arising from the mean-variance specification, implies that the optimal solution is unique, as I prove in Proposition 1 below.

The fact that the ads are sent independently across firms and destinations, and the existence of a continuum number of consumers, imply that the total

18. For a similar assumption, but in different settings, see Ramondo *et al.* (2013), Albornoz *et al.* (2012) and Conconi *et al.* (2016).

19. Other works in trade, such as Antras *et al.* (2014), Blaum *et al.* (2015) and Morales *et al.* (2014), deal with similar combinatorial problems, but in different contexts.

demand for variety z in country j is:

$$q_{ij}(z) = \alpha_j(z)\frac{p_{ij}(z)^{-\sigma}}{P_j^{1-\sigma}}n_{ij}(z)Y_j, \tag{5}$$

where Y_j is the total income spent by consumers in j, and P_j is the Dixit-Stiglitz price index:

$$P_j^{1-\sigma} \equiv \sum_i \int_{\Omega_{ij}} n_{ij}(z)\alpha_j(z)\left(p_{ij}(z)\right)^{1-\sigma} dz. \tag{6}$$

Therefore, the first stage problem consists of choosing $n_{ij}(z)$ to maximize the following objective function:

$$\max_{\{n_{ij}\}} \sum_j E\left(\frac{\pi_{ij}(z)}{P_i}\right) - \frac{\gamma}{2}\sum_j\sum_s Cov\left(\frac{\pi_{ij}(z)}{P_i}, \frac{\pi_{is}(z)}{P_i}\right) \tag{7}$$

$$\text{s. to } 1 \geq n_{ij}(z) \geq 0 \tag{8}$$

where $\pi_{ij}(z)$ are net profits from destination j:

$$\pi_{ij}(z) = q_{ij}(n_{ij}(z))p_{ij}(z) - q_{ij}(n_{ij}(z))\frac{\tau_{ij}w_i}{z} - f_{ij}(z), \tag{9}$$

and $\tau_{ij} \geq 1$ are iceberg trade costs and f_{ij} are marketing costs.[20] In particular, I assume that there is a non-stochastic cost, $f_j > 0$, to reach each consumer in country j, and that this cost is paid in both domestic and foreign labor, as in Arkolakis (2010). Thus, total marketing costs are:

$$f_{ij}(z) = w_i^{\beta}w_j^{1-\beta}f_jL_jn_{ij}(z). \tag{10}$$

where $L_j \equiv \tilde{L}_j + M_j$ is the total measure of consumers in country j, and $\beta > 0$.[21]

The bounds on $n_{ij}(z)$ in equation (8) are a resource constraint: the number of consumers reached by a firm cannot be negative and cannot exceed the total size of the population. Using finance jargon, a firm cannot "short" consumers ($n_{ij}(z) < 0$) or "borrow" them from other countries ($n_{ij}(z) > 1$). This makes the maximization problem in (7) quite challenging, because it is subject to $2N$ *inequality* constraints. In finance, it is well known that there is no closed form solution for a portfolio optimization problem with lower and upper bounds (see Jagannathan and Ma (2002) and Ingersoll (1987)).

20. I normalize domestic trade barriers to $\tau_{ii} = 1$, and I further assume $\tau_{ij} \leq \tau_{iv}\tau_{vj}$ for all i, j, v to exclude the possibility of transportation arbitrage.

21. Note that the marginal cost of reaching an additional consumer is constant, which is a special case of Arkolakis (2010).

Notice that the variance of global real profits is the sum of the variances of the profits reaped in all potential destinations. In turn, these variances are the sum of the covariances of the profits from j with all markets, including itself. If the demand shocks were not correlated across countries, then the objective function would simply be the sum of the expected profits minus the sum of the variances.

The assumption that the shocks are independent across a continuum of varieties implies that aggregate variables w_j and P_j are non-stochastic. Therefore, plugging into $\pi_{ij}(z)$ the optimal consumers' demand from equation (5), I can write expected profits more compactly as:

$$E\left(\pi_{ij}(z)\right) = \bar{\alpha}_j n_{ij}(z) r_{ij}(z) - \frac{1}{P_i} f_{ij}(z), \tag{11}$$

where $\bar{\alpha_j}$ is the expected value of the demand shock in destination j, and

$$r_{ij}(z) \equiv \frac{1}{P_i} \frac{Y_j p_{ij}(z)^{-\sigma}}{P_j^{1-\sigma}} \left(p_{ij}(z) - \frac{\tau_{ij} w_i}{z}\right). \tag{12}$$

Note that $n_{ij}(z) r_{ij}(z)$ are real gross profits in j. Similarly, since marketing costs are non-stochastic, the covariance between $\pi_{ij}(z)$ and $\pi_{is}(z)$ is simply:

$$Cov\left(\frac{\pi_{ij}(z)}{P_i}, \frac{\pi_{is}(z)}{P_i}\right) = n_{ij}(z) r_{ij}(z) n_{is}(z) r_{is}(z) Cov(\alpha_j, \alpha_s), \tag{13}$$

where $Cov(\alpha_j, \alpha_s)$ is the covariance between the shock in country j and in country s.

Although there is no *analytical* solution to the first stage problem, because of the presence of inequality constraints, we can take a look at the firm's *interior* first order condition:

$$\underbrace{r_{ij}(z)\bar{\alpha}_j - \gamma r_{ij}(z) \sum_s n_{is}(z) r_{is}(z) Cov(\alpha_j, \alpha_s)}_{\text{marginal benefit}} = \underbrace{\frac{1}{P_i} w_i^{\beta} w_j^{1-\beta} f_j L_j}_{\text{marginal cost}}. \tag{14}$$

Equation (14) equates the real marginal benefit of adding one consumer to its real marginal cost. While the marginal cost is constant, the marginal benefit is decreasing in $n_{ij}(z)$. In particular, it is equal to the marginal revenues minus a "penalty" for risk, given by the sum of the profits covariances that destination j has with all other countries (including itself). The higher the covariance of demand, and thus profits, in market j with the other countries, the smaller the diversification benefits the market provides to a firm exporting there.

An additional interpretation is that a market with a high demand covariance with the other countries must have high average real profits to compensate the firm for the additional risk taken: this trade-off between risk and return is determined by the degree of risk aversion. I will indeed use this intuition to calibrate the risk aversion parameter in the data.

Note the difference in the optimality condition with Arkolakis (2010). In his paper, the marginal benefit of reaching an additional consumer is constant, while the marginal penetration cost is increasing in $n_{ij}(z)$. In my setting, instead, the marginal benefit of adding a consumer is decreasing in $n_{ij}(z)$, due to the concavity of the utility function of the entrepreneur, while the marginal cost is constant.

To find the general solution for n_{ij} and p_{ij}, I only need to make the following assumption, which I assume will hold throughout the paper:

Assumption 2. $det(\Sigma) > 0$

Assumption 2 is a necessary and sufficient condition to have uniqueness of the optimal solution. Since Σ is a covariance matrix, which by definition always has a non-negative determinant, this assumption simply rules out the knife-edge case of a zero determinant.[22] In the Appendix, I prove that (dropping the subscripts i and z for simplicity):

Proposition 1. *For firm z from country i, the unique vector of optimal* **n** *satisfies:*

$$\mathbf{n} = \frac{1}{\gamma}\tilde{\Sigma}^{-1}\left[\pi - \mu + \lambda\right], \tag{15}$$

where $\tilde{\Sigma}$ is firm z's matrix of profits covariances, π is the vector of expected net profits, μ and λ are the vectors of Lagrange multipliers associated with the bounds.

Moreover, the optimal price charged in destination j is a constant markup over the marginal cost:

$$p_{ij}(z) = \frac{\sigma}{\sigma - 1}\frac{\tau_{ij}w_i}{z}. \tag{16}$$

Proposition 1 shows that the optimal solution, as expected, resembles the standard mean-variance optimal rule, which dictates that the fraction of wealth allocated to each asset is proportional to the inverse of the covariance matrix times the vector of expected excess returns (see Ingersoll (1987) and Campbell and Viceira (2002)). The novelty of this paper is that such diversification concept is applied to the problem of the firm. The entrepreneurs, rather than solving a maximization problem country by country, as in traditional trade models, perform a *global* diversification

22. A zero determinant would happen only in the case where all pairwise correlations are exactly 1.

strategy: they trade off the expected global profits with their variance, the exact slope being governed by the absolute degree of risk aversion $\gamma > 0$.

Note that the firm's entry decision in a market (that is, whether $n > 0$) does not depend on a market-specific entry cutoff, but rather on the global diversification strategy of the firm. Therefore, firms' sorting into exporting is not strictly hierarchical, as in traditional trade models with fixed costs, such as Melitz (2003) and Chaney (2008). This can rationalize the recent empirical evidence (e.g. Eaton *et al.* (2011) and Armenter and Koren (2015)) which shows that only a fraction of firms strictly sort into foreign markets.

Finally, since the pricing decision is made after the uncertainty is resolved, and for a given $n_{ij}(z)$, the optimal price follows a standard constant markup rule over the marginal cost, shown in equation (16). This is because the realization of the shock in market j only shifts upward or downward the demand curve, without changing its slope.

A limit case. It is worth looking at the optimal solution in the special case of risk neutrality, i.e. $\gamma = 0$. In the Appendix I show that, in this case, a firm sells to country j only if its productivity exceeds an entry cutoff:

$$\left(\bar{z}_{ij}\right)^{\sigma-1} = \frac{w_i^{\beta} w_j^{1-\beta} f_j L_j P_j^{1-\sigma} \sigma}{\bar{\alpha}_j \left(\frac{\sigma}{\sigma-1}\tau_{ij} w_i\right)^{1-\sigma} Y_j}, \tag{17}$$

and that, whenever the firm enters a market, it sells to all consumers, so that $n_{ij}(z) = 1$. This case is isomorphic (with $\bar{\alpha}_j = 1$) to the firm's optimal behavior in trade models with risk-neutrality and fixed entry costs, such as Melitz (2003) and Chaney (2008). In these models, firms enter all profitable locations, i.e. the markets where the revenues are higher than the fixed costs of production, and upon entry they serve all consumers. The case of $\gamma = 0$ constitutes an important benchmark, as I will compare the welfare impact of counterfactual policies in my model with a positive risk aversion versus models with risk neutrality.

3.2.1. Trade patterns. I now investigate how trade patterns are affected by risk. To this end, I define a country-level measure of risk diversification as follows:

Definition. *Given a covariance matrix Σ and a vector of expected values $\bar{\alpha}$, the Diversification Index is defined as*

$$D \equiv (\Sigma)^{-1}\bar{\alpha}. \tag{18}$$

The Diversification Index is a measure of country-level risk diversification. For example, with two symmetric countries, it equals:

$$D = \frac{\bar{\alpha}}{\sigma^2(1+\rho)}, \tag{19}$$

where σ^2 and $\bar{\alpha}$ denote the variance and the mean of the demand shocks, respectively, and ρ is the cross-country correlation. Equation (19) shows that the Diversification Index is decreasing in the volatility of the shocks, and decreasing in the correlation of demand with the other country. For the case with N countries, given by equation (18), it is easily verifiable that D_j is decreasing in the variance of demand in market j and in the covariance with demand in the other countries. The intuition is that the more volatile demand in market j, relative to its mean, or the more demand covariates with the other countries, the riskier is country j, and the *lower* D_j. Therefore the Diversification Index summarizes the diversification benefits that a country provides to firms, since it is inversely proportional to the overall riskiness of its demand.[23]

To gain more intuition from Proposition 1, let us ignore for a moment the inequality constraints of the firm's problem. Then, equation (15) becomes:

$$n_{ij}(z) = \frac{D_j}{r_{ij}(z)\gamma} - \frac{\sum_k C_{jk} \frac{w_i f_k L_k}{r_{ik}(z)}}{r_{ij}(z)\gamma}, \tag{20}$$

and C_{jk} is the $j-k$ cofactor of Σ.[24] Equation (20) suggests that firms are more likely to enter a market with a higher Diversification Index, i.e. a market that provides good diversification benefits, conditional on trade barriers and market specific characteristics.[25] In addition, conditional on entering a destination, the amount exported is larger in markets with high Diversification Index. The intuition is that, if a market is "safe", then firms optimally choose to be more exposed there to hedge their business risk, and thus export more intensely to that market.

In the Appendix, I prove that this result holds also in the general case where some inequality constraints are binding, i.e. the firm does not enter all markets:

Proposition 2. *Define A a matrix whose $i-j$ element equals $A_{ij} = -\sum_{k\neq 1} C_{ik} Cov(\alpha_k, \alpha_j)$ for $i \neq j$, and $A_{ij} = 1$ for $i = j$. If A is a M-matrix, then the probability of exporting and the amount exported to a market are increasing in its Diversification Index.*

---

23. It is worth noting that the Diversification Index nests as special case the classical Sharpe Ratio proposed by Sharpe (1966). In fact, in the limit case in which all demand correlations are zero, the Diversification Index equals the simple ratio between mean and variance, similarly to the Sharpe Ratio.

24. The cofactor is defined as $C_{kj} \equiv (-1)^{k+j} M_{kj}$, where M_{kj} is the (k, j) minor of Σ. The minor of a matrix is the determinant of the sub-matrix formed by deleting the k-th row and j-th column.

25. Note that if the Diversification Index of a country changes because of a shock to the covariance matrix, that will have also a general equilibrium effect on wages and prices. Equation (20) and Proposition 2 focus on the partial equilibrium effect of the Diversification Index on the firm decision. The prediction, however, holds true also in general equilibrium, as I show in the counterfactual analysis in Section 5.

Proposition 2 suggests that neither the demand volatility in a market, nor the bilateral covariance of demand with the domestic market, are sufficient to predict the direction of trade. Instead, what determines trade patterns is the multilateral covariance, i.e. how much the demand in a market co-varies with demand in all other countries. The sufficient, but not necessary, condition to have a positive effect of the Diversification Index on $n_{ij}(z)$ is that the matrix A is a M-matrix, i.e. all off-diagonal elements are negative. It is easy to verify that A is a M-matrix whenever *some* demand correlations are negative.[26]

Propositions 1 and 2 also suggest how my model can reconcile the positive relationship between firm entry and market size with the existence of many small exporters in each destination, as shown by Eaton *et al.* (2011) and Arkolakis (2010). On one hand, upon entry firms can extract higher profits in larger markets. Therefore, more companies enter markets with larger population size. On the other hand, the firms' global diversification strategy may induce them to optimally reach only few consumers, and thus export small amounts. In contrast, the standard fixed cost models, such as Melitz (2003) and Chaney (2008), require *large* fixed costs to explain firm entry patterns, which contradict the existence of many small exporters. In the empirical section, I will use this feature to test the model's goodness of fit in the data.

Having characterized the exporting behavior of risk averse firms, I now define the world equilibrium and discuss its properties.

3.3. General equilibrium

I now describe the equations that define the trade equilibrium of the model. Following Helpman *et al.* (2004), Chaney (2008) and Arkolakis *et al.* (2008), I assume that the productivities are drawn, independently across firms and countries, from a Pareto distribution with density:

$$g(z) = \theta z^{-\theta-1}, \ z \geq \underline{z}, \tag{21}$$

where $\underline{z} > 0$. The price index is:

$$P_i^{1-\sigma} = \sum_j M_j \int_{\underline{z}}^{\infty} \bar{\alpha}_i n_{ji}(z) p_{ji}(z)^{1-\sigma} g(z) dz, \tag{22}$$

26. This can be seen, for example, for the case $N = 4$, where a typical element of the matrix A looks like:

$$A_{21} = \rho_{12}\sigma_1^3\sigma_2\sigma_3^2\sigma_4^2(1 - \rho_{13}^2 - \rho_{14}^2 - \rho_{34}^2 + 2\rho_{13}\rho_{14}\rho_{34}).$$

Then, to have $A_{21} < 0$, at least one correlation needs to be negative.

where $n_{ji}(z)$ and $p_{ji}(z)$ are shown in Proposition 1.[27] Since the optimal fraction of consumers reached, $n_{ij}(z)$, is bounded between 0 and 1, a sufficient condition to have a finite integral is that $\theta > \sigma - 1$. As in Chaney (2008), the number of firms is fixed to M_i, implying that in equilibrium there are profits, which equal:

$$\Pi_i = M_i \sum_j \left(\frac{1}{\sigma} \int_{\underline{z}}^{\infty} \bar{\alpha}_j \tilde{q}_{ij}(z) p_{ij}(z) g(z) dz - \int_{\underline{z}}^{\infty} f_{ij}(z) g(z) dz \right). \tag{23}$$

where $\tilde{q}_{ij} = \frac{p_{ij}(z)^{-\sigma}}{P_j^{1-\sigma}} n_{ij}(z) Y_j$ is the non-stochastic part of demand. I impose a balanced current account, thus the sum of labor income and business profits must equal the total income spent in the economy:

$$Y_i = w_i \tilde{L}_i + \Pi_i. \tag{24}$$

Finally, the labor market clearing condition states that in each country the supply of labor must equal the amount of labor used for production and marketing:

$$M_i \sum_j \int_{\underline{z}}^{\infty} \frac{\tau_{ij}}{z} \bar{\alpha}_j \tilde{q}_{ij}(z) g(z) dz + M_i \sum_j \int_{\underline{z}}^{\infty} f_j n_{ij}(z) L_j g(z) dz = \tilde{L}_i, \tag{25}$$

Therefore the trade equilibrium in this economy is characterized by a vector of wages $\{w_i\}$, price indexes $\{P_i\}$ and income $\{Y_i\}$ that solve the system of equations (22), (24), (25), where n_{ij} is given by equation (15). Given the analytical complexity of the firm problem, and thus of the model, finding sufficient conditions that guarantee the uniqueness of the equilibrium is difficult. However, when solved numerically, the model does not display the occurrence of multiple equilibria.

Proposition 1 implies that the sales of firm z to country j are given by:

$$x_{ij}(z) = p_{ij}(z) q_{ij}(z) = \alpha_j(z) \left(\frac{\sigma}{\sigma - 1} \frac{\tau_{ij} w_i}{z} \right)^{1-\sigma} \frac{Y_j}{P_j^{1-\sigma}} n_{ij}(z). \tag{26}$$

From equation (26), aggregate trade flows from i to j are:

$$X_{ij} = M_i \int_{\underline{z}}^{\infty} \bar{\alpha}_j \left(\frac{\sigma}{\sigma - 1} \frac{\tau_{ij} w_i}{z} \right)^{1-\sigma} \frac{Y_j}{P_j^{1-\sigma}} n_{ij}(z) \theta z^{-\theta-1} dz. \tag{27}$$

Proposition 2 then implies that aggregate trade flows X_{ij} are increasing in D_j, the measure of diversification benefits that destination j provides to exporters. I will test this prediction in the data in the empirical section.

27. The assumption that the demand shocks are i.i.d. across varieties implies that, in (22), $\bar{\alpha}_i = \bar{\alpha}_i(z) \equiv \int_0^{\infty} \alpha_i(z) g_i(\alpha) d\alpha$.

3.4. Welfare gains from trade

I define welfare in country i as the equally-weighted sum of the welfare of workers and entrepreneurs:

$$W_i = U_i^w \tilde{L}_i + M_i \int_{\underline{z}}^{\infty} U_i^e(z)\, dG(z), \tag{28}$$

where U_i^w is the indirect utility of each worker (which is the same for all workers), while $U^e(z)$ is the indirect utility of each entrepreneur (which differs depending on the productivity z). Since workers maximize a CES utility, their welfare is simply the real wage $\frac{w_i}{P_i}$, as in ACR. In contrast, the entrepreneurs maximize a stochastic utility, and thus the correct *money-metric* measure of their welfare is the Certainty Equivalent (see Pratt (1964) and Pope *et al.* (1983)). The Certainty Equivalent is the *certain* level of wealth for which the decision-maker is indifferent with respect to the uncertain alternative. The assumption of CARA utility implies that the Certainty Equivalent is, for entrepreneur z:

$$U_i^e(z) = E\left(\frac{\pi_i(z)}{P_i}\right) - \frac{\gamma}{2} Var\left(\frac{\pi_i(z)}{P_i}\right). \tag{29}$$

Then, aggregate welfare equals:

$$W_i = \frac{w_i \tilde{L}_i}{P_i} + \frac{\Pi_i}{P_i} - R_i, \tag{30}$$

where $R_i \equiv M_i \int_{\underline{z}}^{\infty} \frac{\gamma}{2} Var\left(\frac{\pi_i(z)}{P_i}\right) dG(z)$ is the aggregate "risk premium". Note that when the risk aversion equals zero, or when there is no uncertainty, total welfare simply equals real income, as in canonical trade models (see Chaney (2008), Arkolakis (2010)).

Welfare gains from trade. I now characterize the percentage change in the aggregate certainty equivalent associated with a change in trade costs from τ_{ij} to $\tau'_{ij} < \tau_{ij}$. For small changes in trade costs, the welfare gains are, from equation (30):

$$d\ln W_i = \underbrace{\frac{w_i \tilde{L}_i / P_i}{W_i} d\ln\left(\frac{w_i}{P_i}\right)}_{\text{workers' gains}} + \underbrace{\underbrace{\frac{\Pi_i / P_i}{W_i} d\ln\left(\frac{\Pi_i}{P_i}\right)}_{\text{profit effect}} - \underbrace{\frac{R_i}{W_i} d\ln R_i}_{\text{risk effect}}}_{\text{entrepreneurs' gains}}. \tag{31}$$

The first term reflects the gains that are accrued by workers, since their welfare is simply given by the real wage. The second term in (31) represents the entrepreneurs' welfare gains, which are the sum of a profit effect and a risk effect. The first effect is the change in real profits after the trade shock, weighted by the share of real profits in total welfare. Note that in models with risk neutrality and Pareto distributed productivities, such as Chaney (2008) and Arkolakis *et al.* (2008), profits are a constant share of total income. Consequently, the sum of workers' gains and the profits effect simply equals $-d\ln P_i$ (taking the wage as numeraire). In my model, in contrast, profits are no longer a constant share of Y_i, as can be gleaned from equation (24).

The third term in (31) is the percentage change in the aggregate risk premium. Note that, a priori, it is ambiguous whether this term increases or decreases after a trade liberalization. Indeed, lower trade barriers imply that firms can better diversify their risk across markets, and thus the volatility of their profits goes down. However, lower trade costs imply higher profits and, mechanically, also higher variance. In the case of two symmetric countries, as well as in empirical analysis, I show that the first effect dominates and the overall variance decreases after a trade liberalization.

A limit case. As shown earlier, when the risk aversion is zero the firm optimal behavior is the same as in standard monopolistic competition models, as Melitz (2003). It is easy to show that, in the special case of $\gamma = 0$, the welfare gains after a reduction in trade costs are given by:

$$d\ln W_i|_{\gamma=0} = -d\ln P_i = -\frac{1}{\theta} d\ln \lambda_{ii} \tag{32}$$

where λ_{ii} denotes the domestic trade share in country i and θ equals the trade elasticity. As shown by ACR, several trade models predict the welfare gains from trade to be equal to equation (32), such as Eaton and Kortum (2002), Melitz (2003), Arkolakis *et al.* (2008) and Chaney (2008). Therefore, in the following section and in the quantitative analysis the case of $\gamma = 0$ will be an important benchmark for the welfare gains from trade in my model.

In the following sub-section I analytically solve the model in the special case of two symmetric countries, and derive an analytical expression for the welfare gains from trade directly as a function of the Diversification Index.

3.4.1. Two symmetric countries. To illustrate some properties of the model and to obtain a closed-form expression for the welfare gains from trade, I study the special case where there are two perfectly symmetric countries, home and foreign. Define $\bar{\alpha}$ to be the expected value of the demand shock, $Var(\alpha)$ its variance and ρ the cross-country correlation of shocks. For simplicity, I assume that $\bar{\alpha} = Var(\alpha) = 1$, and I also set $\underline{z} = 1$. I consider two opposite equilibria: one in which there is autarky, and one in which there is free trade, so $\tau_{ij} = 1$ for all i and j.

Under autarky, the Diversification Index is simply the ratio between the mean and the variance of the demand shocks:

$$D_A = \frac{\bar{\alpha}}{Var(\alpha)} = 1. \tag{33}$$

Instead, under free trade the Diversification Index is

$$D = \frac{\bar{\alpha}}{Var(\alpha)\,(1+\rho)} = \frac{1}{1+\rho}. \tag{34}$$

Notice that the Diversification Index is decreasing in the cross-country correlation of demand: the larger this correlation, then the smaller the diversification benefits from selling abroad.

In the Appendix, I show that in both equilibria the firm's optimal solution is:[28]

$$n(z) = 0 \text{ if } z \leq z^*$$
$$0 < n(z) < 1 \text{ if } z > z^*$$

where $n(z)$ is given by:

$$n(z) = \frac{D}{\gamma} \frac{\left(1 - \left(\frac{z^*}{z}\right)^{\sigma-1}\right)}{r(z)}, \tag{35}$$

where $r(z)$ are real gross profits, as in equation (12), and the entry cutoff is:

$$z^* = \left(\left(\frac{\sigma}{\sigma-1} \right)^{\sigma-1} \frac{fP^{1-\sigma}\sigma}{\bar{\alpha}Y} \right)^{\frac{1}{\sigma-1}}. \tag{36}$$

Notice that the entrepreneur's optimal decision under free trade is the same as in autarky, except that the Diversification Index under free trade reflects the cross-country correlation of demand.[29] The more correlated is demand with the foreign country, the "riskier" the world and thus the lower the number of consumers reached. The existence of a single entry cutoff means that there is strict sorting of firms into markets, as in Melitz (2003). However,

28. I assume that $\gamma > \tilde{\gamma}$ (where $\tilde{\gamma}$ depends only on parameters), so that $n(z) < 1$ always for all z. This allows me to get rid of the multiplier of the upper bound. The intuition is that the entrepreneurs are sufficiently risk averse so that they always prefer to *not* reach all consumers. See Appendix for more details.

29. The perfect symmetry and the absence of trade costs imply that any firm will choose the same $n(z)$ in both the domestic and foreign market. This means that either a firm enters in both countries, or in neither of the two. This feature is the reason why perfect symmetry and free trade is the only case in which I can derive an analytical expression for $n(z)$. If there were trade costs $\tau_{ij} > 1$, the optimal $n(z)$ would still depend on the Lagrange multiplier of the other destination.

that happens only because of the perfect symmetry between the two countries, which implies that $n(z)$ is not affected by the Lagrange multipliers of the other location. In the general case of N asymmetric countries, firms do not strictly sort into foreign markets, as explained in the previous section.

I now investigate the welfare impact of going from autarky to free trade, and study how the Diversification Index plays a role in determining the welfare gains from trade. Recall from the previous section, equation (30), that welfare can be written as total real income minus the aggregate risk premium. In the Appendix I prove the following result:

Proposition 3. *Welfare gains of going from autarky to free trade are given by:*

$$\hat{W} = \frac{W_{FT}}{W_A} - 1 = D^{\frac{1}{\theta+1}} \xi - 1 \tag{37}$$

where $\xi > 1$ is a function of θ and σ. Moreover, welfare gains are higher than ACR only if $\rho < \bar{\rho}$, where $\bar{\rho} < 1$ is a function of parameters.

Proposition 3 states that the welfare gains of moving from autarky to free trade are increasing in the Diversification Index, or equivalently, are decreasing in ρ, the cross-country correlation of demand. The intuition is simple: if the correlation is low, or even negative, firms increase their exports to the foreign country in order to hedge their domestic demand risk, by equation (35). This implies tougher competition among firms, which leads to lower prices, by equation (6). If instead the correlation is high, and closer to 1, demand in the foreign market moves in the same direction as the domestic demand, and thus firms cannot fully hedge risk by exporting abroad. This implies a lower competitive pressure, and a smaller decrease in the price index. It is easy to verify that, as long as $\theta > \sigma - 1$, the expression in (31) is always positive, and thus there are always gains from trade.

Furthermore, my model predicts larger welfare gains from trade than models with risk neutral firms, as long as the correlation is sufficiently low. The reason is that when the correlation is low, or even negative, the trade-induced decrease in prices is stronger than in a model with risk neutral firms, where firms use international trade only to increase profits, not to decrease their variance. Thus, the additional gains from the risk diversification strategy raise aggregate welfare gains compared to ACR. Conversely, when the correlation is high, firms rely less on international trade to diversify risk, implying less competition among firms compared to a model with risk neutral firms, and thus welfare gains from trade are lower.

Having characterized the theoretical properties of the general equilibrium model, in the following section I first test its predictions in the data. Then, I calibrate the parameters of the model to match salient features of the data, which will allow me, in Section 5, to quantify the risk diversification benefits of international trade.

4. Empirical Analysis

The analysis mostly relies on a panel dataset on international sales of Portuguese firms to 210 countries, between 1995 and 2005. These data come from Statistics Portugal and roughly aggregate to the official total exports of Portugal. I merged this dataset with data on some firm characteristics, such as number of employees, total sales and equity, which I extracted from a matched employer–employee panel dataset called Quadros de Pessoal. I also merged the trade data with another dataset, called Central de Balancos, containing balance sheet information, such as net profits, for all Portuguese firms from 1995 to 2005. I describe these datasets in more detail in the Appendix.

Moreover, in the calibration I use data on manufacturing trade flows in 2005 from the UN Comtrade database as the empirical counterpart of aggregate bilateral trade in the model, and data on manufacturing production from WIOD and UNIDO (see Dietzenbacher *et al.* (2013)).

From the Portuguese trade dataset, I consider the 10,934 manufacturing firms that, between 1995 to 2005, were selling domestically and exporting to at least one of the top 34 destinations served by Portugal.[30] I exclude from the analysis foreign firms' affiliates, i.e. firms operating in Portugal but owned by foreign owners, since their exporting decision is most likely affected by their parent's optimal strategy. The universe of Portuguese manufacturing exporters is comprised of mostly small firms, the average number of destinations served was 5 in 2005, and the average export share 30%.[31]

4.1. Testing the model predictions

In this section I test the main predictions of the model. In particular, I first use firm-level data from 1995 and 2004 to estimate the demand covariance matrix Σ, and then test Proposition 2 using data for 2005.

4.1.1. Estimation of Σ. Given the static nature of the model, Σ is a *long-run* covariance matrix that firms know and take as given when they choose their risk diversification strategy. However, there is evidence that, in the short run, firms sequentially enter different markets to learn their demand behavior (see Albornoz *et al.* (2012), Ruhl and Willis (2014) and Berman *et al.* (2015b) among others). In the data, this behavior may confound the exporters'

30. I first select the top 45 destinations from Portugal by value of exports, and then I keep the countries for which there is data on manufacturing production, in order to construct bilateral trade flows. Trade flows to these countries accounted for 90.56% of total manufacturing exports from Portugal in 2005. See the list of countries in Table B.1 in the Data Appendix.

31. Other empirical studies have revealed similar statistics using data from other countries, such as Bernard *et al.* (2003) and Eaton *et al.* (2011).

risk diversification behavior predicted by my model, affecting the estimation of Σ. For this reason, I estimate the covariance matrix considering only "established" firm-destination pairs, i.e. exporters selling to a certain market for at least 5 years. For these exporters, the learning process is most likely over, and therefore the estimates of the covariance matrix are less affected by the noisy learning process.

I make the following parametric assumption:

Assumption 3. $\log\alpha(z,t) \sim N\left(\mathbf{0}, \hat{\Sigma}\right)$, i.i.d. across z and across t

where z and t stand for firm and year, respectively. Assumption 3 states that the demand shocks are drawn from a multivariate log-normal distribution with vector of means 0 and covariance matrix $\hat{\Sigma}$, and that the shocks are drawn independently across firms and time. In other words, the log of demand shocks follow a Standard Brownian Motion.[32] This assumption allows to exploit *both* cross-sectional and time-series variation in trade flows to estimate the country-level covariance matrix.[33]

The estimation of Σ entails several steps.

Step 1. To identify the demand shocks, I assume that the parameters of the model stay constant during the estimation period. This implies, from equation (26), that any variation over time of x_{Pjz}, i.e. the exports of firm z from Portugal to destination j, is due solely to the demand shock α_{jz}. However, in the estimation I control for other types of shocks as well. Specifically, I run the following regression (omitting the source subscript):

$$\Delta\tilde{x}_{jzt} = f_{jt} + f_{zt} + \varepsilon_{jzt} \tag{38}$$

where $\Delta\tilde{x}_{jzt} \equiv log\left(x_{jzt}\right) - log\left(x_{jzt-1}\right)$ is the growth rate of exports of firm z to destination j at time t. f_{jt} is a destination-time fixed effect, which controls for any aggregate shock affecting all products in market j at time t; f_{zt} is a firm-time fixed effect, which controls for any unobserved firm characteristics, like productivity or endogenous markups, affecting the sales of firm z to all destinations.[34] The residual from the above regression, ε_{jzt}, is the change in the log of the demand shock for firm z in market j, $\Delta\tilde{\alpha}_{jzt}$. A similar approach, i.e. using annual sales growth rates to identify firm-specific shocks as deviations from country-specific trends, has been adopted by Di Giovanni *et al.* (2014), Gabaix (2011) and Castro *et al.* (2010).[35]

32. See Arkolakis (2016) for a similar assumption.

33. The data supports this assumption: most of the firm-destinations pairs do not have strongly serially correlated demand shocks, according to Durbin-Watson tests not reported here.

34. Controlling for destination, time or firm fixed effects has a marginal impact on the estimates.

35. An alternative approach could be to use the observed firm exports and equation (26) to recover the unobservable firm-destination demand shocks $\alpha_j(z)$, and then use a Maximum

Step 2. Assumption 3 implies that I can stack the residuals $\Delta\tilde{\alpha}_{jzt}$ and compute the NxN unbiased covariance matrix $\Sigma_\Delta$of the *change* of the *log* shocks, which are normally distributed with mean 0.[36]
Step 3. From Σ_Δ, estimated in Step 2, I easily obtain, as shown in the Appendix, the long run covariance matrix of the *level* of the shocks, Σ.

Results. Using the estimated covariance matrix Σ, I compute the country-level Diversification Indexes, using equation (18) and setting $\bar{\alpha} = \mathbf{1}$, as in Eaton *et al.* (2011). Table B.1 in the Appendix lists the estimated Diversification Indexes for the destinations in the sample, together with their standard errors, computed with a bootstrap technique.[37] We can see that the standard errors are small relative to the point estimates, suggesting that the Diversification Indexes are quite precisely estimated.

Recall that D_j summarizes the multilateral covariance of a country's demand with the other countries, and therefore is affected by both its variance and the correlation with the other markets. Figure B.1 plots the estimated Diversification Indexes against the estimated demand variance (top figure), as well as the average demand correlation with the other countries (bottom figure). As expected, in both panels there is a negative relationship: the higher the volatility of demand, or the larger is the average correlation with the other countries, the smaller the risk diversification benefits and thus the lower the Diversification Index.

Interestingly, some markets, e.g. Turkey and Korea, have a high demand variance but relatively low correlation with the other countries, while other markets, e.g. Chile and Czech Republic, have a low variance but feature a high correlation with the rest of the world. Therefore a market can be "risky", i.e. it has a low Diversification Index, either because of a high volatility or a high average correlation.

4.1.2. Extensive margin and risk. Proposition 2 states that the probability of entering a market is increasing in the market's Diversification Index.[38] I test this prediction in the data with the following regression:

Likelihood procedure to estimate Σ. However, that would mean iterating over the $N(N-1)/2 =$ 595 demand covariances, plus all other parameters of the model, while solving the general equilibrium model at each iteration. Unfortunately, the excessive computational time needed to implement this approach makes it unfeasible.

36. An alternative would be to compute a covariance matrix for each year and take the average $\bar{\Sigma}_\Delta = \frac{1}{T}\sum_t \Sigma_\Delta^t$. In the Appendix I prove that, since the mean of $\Delta\tilde{\alpha}_{jzt}$ is zero, this leads to exactly the same covariance matrix.

37. For the bootstrap, I repeat the estimation process 1,000 times, replacing the original data with a random sample, drawn with replacement, of the original firms in the dataset. The bootstrapped standard errors are not centered.

38. The complexity of the firm problem, being subject to 2*N inequality constraints, does not allow to explicitly write the firm-level trade flows as a log-linear function of the Diversification Index. Therefore, one can interpret equation (39) as a "reduced-form" test of Proposition 2.

$$Pr\left(x_{jz} > 0\right) = \delta_0 + \delta_1 \ln\left(D_j\right) + \delta_2 \Gamma_j + \kappa_z + \varepsilon_{jz} \tag{39}$$

where x_{jz} are trade flows of Portuguese firm z to market j in 2005, D_j is the Diversification Index of country j, computed using the estimated covariance matrix from the previous section, and Γ_j is a vector of country-level controls. Specifically, I include standard variables used in gravity regressions, such as distance from Portugal, dummies for trade agreement with Portugal, contiguity, common language, colonial links, common currency, WTO membership. Since I cannot control for destination fixed effects, given the presence of D_j in the regression, I additionally control for the log of GDP, log of openness (trade/GDP), export and import duties as a fraction of trade, and an index of the remoteness of the country to further proxy for trade costs (as in Bravo-Ortega and Giovanni (2006) and Frankel and Romer (1999)). Finally, κ_z controls for firm fixed effects.

Columns 1 and 2 in Table B.2 show the results from a linear probability model, that controls for firm fixed effects, and from a Probit model. As predicted by Proposition 2, the coefficient of D_j is positive and statistically significant. When the Diversification Index is high, the market provides good diversification benefits to the firms exporting there, and as a result the probability that a firm enters there is higher, controlling for barriers to trade and to market specific characteristics. Results are very similar also if the dependent variable is the probability to enter *for the first time* a destination in 2005, as shown in Table B.3.[39]

4.1.3. Intensive margin and risk. Proposition 2 states that firm-level trade flows to a market are increasing in the market's Diversification Index. I test this prediction with the same specification as above:

$$\ln\left(x_{jz}\right) = \delta_0 + \delta_1 \ln\left(D_j\right) + \delta_2 \Gamma_j + \kappa_z + \varepsilon_{jz} \tag{40}$$

where the dependent variable is the log of trade flows of firm z from Portugal to country j, in 2005. As before, we expect risk averse firms to export more to locations with a higher Diversification Index, conditional on entering there. Column 3 in Table B.2 shows the result of a least square regression, indicating that the effect of the Diversification Index on trade flows is positive and statistically significant, as predicted by Proposition 2.[40] The results are robust also to selection bias, as it can be seen from Column 4, where I use a two stages

39. An endogeneity concern could arise from the fact that some firms that were exporting to a destination in 2005 are also in the sample used to compute the Diversification Index of that destination. Using firms that export to a country for the first time in 2005 should not be subject to this concern.

40. The findings are also robust to heteroskedasticity, as revealed by the results, not reported here, from a PPML specification.

Heckman procedure to correct for the selection of firms into exporting, using the entry equation (39).[41]

Proposition 2 and equation (27) suggest that the Diversification Index positively affect trade also at the aggregate level. I test this implication of the model using a specification similar to equation (40), using as dependent variable the log of bilateral manufacturing trade flows in 2005 for the 35 countries in the sample, as shown in the Robustness Appendix. Table B.4 shows that aggregate bilateral trade flows are increasing in the Diversification Index of the destination country, controlling for trade barriers and other country characteristics, lending support to the model prediction.

Finally, I further investigate the relationship between the Diversification Index and trade patterns. Recall that the Diversification Index is a measure that summarizes the *multilateral* covariance of a country's demand with the other countries. Thus, the effect of the Diversification Index on extensive and intensive margins can be decomposed into a variance and a covariance components. Table B.5 reports the results of regressions similar to (39) and (40), where I control, rather than for the Diversification Index, for the variance of demand and the simple average covariance with the other countries in the sample. The table suggests that both components have a significant impact on trade patterns.

Having established that the key predictions of the model are consistent with the data, I now turn to the problem of calibrating the other parameters of the model, in order to perform counterfactual analysis in Section 5.

4.2. Parameters estimation

The year in which I calibrate the model is 2005, in which I assume the world equilibrium reached its steady state. The estimation approach is tightly connected to the model, and consists of two main stages. In the first, I use data on firm profits from 1995 and 2004 to estimate the risk aversion parameter γ. To implement the first stage, I do not need to solve for the general equilibrium model. In the second stage, taking as given $G(\bar{\alpha}, \Sigma)$, estimated in the previous section, and γ, I calibrate the remaining parameters with the Simulated Method of Moments.

4.2.1. Estimation of risk aversion. To estimate the firms' risk aversion, I follow Allen and Atkin (2016) and directly use the firms' first order conditions. For simplicity, I assume that marketing costs are sufficiently high so that there is no Portuguese firm selling to the totality of consumers in any country (given the size of the median Portuguese firm, this seems a reasonable assumption).

41. I follow Helpman *et al.* (2008) and use the dummy for common language to provide the needed exclusion restriction for identification of the second stage trade equation.

This implies that $\mu_j(z) = 0$ for all j and z. For each destination j where firm z is selling to, the FOC is (omitting the source subscript, since all firms are from Portugal):

$$\bar{\alpha}_j r_j(z) - w^{\beta} w_j^{1-\beta} f_j L_j / P - \gamma \sum_s r_j(z) n_s(z) r_s(z) Cov(\alpha_j, \alpha_s) = 0$$

where I set $\lambda_j(z) = 0$, since $n_j(z) > 0$. Multiplying and dividing by $n_j(z)$, and summing over j, the above can be rewritten as:

$$E[\pi(z)] = \gamma Var(\pi(z)) \tag{41}$$

where $E[\pi(z)]$ are expected net profits and $Var(\pi(z))$ is their variance. The intuition behind equation (41) is that the risk aversion regulates the slope of the relationship between the mean of profits and their variance. The higher γ, the more firms want to be compensated for taking additional risk, and thus higher variance of profits must be associated with higher expected profits.

To estimate equation (41), I use Portuguese data on firms' total net profits from 1995 to 2004, and for each firm I compute the average and variance of profits.[42] Table B.6 shows that there is a positive and statistically significant relationship between the average profits and their variance, with a risk-aversion parameter of 0.0046. The reason for such a small number is that equation (41) is in *levels*, and the variance is proportional to the square of the mean. If instead I were to estimate equation (41) in *logs*, I would obtain a risk aversion of 0.707, very close to the estimate of 1 in Allen and Atkin (2016), which use the log returns of crops to estimate Indian farmers' risk aversion.

It is worth noting that estimating equation (41) may not exactly identify the risk aversion parameter, because some firms in the sample may actively hedge profits fluctuations by means of financial derivatives. If such derivatives hedging was effective, then some firms could reduce the volatility of their cash-flows, which means that I would overestimate the true risk aversion. However, this concern is mitigated by the evidence that hedging practices are not widespread among Portuguese firms (see Iyer *et al.* (2014)), and by the fact that the sample is composed mostly by small firms, whose access to financial markets is limited (see Gertler and Gilchrist (1994), Hoffmann and Shcherbakova-Stewen (2011)).

4.2.2. Simulated Method of Moments. Given the estimated covariance matrix Σ and risk aversion γ, the remaining parameters are calibrated with the Simulated Method of Moments, so that endogenous outcomes from the model match salient features of the data.

42. Note that I only observe each firm's total net profits, not firm-destination profits. I consider only Portuguese firms active for at least 5 years during the sample period.

For the full calibration, I add three elements to the model, following Caliendo and Parro (2014) and Arkolakis and Muendler (2010). (i) I introduce a non-tradeable good produced, under perfect competition, with labor and unitary productivity. Consumers spend a constant share ξ of their income on the manufacturing tradeable goods, and a share $1 - \xi$ on the non-tradeable good.[43] I set $\xi = 0.23$, which is the median value, across several countries, of the consumption shares on manufacturing estimated by Caliendo and Parro (2014). (ii) I introduce intermediate inputs. In particular, I assume that the production of each variety uses a Cobb-Douglas aggregate of labor, a composite of all manufactured tradeable products, and the non-tradeable good. Therefore the total variable input cost is:

$$c_i = (w_i)^{\gamma_i^w} \left(P_i^T\right)^{\gamma_i^T} \left(P_i^N\right)^{\gamma_i^N}$$

where P_i^T is the price index of tradeables, P_i^N is the price index of non-tradeables, and $\gamma_i^w + \gamma_i^T + \gamma_i^N = 1$. I compute these shares using data from UNIDO and WIOD in 2005.[44] (iii) I allow for a manufacturing trade deficit D_i. The deficits are assumed to be exogenous and set to their observed levels in 2005, using data from UN Comtrade.

To reduce the dimensionality of the problem, I assume, similarly to Tintelnot (2016), that trade costs have the following functional form:

$$\ln\tau_{ij} = \kappa_0 + \kappa_1 \ln\left(dist_{ij}\right) + \kappa_2 cont_{ij} + \kappa_3 lang_{ij} + \kappa_4 RTA_{ij}, \;\; i \neq j, \tag{42}$$

where $dist_{ij}$ is the geographical distance between countries i and j, $cont_{ij}$ is a dummy equal to 1 if the two countries share a border, $lang_{ij}$ is a dummy equal to 1 if the two countries share the same language, and RTA_{ij} is a dummy equal to 1 if the two countries have a regional trade agreement.[45]

I follow Arkolakis (2010) and assume that per-consumer marketing costs f_j are given by:

$$f_j = \tilde{f}\left(L_j\right)^{\chi - 1} \tag{43}$$

where $\tilde{f} > 0$. This functional form can be micro-founded as each firm sending costly ads that reach consumers in j, and the number of consumers who see each ad is given by $L_j^{1-\chi}$. Assuming that the labor requirement for each ad is $\tilde{f}$, the amount of labor required to reach a fraction $n_{ij}(z)$ of consumers in a market of size L_j is equal to $f_{ij} = w_i^{\beta} w_j^{1-\beta} f_j n_{ij}(z) L_j$. I follow Arkolakis

43. I assume that demand for the non-tradeable is non stochastic.

44. For countries for which I do not have this information, I set the shares equal to the median value of the other countries. I also exclude agriculture and mining sectors.

45. These "gravity" variables were downloaded from the CEPII website. See Head *et al.* (2010) and Head and Mayer (2013).

(2010) and set $\beta = 0.71$. I set the elasticity of substitution to $\sigma = 4$, consistent with estimates of an average mark-up of 33% in the manufacturing sector (see Domowitz *et al.* (1988) and Christopoulou and Vermeulen (2012)). I proxy $\tilde{L}_j$ with the total number of workers in the manufacturing sector, while M_j is the total number of manufacturing firms, both from UNIDO. Finally, I normalize the lower bound of the Pareto distribution to 1.

The calibration algorithm works as follows:

1) Guess a vector $\Theta = \left\{\theta, \kappa_0, \kappa_1, \kappa_2, \kappa_3, \kappa_4, \chi, \tilde{f}\right\}$.

2) Solve the trade equilibrium using the system of equations (15), (22), (24) and (25).[46]

3) Produce 3 sets of moments:

- **Moment 1**. Aggregate trade shares, $\lambda_{ij} \equiv \frac{X_{ij}}{\sum_k X_{kj}}$, for $i \neq j$, where X_{ij} are total trade flows from i to j, as shown in equation (27). I stack these trade shares in a $N(N-1)$-element vector $\hat{m}(1;\Theta)$ and compute the analogous moment in the data, $m^{data}(1)$, using manufacturing trade data in 2005. This moment is used to calibrate the trade costs parameters.
- **Moment 2.** Number of Portuguese exporters M_{Pj} to destination $j \neq P$, normalized by trade shares λ_{Pj}. Stack all M_{Pj}/λ_{Pj} in a $(N-1)$-element vector $\hat{m}(2;\Theta)$, and compute the analogous moment in the data, $m^{data}(2)$, using the Portuguese data in 2005. This moment is used to calibrate the marketing costs parameters.
- **Moment 3**. Median and standard deviation of export shares of Portuguese exporters, computed as the ratio between total exports and total sales. Compute the analogous moment in the data, $m^{data}(3)$, using the Portuguese data in 2005. This moment is used to calibrate the technology parameter θ, since it regulates the dispersion of productivities, and thus export shares, across firms (see Gaubert and Itskhoki (2015)).

4) I stack the differences between observed and simulated moments into a vector of length 1,226, $y(\Theta) \equiv m^{data} - \hat{m}(\Theta)$. I iterate over Θ such that the following moment condition holds:

$$E[y(\Theta_0)] = 0$$

where Θ_0 is the true value of Θ. In particular, I seek a $\hat{\Theta}$ that achieves:

$$\hat{\Theta} = \text{argmin}_{\Theta} g(\Theta) \equiv y(\Theta)' \mathbf{W} y(\Theta)$$

where $\mathbf{W}$ is a positive semi-definite weighting matrix. Ideally I would use $\mathbf{W} = \mathbf{V}^{-1}$ where $\mathbf{V}$ is the variance-covariance matrix of the moments. Since

46. To solve the general equilibrium, I simulate a large number of firms, each with a given productivity z, and compute the optimal $n_{ij}(z)$ for all firms and countries. Since the firm maximization problem is a quadratic problem with bounds, it can be quickly solved in Matlab, for example, using the function quadprog.m. Finally, to solve for the general equilibrium, I normalize world GDP to a constant, as in Allen *et al.* (2014).

the true matrix is unknown, I follow Eaton *et al.* (2011) and Arkolakis *et al.* (2015) and use its empirical analogue:

$$\hat{\mathbf{V}} = \frac{1}{T^{sample}} \sum_{t=1}^{T} \left(m^{data} - m_t^{sample} \right) \left(m^{data} - m_t^{sample} \right)'$$

where m_t^{sample} are the moments from a random sample drawn with replacement of the original firms in the dataset and $T^{sample} = 1,000$ is the number of those draws. To find $\hat{\Theta}$, I use the derivative-free Nelder-Mead downhill simplex search method.[47]

Results and model fit. The best fit is achieved with the values shown in Table B.7. The calibrated parameters are consistent with previous estimates in the trade literature. In particular, the technology parameter θ is equal to 5.286, which is in line with the results obtained using different methodologies (see Bernard *et al.* (2003), Costinot *et al.* (2012), Simonovska and Waugh (2014) and Melitz and Redding (2015)). Both the elasticity of marketing costs with respect to the size of the market, χ, and the cost of each ad, $\tilde{f}$, roughly correspond with the values estimated in Arkolakis (2010). Using equation (24), these estimates indicate that, in the median country, marketing costs dissipate around 40% of gross profits.[48]

To test the fit of the model, I show how the model matches the distribution of exports in a given destination. Specifically, Figure B.2 plots the simulated and the actual values of the 5th and median percentile sales to each market against actual mean Portuguese sales in that market. The model captures quite well both the distance between the two percentiles in any given market, with few exceptions, and the variation of each percentile across markets. Interestingly, the model does a good job in capturing the left tail of the distribution, i.e. the 5th percentile. The reason is that risk-averse firms may optimally choose to reach a small number of consumers in a certain destination, rather than the whole market, and therefore export small amounts of their goods. This stands in sharp contrast with the traditional Melitz-Chaney framework, in which the presence of fixed costs is not compatible with the existence of small exporters, as discussed in Arkolakis (2010) and Eaton *et al.* (2011).

47. Numerical simulations suggest that the rank condition needed for identification, $\nabla_{\Theta} g(\Theta) = dim(\Theta)$, holds, and therefore the objective function has a unique local minimizer (see Hayashi (2000)).

48. For comparison, Eaton *et al.* (2011) estimate this fraction to be 59 percent, using French data.

5. Counterfactual Analysis

In this section I use the calibrated model to conduct a counterfactual simulation to quantify the welfare benefits of risk diversification. Following Costinot and Rodriguez-Clare (2013), I focus on an important counterfactual exercise: moving to autarky. Formally, starting from the calibrated trade equilibrium in 2005, I assume that variable trade costs in the new equilibrium are such that $\tau_{ij} = +\infty$ for all pair of countries $i \neq j$. All other structural parameters are the same as in the initial equilibrium. Once I solve the equilibrium under autarky, I compute the welfare gains associated with moving from autarky to the observed equilibrium.

Figure B.3 illustrates the welfare gains for the 35 countries in the sample, as a function of their measure of risk-return, the Diversification Index. We can see that the total gains are increasing in D_j: countries that provide a better risk-return trade-off to foreign firms benefit more from opening up to trade. Firms exploit a trade liberalization not only to increase their profits, but also to diversify their demand risk. This implies that they optimally increase trade flows toward markets that provide better diversification benefits, as shown in Proposition 2. This also implies that the increase in foreign competition is stronger in these countries, additionally lowering the price level, as suggested by Proposition 3.

In addition, I compare the welfare gains in my model with those predicted by models without risk aversion. As shown earlier, if the risk aversion is 0, welfare gains from trade are the same as the ones predicted by the ACR formula, and therefore can be written only as a function of the change in domestic trade shares and the trade elasticity θ. Since in autarky domestic trade shares are by construction equal to 1, it suffices to know the domestic trade shares in the initial calibrated equilibrium to compute the welfare gains under risk neutrality (see also Edmond *et al.* (2015)).

Figure B.4 plots the percentage deviations of the welfare gains in my model against those in ACR, as a function of the Diversification Index. As expected, the gains from trade in countries with good risk-return profiles are higher than the gains in risk neutral models, while the opposite happens for "riskier" markets. For the median country, gains from trade in my model are 15.4% higher than in risk neutral models, with the differences ranging between +80% in Ireland and -12% in Mexico.

The difference between the gains from trade in my model and in traditional models with risk neutrality arises from several channels. The first channel is through prices. The entrepreneurs' risk aversion implies that the firm's response to lower trade barriers is directed more toward countries with a higher Diversification Index. In these countries, there is tougher competition and lower prices. Therefore we expect the increase in the real wages predicted by my model to be larger than in ACR. Indeed, for the median country, the real wage increase is 18.9% higher than in ACR.

The second channel is through entrepreneurs' real profits. There are two effect on real profits: while prices go down as explained above (although with different magnitudes across countries), nominal profits can either increase due to the expansion to foreign markets, or decrease due to the stronger competition coming from foreign firms, with the latter being even stronger in markets with a high Diversification Index. The net effect is shown in Figure B.5, which suggests that markets with very large decrease in prices also experienced a corresponding increase in real profits. However, for the median country, the profit effect equals -6%.

The third channel affecting welfare gains is the variance of real profits. Figure B.5 shows that, as expected, the aggregate variance decreases in all countries after a trade liberalization. Having access to foreign markets allows firms to hedge demand fluctuations and lower the total variability of profits. Interestingly, large countries, such as China, USA and Russia, experience a smaller decrease in the aggregate variance.

Finally, these findings are robust to the specification used for the entrepreneurs' utility. In particular, Figure B.6 in the Robustness Appendix shows that assuming a utility with decreasing, rather than constant, absolute risk aversion does not affect substantially the welfare results.

6. Concluding remarks

In this paper, I characterize the link between demand risk, firms' exporting decisions, and welfare gains from trade. The proposed framework is sufficiently tractable to deliver testable implications and to be calibrated using firm-level data. Overall, an important message emerges from my analysis: welfare gains from trade significantly differ from standard trade models that neglect firms' risk aversion. In addition, I stress the importance of the cross-country multilateral covariance of demand in amplifying the impact of a change in trade costs through a novel "pro-competitive" effect.

An interesting, and novel, conclusion that can be drawn from the paper is that policy makers should implement policies aiming to stabilize a country's demand, in order to improve its risk-return profile and thus stimulate competition among firms.

Interesting avenues for future research emerge from my study. For example, it would be interesting to introduce the possibility of *product* diversification as a tool to reduce profits volatility, as opposed to, or together with, *geographical* diversification, which has been the focus of this paper. Or, one could study the effects of risk diversification through trade on labor markets.

References

Agnew, Julie, Pierluigi Balduzzi, and Annika Sunden (2003). "Portfolio choice and trading in a large 401 (k) plan." *American Economic Review*, pp. 193–215.

Albornoz, Facundo, Hector F Calvo Pardo, Gregory Corcos, and Emanuel Ornelas (2012). "Sequential exporting." *Journal of International Economics*, 88(1), 17–31.

Allayannis, George, Brian Rountree, and James P Weston (2008). "Do investors value smooth performance?" *Journal of Financial Economics*, 90(3), 237–251.

Allen, Treb, Costas Arkolakis, and Yuta Takahashi (2014). "Universal Gravity." Tech. rep., Mimeo Northwestern and Yale University.

Allen, Treb and David Atkin (2016). "Volatility and the Gains from Trade." Tech. rep., National Bureau of Economic Research.

Antras, Pol, Teresa C Fort, and Felix Tintelnot (2014). "The margins of global sourcing: theory and evidence from US firms." Tech. rep., National Bureau of Economic Research.

Arkolakis, Costas (2010). "Market Penetration Costs and the New Consumers Margin in International Trade." *Journal of Political Economy*, 118(6), 1151–1199.

Arkolakis, Costas (2016). "A unified theory of firm selection and growth." *The Quarterly Journal of Economics*, 131(1), 89–155.

Arkolakis, Costas, Arnaud Costinot, and Andres Rodríguez-Clare (2012). "New Trade Models, Same Old Gains?" *American Economic Review*, 102(1), 94–130.

Arkolakis, Costas, Sharat Ganapati, and Marc-Andreas Muendler (2015). "The Extensive Margin of Exporting Products: A Firm-level Analysis."

Arkolakis, Costas and Marc-Andreas Muendler (2010). "The extensive margin of exporting products: A firm-level analysis." Tech. rep., National Bureau of Economic Research.

Arkolakis, K, Pete Klenow, Svetlana Demidova, and Andres Rodriguez-Clare (2008). "The gains from trade with endogenous variety." In *American Economic Review Papers and Proceedings*, vol. 98, pp. 444–450.

Armenter, Roc and Miklós Koren (2015). "Economies of Scale and the Size of Exporters." *Journal of the European Economic Association*, 13(3), 482–511.

Benartzi, Shlomo and Richard H Thaler (2001). "Naive diversification strategies in defined contribution saving plans." *American economic review*, pp. 79–98.

Bento, Pedro and Diego Restuccia (2016). "Misallocation, Establishment Size, and Productivity." Tech. rep., National Bureau of Economic Research.

Berman, Abraham and Robert J Plemmons (1994). *Nonnegative matrices in the mathematical sciences*. SIAM.

Berman, Nicolas, Antoine Berthou, and Jérôme Héricourt (2015a). "Export dynamics and sales at home." *Journal of International Economics*.

Berman, Nicolas, Vincent Rebeyrol, and Vincent Vicard (2015b). "Demand learning and firm dynamics: evidence from exporters."

Bernard, Andew B., Jonathan Eaton, J. Bradford Jensen, and Samuel Kortum (2003). "Plants and Productivity in International Trade." *American Economic Review*, 93(4), 1268–1290.

Blaum, Joaquin, Claire Lelarge, and Michael Peters (2015). "The Gains From Input Trade in Firm-Based Models of Importing."

Bravo-Ortega, Claudio and Julian Di Giovanni (2006). "Remoteness and real exchange rate volatility." *IMF Staff Papers*, pp. 115–132.

Bricongne, Jean-Charles, Lionel Fontagné, Guillaume Gaulier, Daria Taglioni, and Vincent Vicard (2012). "Firms and the global crisis: French exports in the turmoil." *Journal of international Economics*, 87(1), 134–146.

Caliendo, Lorenzo and Fernando Parro (2014). "Estimates of the Trade and Welfare Effects of NAFTA." *The Review of Economic Studies*, p. rdu035.

Campbell, John Y and Luis M Viceira (2002). *Strategic asset allocation: portfolio choice for long-term investors*. Oxford University Press.

Cardoso, Ana Rute and Pedro Portugal (2005). "Contractual wages and the wage cushion under different bargaining settings." *Journal of Labor economics*, 23(4), 875–902.

Caselli, Francesco, Miklos Koren, Milan Lisicky, and Silvana Tenreyro (2012). "Diversification through trade." In *Society for Economic Dynamics Meeting Papers*, 539.

Castro, Rui, Gian Luca Clementi, and Yoonsoo Lee (2010). "Cross–Sectoral Variation in Firm–Level Idiosyncratic Risk."

Chaney, Thomas (2008). "Distorted Gravity: The Intensive and Extensive Margins of International Trade." *American Economic Review*, 98(4), 1707–1721.

Chen, Hui, Jianjun Miao, and Neng Wang (2010). "Entrepreneurial finance and nondiversifiable risk." *Review of Financial Studies*, p. hhq122.

Christopoulou, Rebekka and Philip Vermeulen (2012). "Markups in the Euro area and the US over the period 1981–2004: a comparison of 50 sectors." *Empirical Economics*, 42(1), 53–77.

Conconi, Paola, André Sapir, and Maurizio Zanardi (2016). "The internationalization process of firms: from exports to FDI." *Journal of International Economics*, 99, 16–30.

Costinot, Arnaud, Dave Donaldson, and Ivana Komunjer (2012). "What goods do countries trade? A quantitative exploration of Ricardo's ideas." *The Review of Economic Studies*, 79(2), 581–608.

Costinot, Arnaud and Andres Rodriguez-Clare (2013). "Trade theory with numbers: Quantifying the consequences of globalization." Tech. rep., National Bureau of Economic Research.

Crozet, Matthieu, Keith Head, and Thierry Mayer (2012). "Quality sorting and trade: Firm-level evidence for French wine." *The Review of Economic Studies*, 79(2), 609–644.

Cucculelli, Marco, Barbara Ermini, *et al.* (2012). "Individual risk attitude, product innovation and firm performance. Evidence from survey data." *Economics Bulletin*, 32(4), 3197–3212.

Das, Sanghamitra, Mark J Roberts, and James R Tybout (2007). "Market entry costs, producer heterogeneity, and export dynamics." *Econometrica*, 75(3), 837–873.

de Gortari, Alonso, Pol Antras, *et al.* (2016). "On the Geography of Global Value Chains." In *2016 Meeting Papers*, 1252, Society for Economic Dynamics.

De Sousa, José, Anne-Célia Disdier, and Carl Gaigné (2015). "Export Decision under Risk."

Di Giovanni, Julian, Andrei A Levchenko, and Isabelle Méjean (2014). "Firms, destinations, and aggregate fluctuations." *Econometrica*, 82(4), 1303–1340.

Dietzenbacher, Erik, Bart Los, Robert Stehrer, Marcel Timmer, and Gaaitzen de Vries (2013). "The construction of world input–output tables in the WIOD project." *Economic Systems Research*, 25(1), 71–98.

Domowitz, Ian, R. Glenn Hubbard, and Bruce C. Petersen (1988). "Market Structure and Cyclical Fluctuations in US Manufacturing." *Review of Economics and Statistics*, 70(1), 55–66.

Eaton, Jonathan and Gene M Grossman (1985). "Tariffs as insurance: Optimal commercial policy when domestic markets are incomplete." *Canadian Journal of Economics*, pp. 258–272.

Eaton, Jonathan and Samuel Kortum (2002). "Technology, Geography and Trade." *Econometrica*, 70(5), 1741–1779.

Eaton, Jonathan, Samuel Kortum, and Francis Kramarz (2011). "An Anatomy of International Trade: Evidence from French Firms." *Econometrica*, 79(5), 1453–1498.

Edmond, Chris, Virgiliu Midrigan, and Daniel Yi Xu (2015). "Competition, markups, and the gains from international trade." *The American Economic Review*, 105(10), 3183–3221.

Eeckhoudt, Louis, Christian Gollier, and Harris Schlesinger (2005). *Economic and financial decisions under risk*. Princeton University Press.

Faccio, Mara, Maria-Teresa Marchica, and Roberto Mura (2011). "Large shareholder diversification and corporate risk-taking." *Review of Financial Studies*, p. hhr065.

Fernandes, Ana M, Caroline Freund, and Martha Denisse Pierola (2016). "Exporter behavior, country size and stage of development: Evidence from the exporter dynamics database." *Journal of Development Economics*, 119, 121–137.

Fillat, Jose and Stefania Garetto (2015). "Risk, Return and Multinational Production." *The Quarterly Journal Economics*, 130(4), 2027–2073.

Frankel, Jeffrey A and David Romer (1999). "Does trade cause growth?" *American economic review*, pp. 379–399.

Froot, Kenneth A, David S Scharfstein, and Jeremy C Stein (1993). "Risk management: Coordinating corporate investment and financing policies." *the Journal of Finance*, 48(5), 1629–1658.

Gabaix, Xavier (2011). "The granular origins of aggregate fluctuations." *Econometrica*, 79(3), 733–772.

Gaubert, Cecile and Oleg Itskhoki (2015). "Granular comparative advantage." Tech. rep., UC Berkeley, mimeo.

Gertler, Mark and Simon Gilchrist (1994). "Monetary Policy, Business Cycles, and the Behavior of Small Manufacturing Firms." *The Quarterly Journal of Economics*, pp. 309–340.

Gervais, Antoine (2016). "Uncertainty, risk aversion and international trade." *Browser Download This Paper*.

Guay, Wayne and Sri Prakash Kothari (2003). "How much do firms hedge with derivatives?" *Journal of Financial Economics*, 70(3), 423–461.

Handley, Kyle and Nuno Limao (2015). "Trade and investment under policy uncertainty: theory and firm evidence." *American Economic Journal: Economic Policy*, 7(4), 189–222.

Hayashi, Fumio (2000). "Econometrics. 2000." *Princeton University Press. Section*, 1, 60–69.

Head, Keith and Thierry Mayer (2013). *Gravity equations: Workhorse, toolkit, and cookbook*. Centre for Economic Policy Research.

Head, Keith, Thierry Mayer, and John Ries (2010). "The erosion of colonial trade linkages after independence." *Journal of international Economics*, 81(1), 1–14.

Heaton, John and Deborah Lucas (2000). "Portfolio choice and asset prices: The importance of entrepreneurial risk." *The journal of finance*, 55(3), 1163–1198.

Heiland, Inga (2016). "Global Risk Sharing Through Trade in Goods and Assets: Theory and Evidence."

Helpman, Elhanan, Marc Melitz, and Yona Rubinstein (2008). "Estimating Trade Flows: Trading Partners and Trading Volumes." *Quarterly Journal of Economics*, 2(5), 441–487.

Helpman, Elhanan, Marc J. Melitz, and Stephen R. Yeaple (2004). "Export Versus FDI with Heterogeneous Firms." *American Economic Review*, 94(1), 300–316.

Helpman, Elhanan and Assaf Razin (1978). "Uncertainty and international trade in the presence of stock markets." *The Review of Economic Studies*, pp. 239–250.

Hentschel, Ludger and Sri Prakash Kothari (2001). "Are corporations reducing or taking risks with derivatives?" *Journal of Financial and Quantitative Analysis*, 36(01), 93–118.

Herranz, Neus, Stefan Krasa, and Anne Villamil (2015). "Entrepreneurs, Risk Aversion, and Dynamic Firms." *The Journal of Political Economy*, 123(5), 1133–1176.

Herranz, Neus, Stefan Krasa, and Anne P Villamil (2013). "Entrepreneurs, Risk Aversion and Dynamic Firms." Tech. rep., Economics, The Univeristy of Manchester.

Hoffmann, Mathias (2014). "The Consumption–Income Ratio, Entrepreneurial Risk, and the US Stock Market." *Journal of Money, Credit and Banking*, 46(6), 1259–1292.

Hoffmann, Mathias and Iryna Shcherbakova-Stewen (2011). "Consumption risk sharing over the business cycle: the role of small firms' access to credit markets." *Review of Economics and Statistics*, 93(4), 1403–1416.

Hottman, Colin, Stephen J Redding, and David E Weinstein (2015). "Quantifying the Sources of Firm Heterogeneity." *The Quarterly Journal of Economics*.

Impullitti, Giammario, Alfonso A Irarrazabal, and Luca David Opromolla (2013). "A theory of entry into and exit from export markets." *Journal of International Economics*, 90(1), 75–90.

Ingersoll, Jonathan E (1987). *Theory of financial decision making*, vol. 3. Rowman & Littlefield.

Iyer, Rajkamal, José-Luis Peydró, Samuel da Rocha-Lopes, and Antoinette Schoar (2014). "Interbank liquidity crunch and the firm credit crunch: Evidence from the 2007–2009 crisis." *Review of Financial studies*, 27(1), 347–372.

Jagannathan, Ravi and Tongshu Ma (2002). "Risk reduction in large portfolios: Why imposing the wrong constraints helps." Tech. rep., National Bureau of Economic Research.

Kihlstrom, Richard E and Jean-Jacques Laffont (1979). "A general equilibrium entrepreneurial theory of firm formation based on risk aversion." *The Journal of Political Economy*, pp. 719–748.

Kramarz, Francis, Julien Martin, and Isabelle Mejean (2014). "Diversification in the Small and in the Large: Evidence from Trade Networks." Tech. rep., working paper, CREST.

Krugman, Paul (1980). "Scale Economies, Product Differentiation, and the Pattern of Trade." *American Economic Review*, 70(5), 950–959.

Limão, Nuno and Giovanni Maggi (2013). "Uncertainty and Trade Agreements." Tech. rep., National Bureau of Economic Research.

Luo, Yulei, Liutang Gong, and Heng-fu Zou (2010). "A Note on Entrepreneurial Risk, Capital Market Imperfections, and Heterogeneity." *Macroeconomic Dynamics*, 14(02), 269–284.

Lyandres, Evgeny, Maria-Teresa Marchica, Roni Michaely, and Roberto Mura (2013). "The Effects of Owners' Portfolio Diversification on Firm Strategies: Theory and Evidence from Private and Public Firms." *Johnson School Research Paper Series*, (18-2013).

Maloney, William F and Rodrigo R Azevedo (1995). "Trade reform, uncertainty, and export promotion: Mexico 1982-88." *Journal of Development Economics*, 48(1), 67–89.

Markowitz, Harry (1952). "Portfolio selection*." *The journal of finance*, 7(1), 77–91.

Martin, William and Cong Si Pham (2015). "Estimating the gravity model when zero trade flows are frequent and economically determined." *World Bank Policy Research Working Paper*, (7308).

Melitz, Marc J. (2003). "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity." *Econometrica*, 71(6), 1695–1725.

Melitz, Marc J and Stephen J Redding (2015). "New trade models, new welfare implications." *The American Economic Review*, 105(3), 1105–1146.

Mion, Giordano and Luca David Opromolla (2014). "Managers' mobility, trade performance, and wages." *Journal of International Economics*, 94(1), 85–101.

Morales, Eduardo, Gloria Sheu, and Andrés Zahler (2014). "Gravity and extended gravity: Using moment inequalities to estimate a model of export entry." Tech. rep., National Bureau of Economic Research.

Morales, Eduardo, Gloria Sheu, and Andres Zahler (2015). "Extended gravity." *NBER Working Paper*, 21351.

Moskowitz, Tobias J and Annette Vissing-Jorgensen (2002). "The returns to entrepreneurial investment: A private equity premium puzzle?" Tech. rep., National Bureau of Economic Research.

Munch, Jakob R and Daniel X Nguyen (2014). "Decomposing firm-level sales variation." *Journal of Economic Behavior & Organization*, 106, 317–334.

Newbery, David MG and Joseph E Stiglitz (1984). "Pareto inferior trade." *The Review of Economic Studies*, pp. 1–12.

Nguyen, Daniel X (2012). "Demand uncertainty: Exporting delays and exporting failures." *Journal of International Economics*, 86(2), 336–344.

Novy, Dennis and Alan M Taylor (2014). "Trade and uncertainty." Tech. rep., National Bureau of Economic Research.

Panousi, Vasia and Dimitris Papanikolaou (2012). "Investment, idiosyncratic risk, and ownership." *The Journal of Finance*, 67(3), 1113–1148.

Parrino, Robert, Allen M Poteshman, and Michael S Weisbach (2005). "Measuring investment distortions when risk-averse managers decide whether to undertake risky projects." *Financial Management*, 34(1), 21–60.

Pena, Juan M (1995). "M-matrices whose inverses are totally positive." *Linear algebra and its applications*, 221, 189–193.

Petersen, Mitchell A and S Ramu Thiagarajan (2000). "Risk measurement and hedging: With and without derivatives." *Financial Management*, pp. 5–29.

Pope, Rulon, Jean-Paul Chavas, and Richard E Just (1983). "Economic welfare evaluations for producers under uncertainty." *American Journal of Agricultural Economics*, 65(1), 98–107.

Pratt, John W (1964). "Risk aversion in the small and in the large." *Econometrica: Journal of the Econometric Society*, pp. 122–136.

Ramondo, Natalia, Veronica Rappoport, and Kim J Ruhl (2013). "The proximity-concentration tradeoff under uncertainty." *The Review of Economic*

Studies, p. rdt018.

Riaño, Alejandro (2011). "Exports, investment and firm-level sales volatility." *Review of World Economics*, 147(4), 643–663.

Rob, Rafael and Nikolaos Vettas (2003). "Foreign direct investment and exports with growing demand." *The Review of Economic Studies*, 70(3), 629–648.

Roberts, Mark J. and James R. Tybout (1997). "The Decision to Export in Colombia: An Empirical Model of Entry with Sunk Costs." *American Economic Review*, 87(4), 545–564.

Ross, Stephen A (2004). "Compensation, incentives, and the duality of risk aversion and riskiness." *The Journal of Finance*, 59(1), 207–225.

Roussanov, Nikolai (2010). "Diversification and its discontents: Idiosyncratic and entrepreneurial risk in the quest for social status." *The Journal of Finance*, 65(5), 1755–1788.

Ruhl, Kim J and Jonathan L Willis (2014). "New exporter dynamics."

Sharpe, William F (1964). "Capital asset prices: A theory of market equilibrium under conditions of risk*." *The journal of finance*, 19(3), 425–442.

Sharpe, William F (1966). "Mutual fund performance." *The Journal of business*, 39(1), 119–138.

Silva, J. M. C. Santos and Silvana Tenreyro (2006). "The Log of Gravity." *Review of Economics and Statistics*, 88(4), 641–658.

Simonovska, Ina and Michael E Waugh (2014). "The elasticity of trade: Estimates and evidence." *Journal of International Economics*, 92(1), 34–50.

Tintelnot, Felix (2016). "Global production with export platforms." Tech. rep., National Bureau of Economic Research.

Vannoorenberghe, Gonzague (2012). "Firm-level volatility and exports." *Journal of International Economics*, 86(1), 57–67.

Vannoorenberghe, Gonzague, Zheng Wang, and Zhihong Yu (2014). "Volatility and Diversification of Exports: Firm-Level Theory and Evidence."

Appendix A: Data

A.1. Data Appendix

Trade data. Statistics Portugal collects data on export and import transactions by firms that are located in Portugal on a monthly basis. These data include the value and quantity of internationally traded goods (i) between Portugal and other Member States of the EU (intra-EU trade) and (ii) by Portugal with non-EU countries (extra-EU trade). Data on extra-EU trade are collected from customs declarations, while data on intra-EU trade are collected through the Intrastat system, which, in 1993, replaced customs declarations as the source of trade statistics within the EU. The same information is used for official statistics and, besides small adjustments, the merchandise trade transactions in our dataset aggregate to the official total exports and imports of Portugal. Each transaction record includes, among other information, the firm's tax identifier, an eight-digit Combined Nomenclature product code, the destination/origin country, the value of the transaction in euros, the quantity (in kilos and, in some case, additional product-specific measuring units) of transacted goods, and the relevant international commercial term (FOB, CIF, FAS, etc.). I use data on export transactions only, aggregated at the firm-destination-year level.
Data on firm characteristics. The second main data source, Quadros de Pessoal, is a longitudinal dataset matching virtually all firms and workers based in Portugal. Currently, the dataset collects data on about 350,000 firms and 3 million employees. As for the trade data, I was able to gain access to information from 1995 to 2005. The data is made available by the Ministry of Employment, drawing on a compulsory annual census of all firms in Portugal that employ at least one worker. Each year, every firm with wage earners is legally obliged to fill in a standardized questionnaire. Reported data cover the firm itself, each of its plants, and each of its workers. Variables available in the dataset include the firm's location, industry (at 5 digits of NACE rev. 1), total employment, sales, ownership structure (equity breakdown among domestic private, public or foreign), and legal setting. Each firm entering the database is assigned a unique, time-invariant identifying number which I use to follow it over time.
The two datasets are merged by means of the firm identifier. As in Mion and Opromolla (2014) and Cardoso and Portugal (2005), I account for sectoral and geographical specificities of Portugal by restricting the sample to include only firms based in continental Portugal while excluding agriculture and fishery (Nace rev.1, 2-digit industries 1, 2, and 5) as well as minor service activities and extra-territorial activities (Nace rev.1, 2-digit industries 95, 96, 97, and 99). The analysis focuses on manufacturing firms only (Nace rev.1 codes 15 to 37) because of the closer relationship between the export of goods and the

industrial activity of the firm. The location of the firm is measured according to the NUTS 3 regional disaggregation.

Data on $\tilde{L}_j$. $\tilde{L}_j$ is the total number of workers in the manufacturing sector in 2005, obtained from UNIDO. For some countries, I do not observe $\tilde{L}_j$, and thus I set it proportional to the population in country j. In particular, I compute $\tilde{L}_j = L_j/r$, where r is the average ratio of population over manufacturing workers in the other countries.

Data on M. From UNIDO, I also observe the number of *establishments* in the manufacturing sector. To compute the number of *firms*, M_j, I divide the number of establishments in each country by the ratio between number of firms and number of establishments in Portugal, which is 0.32. I obtain the number of manufacturing firms in Portugal, $M_P = 27{,}970$, from Quadros de Pessoal. For the countries for which I do not have data on number of establishments, I set $M_j = 0.021\tilde{L}_j$, where 0.021 is the median ratio of workers to firms in the other countries. Setting the number of firms to be proportional to the working population of a country has been shown to be a good approximation of the data (see Bento and Restuccia (2016) and Fernandes *et al.* (2016)).

Data on firms' profits. I obtain data on firms' net profits from Central de Balanços, a repository of yearly balance sheet data for non financial firms in Portugal.

List of countries. The countries in the sample are the top destinations of Portuguese exporters for which there is available data, from WIOD or UNIDO, to construct manufacturing trade shares. The final list of destinations is provided in Table B.1.

A.2. Robustness

In this section I explore the robustness of the empirical and counterfactual results shown in the main text.

A.2.1. Aggregate trade flows and risk. Proposition 2 and equation (27) suggest that the Diversification Index positively affect trade also at the aggregate level. I test this implication of the model using a specification similar to equation (40):

$$\ln\left(X_{ij}\right) = \delta_0 + \kappa_i + \delta_1 \ln\left(D_j\right) + \delta_2 \Gamma_{ij} + \varepsilon_{ij}$$

where the dependent variable is the log of bilateral manufacturing trade flows for the 35 countries in the sample, for 2005, κ_i is a source fixed effect, and Γ_{ij} is a vector of bilateral gravity variables, such as log of bilateral distance, dummies for bilateral trade agreement, contiguity, common language, colonial links, common currency, WTO membership. I also include, as before, the log of GDP, log of openness (trade/GDP), export and import duties as a fraction of trade, and remoteness.

Column 1 in Table B.4 shows that aggregate bilateral trade flows are increasing in the Diversification Index of the destination country, controlling for trade barriers and other country characteristics, lending support to the model prediction. The results are robust to heteroskedasticity, as shown in Column 2, where I estimate the equation in levels with a Poisson Pseudo-Maximum Likelihood (as in Silva and Tenreyro (2006) and Martin and Pham (2015)).

A.2.2. CRRA Utility. In the baseline model, I assume that entrepreneurs maximize an expected CARA utility in real income. One shortcoming of the CARA utility is that the absolute risk aversion is independent from wealth. This implies that large firms display the same risk aversion as small firms, which may be too restrictive. In this subsection, I consider an extension of the model where the entrepreneurs have a CRRA utility, and thus a decreasing absolute risk aversion. In particular, the owners now maximize the following utility:

$$\max E\left[\frac{1}{1-\rho}\left(\frac{y_i(z)}{P_i}\right)^{1-\rho}\right] \tag{A.1}$$

where the coefficient of absolute risk aversion is given by

$$ARA = \rho\left(\frac{y_i(z)}{P_i}\right)^{-1} \tag{A.2}$$

and therefore is decreasing in the size of the firm, and the coefficient of relative risk aversion is simply $\rho > 0$. By means of a Taylor expansion, the expected utility can be approximated as:[49]

$$\max \frac{1}{1-\rho}\left(E\left[\frac{y_i(z)}{P_i}\right]\right)^{1-\rho} - \frac{\rho}{2}\left(E\left[\frac{y_i(z)}{P_i}\right]\right)^{-1-\rho} Var\left(\frac{y_i(z)}{P_i}\right). \tag{A.3}$$

49. Define $z \equiv \frac{y_i(z)}{P_i}$. Take a second-order expansion of $E\left[\frac{1}{1-\rho}z^{1-\rho}\right]$ around $\bar{z} \equiv E\left(\frac{y_i(z)}{P_i}\right)$:

$$E\left[\frac{1}{1-\rho}z^{1-\rho}\right] \approx E\left[\frac{1}{1-\rho}\bar{z}^{1-\rho} + \bar{z}^{-\rho}(z-\bar{z}) + \frac{(-\rho)}{2}\bar{z}^{-\rho-1}(z-\bar{z})^2\right] =$$

$$= \frac{1}{1-\rho}\bar{z}^{1-\rho} + \bar{z}^{-\rho}E(z-\bar{z}) - \frac{\rho}{2}\bar{z}^{-\rho-1}E(z-\bar{z})^2 =$$

$$= \frac{1}{1-\rho}\bar{z}^{1-\rho} - \frac{\rho}{2}\bar{z}^{-\rho-1}Var(z)$$

Note that I cannot exploit the assumption of log-normally distributed demand shocks to further simplify the expected utility, because the sum of log-normally distributed variables is not log-normally distributed.

I calibrate the parameters of the model with this different specification, and then run the same counterfactual as in section 5. Figure B.6 shows that the overall implications for welfare do not change substantially, with the welfare gains under CRRA utility being positively correlated with the welfare gains under CARA utility. However, we can see that with a CRRA utility the welfare gains from trade are on average lower than in the baseline model. The reason is that the firms' absolute risk aversion is decreasing in the size of the firms. Therefore large firms, which have high expected profits, display a small absolute risk aversion, as suggested by equation (A.2). This means that large firms behave, as their productivity gets larger, as in standard trade models with risk neutrality. For these firms, the risk diversification motive is absent, and thus the general equilibrium effect of risk diversification is weaker, leading to lower welfare gains.

A.3. Analytical appendix

A.3.1. Proof of Proposition 1. Since the firm sets the optimal price after the realization of the shock, in the first stage it chooses the optimal fraction of consumers to reach in each market based on the expectation of what the price will be in the second stage. I solve the optimal problem of the firm by backward induction, starting from the second stage. At this stage, there is no uncertainty and thus the firm chooses the optimal pricing policy that maximizes profits, *given* the optimal $n_{ij}(z, E[p_{ij}(z)])$ chosen in the first stage:

$$\max_{\{p_{ij}\}} \sum_j \alpha_j(z) \frac{p_{ij}(z)^{-\sigma}}{P_j^{1-\sigma}} n_{ij}(z, E[p_{ij}(z)]) Y_j \left(p_{ij}(z) - \frac{\tau_{ij} w_i}{z} \right).$$

noting that the firm has already paid the marketing costs in the first stage. It is easy to see that this leads to the standard constant markup over marginal cost:

$$p_{ij}(z) = \frac{\sigma}{\sigma - 1} \frac{\tau_{ij} w_i}{z}. \tag{A.4}$$

Notice that, given the linearity of profits in $n_{ij}(z, E[p_{ij}(z)])$ and $\alpha_j(z)$, due to the assumptions of CES demand and constant returns to scale in labor, the optimal price does not depend on neither $n_{ij}(z, E[p_{ij}(z)])$ nor α_j. The optimal quantity produced is:

$$q_{ij}(z) = \alpha_j(z) \left(\frac{\sigma}{\sigma - 1} \frac{\tau_{ij} w_i}{z} \right)^{-\sigma} \frac{n_{ij}(z, E[p_{ij}(z)]) Y_j}{P_j^{1-\sigma}}. \tag{A.5}$$

I now solve the firm problem in the first stage, when there is uncertainty on the realization of the shocks. By backward induction, in the first stage the firm takes as given the pricing rule in (A.4) and the quantity produced in (A.5). The maximization problem of firm z is:

$$\max_{\{n_{ij}\}} \sum_j \bar{\alpha}_j n_{ij}(z) r_{ij}(z) - \frac{\gamma}{2} \sum_j \sum_s n_{ij}(z) r_{ij}(z) n_{is}(z) r_{is}(z) Cov(\alpha_j, \alpha_s) - \sum_j w_i^{\beta} w_j^{1-\beta} n_{ij}(z) f_j L_j$$

$$\text{s. to } 1 \geq n_{ij}(z) \geq 0$$

where $r_{ij}(z) \equiv \frac{1}{P_i} \frac{p_{ij}(z)^{-\sigma} Y_j}{P_j^{1-\sigma}} \left(p_{ij}(z) - \frac{\tau_{ij} w_i}{z} \right)$. Given the optimal price in (A.4), this simplifies to:

$$r_{ij}(z) = \frac{1}{P_i} \left(\frac{\sigma}{\sigma - 1} \frac{\tau_{ij} w_i}{z} \right)^{1-\sigma} \frac{Y_j}{P_j^{1-\sigma} \sigma}$$

The Lagrangian is, omitting the z for simplicity:

$$L = \sum_j \bar{\alpha}_j n_{ij} r_{ij} - \frac{\gamma}{2} \sum_j \sum_s n_{ij} r_{ij} n_{is} r_{is} Cov(\alpha_j, \alpha_s) - \sum_j w_i^{\beta} w_j^{1-\beta} n_{ij}(z) f_j L_j - \sum_j \mu_{ij} g(n_{ij})$$

where $g(n_{ij}) = n_{ij} - 1$. The necessary Karush–Kuhn–Tucker conditions are:

$$\frac{\partial L}{\partial n_{ij}} = \frac{\partial U}{\partial n_{ij}} - \mu_{ij} \frac{\partial g(n_{ij})}{\partial n_{ij}} \leq 0 \quad \frac{\partial L}{\partial n_{ij}} n_{ij} = 0$$
$$\frac{\partial L}{\partial \mu_{ij}} \geq 0 \quad \frac{\partial L}{\partial \mu_j} \mu_{ij} = 0$$

A more compact way of writing the above conditions is to introduce the auxiliary variable λ_{ij}, which is such that

$$\frac{\partial U}{\partial n_{ij}} - \mu_{ij} \frac{\partial g(n_{ij})}{\partial n_{ij}} + \lambda_{ij} = 0$$

and thus $\lambda_{ij} = 0$ if $n_{ij} > 0$, while $\lambda_{ij} > 0$ if $n_{ij} = 0$. Then the first order condition for n_{ij} becomes:

$$\bar{\alpha}_j r_{ij} - \gamma \sum_s r_{ij} n_{is} r_{is} Cov(\alpha_j, \alpha_s) - w_i^{\beta} w_j^{1-\beta} f_j L_j / P_i - \mu_{ij} + \lambda_{ij} = 0$$

I can write the solution for $n_{ij}(z)$ in matricial form as:

$$\mathbf{n}_i = \frac{1}{\gamma} \left(\tilde{\Sigma}_i \right)^{-1} \mathbf{r}_i, \tag{A.6}$$

where each element of the $N-$dimensional vector $\mathbf{r}_i$ equals:

$$\mathbf{r}_i^j \equiv r_{ij} \bar{\alpha}_j - w_i^{\beta} w_j^{1-\beta} f_j L_j / P_i - \mu_{ij} + \lambda_{ij}, \tag{A.7}$$

and $\tilde{\Sigma}_i$ is a NxN covariance matrix, whose k, j element is, from equation (13):

$$\tilde{\Sigma}_{i,kj} = r_{ij} r_{ik}(z) Cov(\alpha_j, \alpha_k).$$

The inverse of $\tilde{\Sigma}_i$ is, by the Cramer's rule:

$$\left(\tilde{\Sigma}_i\right)^{-1} = r_i \frac{1}{det(\Sigma)} C_i r_i, \tag{A.8}$$

where r_i is the inverse of a diagonal matrix whose $j-th$ element is r_{ij}, and C_i is the (symmetric) matrix of cofactors of Σ.[50] Since $r_{ij} > 0$ for all i and j, then

$$det(\Sigma) \neq 0$$

is a sufficient condition to have invertibility of $\tilde{\sum}_i$. This is Assumption 2 in the main text. Replacing equations (A.8) and (A.7) into (A.6), the optimal n_{ij} is:

$$n_{ij} = \frac{\sum_k \frac{C_{jk}}{r_{ik}} \left(r_{ik}\bar{\alpha}_k - w_i^{\beta} w_k^{1-\beta} f_k L_k / P_k - \mu_{ik} + \lambda_{ik} \right)}{\gamma r_{ij}},$$

where C_{jk} is the j, k cofactor of Σ, rescaled by $det(\Sigma)$. Finally, the solution above is a global maximum if i) the constraints are quasi convex and ii) the objective function is concave. The constraints are obviously quasi convex since their are linear. The Hessian matrix of the objective function is:

$$H(z) = \begin{bmatrix} \frac{\partial^2 U}{\partial^2 n_{ij}} & & \frac{\partial^2 U}{\partial n_{ij} \partial n_{iN}} \\ . & . & \\ . & & . \\ \frac{\partial^2 U}{\partial n_{iN} \partial n_{ij}} & & \frac{\partial^2 U}{\partial^2 n_{iN}} \end{bmatrix},$$

where, for all pairs j, k:

$$\frac{\partial^2 U}{\partial n_{ij} \partial n_{ik}} = \frac{\partial^2 U}{\partial n_{ik} \partial n_{ij}} = -\gamma \delta_{ij} \delta_{ik} Cov(\alpha_j, \alpha_k) < 0$$

Given that $\frac{\partial^2 U}{\partial^2 n_{ij}} < 0$, the Hessian is negative semi-definite if and only if its determinant is positive. It is easy to see that the determinant of the Hessian can be written as:

$$det(H) = \prod_{j=1}^{N} \gamma \delta_{ij}(z)^2 det(\Sigma),$$

50. The cofactor is defined as $C_{kj} \equiv (-1)^{k+j} M_{kj}$, where M_{kj} is the (k, j) minor of Σ. The minor of a matrix is the determinant of the sub-matrix formed by deleting the k-th row and j-th column.

which is always positive if

$$det(\Sigma) > 0,$$

which always holds by Assumption 2 and since Σ is a covariance matrix. Therefore the function is concave and the solution is a global maximum, given the price index P, income Y and wage w.■

A.3.2. Proof of Proposition 2. From Proposition 1, the optimal solution can be written as (again omitting the z to simplify notation):

$$n_{ij} = \frac{\sum_k \frac{C_{jk}}{r_{ik}} \left(r_{ik}\bar{\alpha}_k - w_i^{\beta} w_k^{1-\beta} f_k L_k / P_k - \mu_{ik} + \lambda_{ik} \right)}{\gamma r_{ij}} =$$

$$= \frac{D_j}{\gamma r_{ij}} - \frac{\sum_k \frac{C_{jk}}{r_{ik}} \left(w_i^{\beta} w_k^{1-\beta} f_k L_k / P_k \right)}{\gamma r_{ij}} + \frac{\sum_k \frac{C_{jk}}{r_{ik}} (\lambda_{ik} - \mu_{ik})}{\gamma r_{ij}} \tag{A.9}$$

where $D_j = \sum_k C_{jk}\bar{\alpha}_k$ is the Diversification Index of destination j. In the case of an interior solution, we have that:

$$n_{ij}(z) = \frac{D_j}{\gamma r_{ij}} - \frac{\sum_k \frac{C_{jk}}{r_{ik}} \left(w_i^{\beta} w_k^{1-\beta} f_k L_k / P_k \right)}{\gamma r_{ij}} \tag{A.10}$$

and therefore both the probability of entering j (i.e. the probability that $n_{ij}(z) > 0$) and the level of exports to j,

$$x_{ij}(z) = \alpha_j(z) \left(\frac{\sigma}{\sigma - 1} \frac{\tau_{ij} w_i}{z} \right)^{1-\sigma} \frac{Y_j}{P_j^{1-\sigma}} n_{ij}(z) \tag{A.11}$$

are increasing in D_j. When instead there is at least one binding constraint (either the firm sets $n_{ik}(z) = 0$ or $n_{ik}(z) = 1$ for at least one k), then the corresponding Lagrange multiplier will be positive. Therefore:

$$\frac{\partial n_{ij}(z)}{\partial D_j} = \underbrace{\frac{1}{\gamma r_{ij}}}_{\text{direct effect}} + \underbrace{\frac{1}{\gamma r_{ij}} \left[\sum_{k \neq j} \frac{C_{jk}}{r_{ik}} \frac{\partial \lambda_{ik}}{\partial D_j} - \sum_{k \neq j} \frac{C_{jk}}{r_{ik}} \frac{\partial \mu_{ik}}{\partial D_j} \right]}_{\text{indirect effect}} \tag{A.12}$$

Note that λ_{ik} is zero if $n_{ik}(z) > 0$, otherwise it equals:

$$\lambda_{ik} = -\bar{\alpha}_k r_{ik} + \gamma r_{ik} \sum_{s \neq j} n_{is} r_{is} Cov(\alpha_k, \alpha_s) + w_i^{\beta} w_k^{1-\beta} f_k L_k / P_k$$

and therefore

$$\frac{\partial \lambda_{ik}}{\partial D_j} = \gamma r_{ik} \sum_{s \neq j} \frac{\partial n_{is}(z)}{\partial D_j} r_{is} Cov(\alpha_k, \alpha_s) \tag{A.13}$$

Similarly for the other Lagrange multiplier:

$$\mu_{ik} = \bar{\alpha}_k r_{ik} - \gamma r_{ik} \sum_{s \neq j} n_{is} r_{is} Cov(\alpha_k, \alpha_s) - \gamma r_{ik}^2 Var(\alpha_k) - w_i^{\beta} w_k^{1-\beta} f_k L_k / P_k$$

and thus:

$$\frac{\partial \mu_{ik}}{\partial D_j} = -\gamma r_{ik} \sum_{s \neq j} \frac{\partial n_{is}(z)}{\partial D_j} r_{is} Cov(\alpha_k, \alpha_s) = -\frac{\partial \lambda_{ik}}{\partial D_j} \tag{A.14}$$

Now notice that either $\mu_{ik} > 0$ and $\lambda_{ik} = 0$, or $\lambda_{ik} > 0$ and $\mu_{ik} = 0$. Combining this fact with equations A.13 and A.14, equation A.12 becomes:

$$\frac{\partial n_{ij}(z)}{\partial D_j} = \frac{1}{\gamma r_{ij}} \left[1 + \gamma \sum_{k \neq j} C_{jk} \sum_{s \neq j} \frac{\partial n_{is}(z)}{\partial D_j} r_{is} Cov(\alpha_k, \alpha_s) \right]$$

Define $x_j \equiv \frac{\partial n_{ij}(z)}{\partial D_j} \gamma r_{ij}$. Then the above can be written as:

$$x_j = 1 + \sum_{k \neq j} C_{jk} \sum_{s \neq j} x_s Cov(\alpha_k, \alpha_s)$$

This is a linear system of N equations in N unknowns, x_j. We can rewrite it as $AX = B$, where A is a NxN matrix:

$$A = \begin{bmatrix} 1 & -\sum_{k \neq 1} C_{1k} Cov(\alpha_k, \alpha_2) & ... & -\sum_{k \neq 1} C_{1k} Cov(\alpha_k, \alpha_N) \\ -\sum_{k \neq 2} C_{2k} Cov(\alpha_k, \alpha_1) & 1 & ... & -\sum_{k \neq 2} C_{2k} Cov(\alpha_k, \alpha_N) \\ ... & ... & ... & ... \\ -\sum_{k \neq N} C_{Nk} Cov(\alpha_k, \alpha_1) & -\sum_{k \neq N} C_{2k} Cov(\alpha_k, \alpha_2) & ... & 1 \end{bmatrix},$$

that is

$$A_{ij} = \begin{cases} -\sum_{k \neq i} C_{ik} Cov(\alpha_k, \alpha_j) \,, & i \neq j \\ 1 \qquad , & i = j \end{cases}.$$

and B is a $Nx1$ vector of ones. It follows that

$$X = A^{-1} B.$$

Since B is a positive vector, in order to have X positive, it is sufficient that A^{-1} is a non-negative matrix. By Theorem 2.3. in chapter 6 of Berman and Plemmons (1994) (see also Pena (1995)), a necessary and sufficient condition for A^{-1} to be non-negative is A being a M-matrix, i.e. all off-diagonal elements are negative and the diagonal elements are positive. Finally, it is easy to verify that A is a M-matrix whenever some, but not all, demand correlations are negative.[51] ■

A.3.3. Model with risk neutrality. With risk neutrality, the objective function is:

$$\max_{\{n_{ij}\}} \sum_j \bar{\alpha}_j n_{ij}(z) r_{ij}(z) - \sum_j w_i^{\beta} w_j^{1-\beta} n_{ij}(z) f_j L_j / P_j$$

Notice that the above is simply linear in $n_{ij}(z)$, and therefore it is always optimal, upon entry, to set $n_{ij}(z) = 1$. Therefore the firm's problem boils down to a standard entry decision, as in Melitz (2003), which implies that the firm enters a market j only if expected profits are positive. This in turn implies the existence of an entry cutoff, given by:

$$\left(\bar{z}_{ij}\right)^{\sigma-1} = \frac{w_i^{\beta} w_j^{1-\beta} f_j L_j P_j^{1-\sigma} \sigma}{\bar{\alpha}_j \left(\frac{\sigma}{\sigma-1} \tau_{ij} w_i\right)^{1-\sigma} Y_j} \tag{A.15}$$

To find the welfare gains from trade in the case of $\gamma = 0$, I first write the equation for trade shares

$$\lambda_{ij} = \frac{M_i \int_{\bar{z}_{ij}}^{\infty} \bar{\alpha}_j p_{ij}(z) q_{ij}(z) g_i(z) dz}{w_j L_j} = \frac{M_i \int_{\bar{z}_{ij}}^{\infty} \bar{\alpha}_j p_{ij}(z)^{1-\sigma} g_i(z) dz}{P_j^{1-\sigma}} \tag{A.16}$$

Inverting the above:

$$\frac{M_i \phi (\tau_{ij} w_i)^{1-\sigma} \left(\bar{z}_{ij}\right)^{\sigma-\theta-1}}{\lambda_{ij}} = P_j^{1-\sigma}. \tag{A.17}$$

where ϕ is a constant. Substituting for the cutoff, and using the fact that when $\gamma = 0$ profits are a constant share of total income (see ACR), I can write the real wage as a function of trade shares:

$$\left(\frac{w_j}{P_j}\right) = \vartheta \lambda_{jj}^{-\frac{1}{\theta}}, \tag{A.18}$$

where ϑ is a constant. Since the risk aversion is zero, and profits are a constant share of total income, the percentage change in welfare is simply:

$$d\ln W_j = -d\ln P_j \tag{A.19}$$

51. For example, this can be seen for the case $N = 4$, where a typical element of the matrix A looks like:

$$A_{21} = \rho_{12}\sigma_1^3\sigma_2\sigma_3^2\sigma_4^2(1 - \rho_{13}^2 - \rho_{14}^2 - \rho_{34}^2 + 2\rho_{13}\rho_{14}\rho_{34}).$$

where I have also set the wage as the numeraire. Substituting A.18 into A.19, we get:

$$d\ln W_j = -\frac{1}{\theta} d\ln\lambda_{jj}$$

Lastly, from the equation for trade share it is easy to verify that $-\theta$ equals the trade elasticity.

A.3.4. Model with autarky.

Lemma 1. Assume that $\gamma > (\chi\tilde{L})^{\frac{\theta+1-\sigma}{(1-\sigma)\theta}} \left(\bar{\alpha} M D_A \sigma \left(\left(\frac{\sigma}{\sigma-1}\right)^{\sigma-1} \frac{\sigma f}{\bar{\alpha}}\right)^{\frac{\theta}{1-\sigma}} \left(\frac{\sigma-1}{\theta+\sigma-1}\right)\right)^{-\frac{1}{\theta}} \left(\frac{D_A\bar{\alpha}}{4f}\right)^{\frac{1+\theta}{\theta}}$. Then the optimal solution is:
- $n(z) = 0$ if $z \leq z^*$
- $0 < n(z) < 1$ if $z > z^*$, where:

$$n(z) = \frac{D_A}{\gamma} \frac{\left(1 - \left(\frac{z^*}{z}\right)^{\sigma-1}\right)}{r(z)}$$

and the cutoff is given by:

$$z^* = \left(\left(\frac{\sigma}{\sigma-1}\right)^{\sigma-1} \frac{fP^{1-\sigma}\sigma}{\bar{\alpha}Y}\right)^{\frac{1}{\sigma-1}}$$

Proof. As in Proposition 1, the optimal price is a constant markup over marginal cost:

$$p = \frac{\sigma}{\sigma-1}\frac{1}{z}$$

and thus total gross profits are:

$$r(z) = \frac{1}{P}\left(\frac{\sigma}{\sigma-1}\frac{1}{z}\right)^{1-\sigma} \frac{Y_j}{P_j^{1-\sigma}\sigma}$$

The Lagrangian is:

$$\mathcal{L}_i(z) = \bar{\alpha}n(z)r(z) - \frac{\gamma}{2}Var(\alpha)n^2(z)r^2(z) - n(z)f + \lambda n(z) + \mu(1-n(z))$$

and the FOCs are:

$$\bar{\alpha}r(z) - f/P - \gamma n(z)r^2(z)Var(\alpha) + \lambda - \mu = 0$$

Thus $n(z)$ becomes:

$$n(z) = \frac{\bar{\alpha}r(z) - f/P + \lambda - \mu}{r^2(z)Var(\alpha)\gamma}$$

To get rid of the upper bound multiplier μ, I now find a restriction on parameters such that it is always optimal to choose $n(z) < 1$. When the optimal solution is $n = 0$, then this holds trivially. If instead $n > 0$, and thus $\lambda = 0$, then it must hold that:

$$n(z) = \frac{\bar{\alpha}r(z) - f/P}{r^2(z)Var(\alpha)\gamma} < 1$$

Rearranging:

$$\gamma > \frac{\bar{\alpha}r(z) - f/P}{r^2(z)Var(\alpha)} \tag{A.20}$$

The RHS of the above inequality is a function of the productivity z. For the inequality to hold for any z, it suffices to hold for the productivity z that maximizes the RHS. It is easy to verify that such z is:

$$z_{max} = \left(\frac{2f}{\bar{\alpha}\tilde{u}}\right)^{\frac{1}{\sigma-1}} \tag{A.21}$$

where $\tilde{u} = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} \frac{Y}{P^{1-\sigma}\sigma}$. Therefore a sufficient condition to have A.20 is:

$$\gamma > \frac{\bar{\alpha}\frac{\tilde{u}}{P}\frac{2f}{\bar{\alpha}\tilde{u}} - f/P}{\left(\frac{\tilde{u}}{P}\frac{2f}{\bar{\alpha}\tilde{u}}\right)^2 Var(\alpha)} = P\frac{\bar{\alpha}^2}{f4Var(\alpha)} \tag{A.22}$$

In what follows (see equation (A.28), I show that if the above inequality holds, the optimal price index is given by:

$$P = \left(\chi\tilde{L}\right)^{\frac{\theta+1-\sigma}{(1-\sigma)(1+\theta)}} (\kappa_2)^{-\frac{1}{\theta+1}} \tag{A.23}$$

where χ depends only on σ and θ, and where $\kappa_2 \equiv \bar{\alpha}M\frac{D_A\sigma}{\gamma}(x)^{\frac{\theta}{1-\sigma}}\left(\frac{\sigma-1}{\theta+\sigma-1}\right)$ and $x \equiv \left(\frac{\sigma}{\sigma-1}\right)^{\sigma-1}\frac{\sigma f}{\bar{\alpha}}$. Plugging equation (A.28) into the above inequality implies that:

$$\gamma > \left(\chi\tilde{L}\right)^{\frac{\theta+1-\sigma}{(1-\sigma)(1+\theta)}} \left(\bar{\alpha}MD_A\sigma\frac{1}{\gamma}(x)^{\frac{\theta}{1-\sigma}}\left(\frac{\sigma-1}{\theta+\sigma-1}\right)\right)^{-\frac{1}{\theta+1}} \frac{D_A\bar{\alpha}}{f4}$$

Rearranging:

$$\gamma > \left(\chi\tilde{L}\right)^{\frac{\theta+1-\sigma}{(1-\sigma)\theta}} \left(\bar{\alpha}MD_A\sigma(x)^{\frac{\theta}{1-\sigma}}\left(\frac{\sigma-1}{\theta+\sigma-1}\right)\right)^{-\frac{1}{\theta}} \left(\frac{D_A\bar{\alpha}}{f4}\right)^{\frac{1+\theta}{\theta}} \tag{A.24}$$

If (A.24) holds, then any firm will always choose to set $n_{ij}(z) < 1$. Then, the FOC becomes:

$$\bar{\alpha}r(z) - f/P - \gamma n(z)r^2(z)Var(\alpha) + \lambda = 0$$

I now guess and verify that the optimal $n(z)$ is such that: if $z > z^*$ then $n(z) > 0$, otherwise $n(z) = 0$. First I find such cutoff by solving $n(z^*) = 0$:

$$z^* = \left(\left(\frac{\sigma}{\sigma-1}\right)^{\sigma-1} \frac{fP^{1-\sigma}\sigma}{\bar{\alpha}Y}\right)^{\frac{1}{\sigma-1}}$$

and the corresponding optimal $n(z)$ is:

$$n(z) = \frac{1}{\gamma}\frac{\bar{\alpha}}{Var(\alpha)}\frac{\left(1-\left(\frac{z^*}{z}\right)^{\sigma-1}\right)}{r(z)}$$

If the guess is correct, then it must be that, when $z < z^*$, the FOC is satisfied with a positive λ and thus $n(z) = 0$. Indeed, notice that setting $n(z) = 0$ gives:

$$\bar{\alpha}r(z) - f + \lambda = 0$$

and so the multiplier is:

$$\lambda = f - \bar{\alpha}r(z)$$

which is positive only if $f > \bar{\alpha}r(z)$, that is, when $z < z^*$. Therefore the guess is verified. Lastly, the optimal solution can be written more compactly as:

$$n(z) = \frac{D_A}{\gamma}\frac{\left(1-\left(\frac{z^*}{z}\right)^{\sigma-1}\right)}{r(z)}$$

where $D_A \equiv \frac{\bar{\alpha}}{Var(\alpha)}$ is the Diversification Index.■

Equilibrium. Assuming that $\theta > \sigma - 1$, and normalizing the wage to 1, current account balance implies that total income is:

$$Y_A = w_i\tilde{L}_i + \Pi_i = \tilde{L} + \kappa_1 P^{1+\theta} Y_A^{\frac{\theta}{\sigma-1}} \tag{A.25}$$

where $\kappa_1 \equiv \frac{MD_A}{\gamma}(x)^{\frac{\theta}{1-\sigma}}\bar{\alpha}\left[\frac{\sigma-1-\theta}{\theta+\sigma-1} + \frac{\theta}{\theta+2\sigma-2}\right]$ and where $x \equiv \left(\frac{\sigma}{\sigma-1}\right)^{\sigma-1}\frac{\sigma f}{\bar{\alpha}}$.
The price index equation is:

$$P_i^{1-\sigma} = \bar{\alpha}M\int_{z^*}^{\infty} n_{ji}(z)p_{ji}(z)^{1-\sigma}\theta z^{-\theta-1}dz =$$

$$= Y_A^{\frac{-\theta-1+\sigma}{1-\sigma}} P^{2-\sigma+\theta}\kappa_2$$

where $\kappa_2 \equiv \bar{\alpha}M\frac{D_A\sigma}{\gamma}(x)^{\frac{\theta}{1-\sigma}}\left(\frac{\sigma-1}{\theta+\sigma-1}\right)$. Rearranging:

$$Y_A^{\frac{\theta+1-\sigma}{1-\sigma}}/\kappa_2 = P^{1+\theta} \tag{A.26}$$

Plug equation A.26 into equation A.25:

$$Y_A = \tilde{L} + \kappa_1 P^{1+\theta} Y_A^{\frac{\theta}{\sigma-1}} =$$

$$= \tilde{L} + \frac{\kappa_1}{\kappa_2} Y_A^{\frac{\theta+1-\sigma}{1-\sigma}} Y_A^{\frac{\theta}{\sigma-1}} = \tilde{L} + \frac{\kappa_1}{\kappa_2} Y_A$$

and therefore total income is:

$$Y_A = \chi \tilde{L} \tag{A.27}$$

where $\chi \equiv \frac{\sigma\left(\frac{\sigma-1}{\theta+\sigma-1}\right)}{\sigma\left(\frac{\sigma-1}{\theta+\sigma-1}\right)-\left[\frac{\sigma-1-\theta}{\theta+\sigma-1}+\frac{\theta}{\theta+2\sigma-2}\right]}$, and the price index is:

$$P_A = \left(\chi \tilde{L}\right)^{\frac{\theta+1-\sigma}{(1-\sigma)(1+\theta)}} \left(\kappa_2\right)^{-\frac{1}{\theta+1}} \tag{A.28}$$

A.3.5. Model with two symmetric countries and free trade.

Lemma 2. Assume countries are perfectly symmetric and there is free trade. Assume that $\gamma > \left(\chi \tilde{L}\right)^{\frac{\theta+1-\sigma}{(1-\sigma)\theta}} \left(\bar{\alpha} 2 M D_{FT} \sigma \left(\left(\frac{\sigma}{\sigma-1}\right)^{\sigma-1} \frac{\sigma f}{\bar{\alpha}}\right)^{\frac{\theta}{1-\sigma}} \left(\frac{\sigma-1}{\theta+\sigma-1}\right)\right)^{-\frac{1}{\theta}} \left(\frac{D\bar{\alpha}}{4f}\right)^{\frac{\theta+1}{\theta}}$.
Then the optimal solution is:
- $n_{ij} = 0$ if $z \leq z^*$
- $0 < n(z) < 1$ if $z > z^*$, where:

$$n(z) = \frac{D_{FT}}{\gamma} \frac{\left(1 - \left(\frac{z^*}{z}\right)^{\sigma-1}\right)}{r(z)}$$

and the cutoff is given by:

$$z^* = \left(\left(\frac{\sigma}{\sigma-1}\right)^{\sigma-1} \frac{f P^{1-\sigma} \sigma}{\bar{\alpha} Y}\right)^{\frac{1}{\sigma-1}}$$

Proof: As in Proposition 1, the optimal price is a constant markup over marginal cost:

$$p = \frac{\sigma}{\sigma-1} \frac{1}{z}$$

and thus total gross profits are:

$$r_{ij}(z) = \frac{1}{P} \left(\frac{\sigma}{\sigma-1} \frac{1}{z}\right)^{1-\sigma} \frac{Y_j}{P_j^{1-\sigma} \sigma}$$

In the first stage, the FOCs are:

$$\bar{\alpha} r_{ih}(z) - f/P - \gamma \left(n_{ih} r_{ih}^2(z) Var(\alpha_h) + r_{ih}(z) n_{if}(z) r_{if}(z) Cov(\alpha_h, \alpha_f)\right) + \lambda_h - \mu_h = 0$$

$$\bar{\alpha} r_{if}(z) - f/P - \gamma \left(n_{if} r_{if}^2(z) Var(\alpha_f) + r_{if}(z) n_{ih}(z) r_{ih}(z) Cov(\alpha_h, \alpha_f)\right) + \lambda_f - \mu_f = 0$$

From the above we have that:

$$n_{ih} = \frac{d_h r_{if}(z) - d_f r_{ih}(z) \rho + r_{if}(z) \left(\lambda_h - \mu_h\right) - r_{ih}(z) \rho \left(\lambda_f - \mu_f\right)}{\gamma Var(\alpha) r_{ih}^2(z) r_{if}(z) \left(1 - \rho^2\right)}$$

$$n_{if} = \frac{d_f r_{ih}(z) - d_h r_{if}(z)\rho + r_{ih}(z)\left(\lambda_f - \mu_f\right) - r_{if}(z)\rho\left(\lambda_h - \mu_h\right)}{\gamma Var(\alpha) r_{if}^2(z) r_{ih}(z)\left(1-\rho^2\right)}$$

where

$$d_j \equiv \bar{\alpha} r_{ij}(z) - f/P$$

To get rid of the upper bound multipliers μ_h and μ_f, I now find a restriction on parameters such that it is always optimal to choose $n_{ij}(z) < 1$. When the optimal solution is $n_{ij} = 0$, then this holds trivially. If instead $n_{ij} > 0$, and thus $\lambda_j = 0$, then it must hold that:

$$n_{ij} = \frac{d_j r_{ik}(z) - d_k r_{ij}(z)\rho}{\gamma Var(\alpha) r_{ij}^2(z) r_{ik}(z)\left(1-\rho^2\right)} < 1$$

for all j, where $k \neq j$. For the home country, this becomes:

$$\left(\bar{\alpha} r_{ih}(z) - f/P\right) r_{if}(z) - \left(\bar{\alpha} r_{if}(z) - f/P\right) r_{ih}(z)\rho < \gamma Var(\alpha) r_{ih}^2(z) r_{if}(z)\left(1-\rho^2\right)$$

Invoking symmetry:

$$\left(\bar{\alpha} u z^{\sigma-1} - f/P\right) u z^{\sigma-1} - \left(\bar{\alpha} u z^{\sigma-1} - f/P\right) u z^{\sigma-1}\rho < \gamma Var(\alpha) u^2 z^{2(\sigma-1)} u z^{\sigma-1}\left(1-\rho^2\right)$$

$$\left(\bar{\alpha} u z^{\sigma-1} - f/P\right)(1-\rho) < \gamma Var(\alpha) u^2 z^{2(\sigma-1)}\left(1-\rho^2\right)$$

$$\left(\bar{\alpha} u z^{\sigma-1} - f/P\right) < \gamma Var(\alpha) u^2 z^{2(\sigma-1)}(1+\rho)$$

where $u = \frac{1}{P}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\frac{Y}{P^{1-\sigma}\sigma}$. Rearranging:

$$\gamma > \frac{1}{Var(\alpha) u z^{\sigma-1}(1+\rho)}\left(\bar{\alpha} - \frac{f/P}{z^{\sigma-1}u}\right) \tag{A.29}$$

The RHS of the above inequality is a function of the productivity z. For the inequality to hold for any z, it suffices to hold for the productivity z that maximizes the RHS. It is easy to verify that such z is:

$$z_{max} = \left(\frac{2f}{\bar{\alpha}\tilde{u}}\right)^{\frac{1}{\sigma-1}} \tag{A.30}$$

where $\tilde{u} = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\frac{Y}{P^{1-\sigma}\sigma}$. Therefore a sufficient condition to have A.29 is:

$$\gamma > \frac{1}{Var(\alpha) u \frac{2f}{\bar{\alpha}\tilde{u}}(1+\rho)}\left(\bar{\alpha} - \frac{f}{\frac{2f}{\bar{\alpha}\tilde{u}}\tilde{u}}\right) = P\frac{\bar{\alpha}^2}{Var(\alpha) 4f(1+\rho)} \tag{A.31}$$

In what follows, I show that if the above inequality holds, the optimal price index is given by:

$$P = \left(\chi \tilde{L}\right)^{\frac{\theta+1-\sigma}{(1-\sigma)(1+\theta)}} \left(\kappa_3\right)^{-\frac{1}{\theta+1}} \tag{A.32}$$

where χ depends only on σ and θ, and $\kappa_3 \equiv \bar{\alpha} 2M \frac{D\sigma}{\gamma} \left(\left(\frac{\sigma}{\sigma-1}\right)^{\sigma-1} \frac{\sigma f}{\bar{\alpha}}\right)^{\frac{\theta}{1-\sigma}} \left(\frac{\sigma-1}{\theta+\sigma-1}\right)$. Therefore the risk aversion has to satisfy:

$$\gamma > \left(\chi \tilde{L}\right)^{\frac{\theta+1-\sigma}{(1-\sigma)(1+\theta)}} \left(\kappa_3\right)^{-\frac{1}{\theta+1}} \frac{\bar{\alpha}^2}{Var(\alpha) 4f\,(1+\rho)}$$

Rearranging:

$$\gamma > \left(\chi \tilde{L}\right)^{\frac{\theta+1-\sigma}{(1-\sigma)\theta}} \left(\bar{\alpha} 2M D_{FT} \sigma \left(\left(\frac{\sigma}{\sigma-1}\right)^{\sigma-1} \frac{\sigma f}{\bar{\alpha}}\right)^{\frac{\theta}{1-\sigma}} \left(\frac{\sigma-1}{\theta+\sigma-1}\right)\right)^{-\frac{1}{\theta}} \left(\frac{D\bar{\alpha}}{4f}\right)^{\frac{\theta+1}{\theta}} \tag{A.33}$$

where the right hand side is only function of parameters.

If (A.33) holds, then any firm will always choose to set $n_{ij}(z) < 1$. Then, given the symmetry of the economy, each firm will either sell to both the domestic and foreign market, or to none. This implies that the FOC becomes:

$$\bar{\alpha} r(z) - f/P - \gamma n_{ih}(z) r^2(z) Var(\alpha_h)\,(1+\rho) + \lambda_h = 0$$

I now guess and verify that the optimal $n_{ih}(z)$ is such that: if $z > z^*$ then $n_{ih}(z) > 0$, otherwise $n_{ih}(z) = 0$. First I find such cutoff by solving $n_{ih}(z^*) = 0$:

$$z^* = \left(\left(\frac{\sigma}{\sigma-1}\right)^{\sigma-1} \frac{f P^{1-\sigma} \sigma}{\bar{\alpha} Y}\right)^{\frac{1}{\sigma-1}}$$

and the corresponding optimal $n(z)$ is:

$$n(z) = \frac{1}{\gamma} \frac{\bar{\alpha}}{Var(\alpha)\,(1+\rho)} \frac{\left(1 - \left(\frac{z^*}{z}\right)^{\sigma-1}\right)}{r(z)}$$

If the guess is correct, then it must be that, when $z < z^*$, the FOC is satisfied with a positive λ_h and thus $n(z) = 0$. Indeed, notice that setting $n(z) = 0$ gives:

$$\bar{\alpha} r(z) - f + \lambda_h = 0$$

and so the multiplier is:

$$\lambda_h = f - \bar{\alpha} r(z)$$

which is positive only if $f > \bar{\alpha} r(z)$, that is, when $z < z^*$. Therefore the guess is verified. Lastly, the optimal solution can be written as:

$$n(z) = \frac{D_{FT}}{\gamma} \frac{\left(1 - \left(\frac{z^*}{z}\right)^{\sigma-1}\right)}{r(z)}$$

where $D_{FT} \equiv \frac{\bar{\alpha}}{Var(\alpha)(1+\rho)}$ is the Diversification Index.■

The intuition is that the risk aversion must be high enough to avoid the firm choosing to sell to all consumers in a certain destination. In a sense, the firm always wants to diversify risk by selling a little to multiple countries, rather than being exposed a lot to only one country. Instead, when $\gamma = 0$, as in standard trade models, it is optimal to always set $n_{ij} = 1$, upon entry. As entrepreneurs become more risk averse, they will choose a lower n_{ij} and diversify their sales across countries.

Equilibrium with free trade. Assuming as before that $\theta > \sigma - 1$, and normalizing the wage to 1, current account balance implies that total income is:

$$Y_{FT} = w_i \tilde{L}_i + \Pi_i = \tilde{L} + \kappa_4 P_{FT}^{1+\theta} Y^{\frac{\theta}{\sigma-1}} \tag{A.34}$$

where $\kappa_4 \equiv \frac{2MD_{FT}}{\gamma} (x)^{\frac{\theta}{1-\sigma}} \bar{\alpha} \left[\frac{\sigma-1-\theta}{\theta+\sigma-1} + \frac{\theta}{\theta+2\sigma-2}\right]$ and where $x \equiv \left(\frac{\sigma}{\sigma-1}\right)^{\sigma-1} \frac{\sigma f}{\bar{\alpha}}$. The price index equation is:

$$P_{FT}^{1-\sigma} = \bar{\alpha} 2M \int_{z^*}^{\infty} n_{ji}(z) p_{ji}(z)^{1-\sigma} \theta z^{-\theta-1} dz =$$

$$= Y_{FT}^{\frac{-\theta-1+\sigma}{1-\sigma}} P_{FT}^{2-\sigma+\theta} \kappa_5$$

where $\kappa_5 \equiv \bar{\alpha} 2M \frac{D_{FT}\sigma}{\gamma} (x)^{\frac{\theta}{1-\sigma}} \left(\frac{\sigma-1}{\theta+\sigma-1}\right)$. Rearranging:

$$Y_{FT}^{\frac{\theta+1-\sigma}{1-\sigma}} / \kappa_5 = P_{FT}^{1+\theta} \tag{A.35}$$

Plug equation (A.35) into equation (A.34):

$$Y_{FT} = \tilde{L} + \kappa_4 P_{FT}^{1+\theta} Y_{FT}^{\frac{\theta}{\sigma-1}} =$$

$$= \tilde{L} + \frac{\kappa_4}{\kappa_5} Y_{FT}^{\frac{\theta+1-\sigma}{1-\sigma}} Y_{FT}^{\frac{\theta}{\sigma-1}} = \tilde{L} + \frac{\kappa_4}{\kappa_5} Y_{FT}$$

and therefore total income is:

$$Y_{FT} = \chi \tilde{L} \tag{A.36}$$

where $\chi \equiv \frac{\sigma\left(\frac{\sigma-1}{\theta+\sigma-1}\right)}{\sigma\left(\frac{\sigma-1}{\theta+\sigma-1}\right) - \left[\frac{\sigma-1-\theta}{\theta+\sigma-1} + \frac{\theta}{\theta+2\sigma-2}\right]}$, and the price index is:

$$P_{FT} = \left(\chi \tilde{L}\right)^{\frac{\theta+1-\sigma}{(1-\sigma)(1+\theta)}} (\kappa_5)^{-\frac{1}{\theta+1}} \tag{A.37}$$

A.3.6. Proof of Proposition 3. Welfare under autarky is:

$$W_A = \frac{Y_A}{P_A} - M\int_{z^*}\frac{\gamma}{2}Var\left(\frac{\pi(z)}{P_A}\right)\theta z^{-\theta-1}dz =$$

$$= \frac{Y_A}{P_A} - M\int_{z^*}\frac{\gamma}{2}Var(\alpha)n^2(z)r^2(z)\theta z^{-\theta-1}dz$$

since marketing costs are non-stochastic. Then

$$W_A = \frac{Y_A}{P_A} - \frac{M}{2}Var(\alpha)\frac{D^2}{\gamma}\int_{z^*}\left(1-\left(\frac{z^*}{z}\right)^{\sigma-1}\right)^2\theta z^{-\theta-1}dz =$$

$$= \frac{Y_A}{P_A} - \frac{M}{2}Var(\alpha)\frac{D^2}{\gamma}\int_{z^*}\left(1+\left(\frac{z^*}{z}\right)^{2(\sigma-1)}-2\left(\frac{z^*}{z}\right)^{\sigma-1}\right)\theta z^{-\theta-1}dz =$$

$$= \frac{Y_A}{P_A} - \frac{M}{2}Var(\alpha)\frac{D^2}{\gamma}(z^*)^{-\theta}\left(\frac{\sigma-1-\theta}{\theta+\sigma-1}+\frac{\theta}{\theta+2-2\sigma}\right) =$$

$$= \frac{Y_A}{P_A} - P_A^{\theta}Y_A^{\frac{\theta}{\sigma-1}}\frac{M}{2\gamma}D\bar{\alpha}x^{\frac{\theta}{1-\sigma}}\left(\frac{\theta}{\theta-2+2\sigma}+\frac{\sigma-1-\theta}{\theta+\sigma-1}\right) =$$

$$= \frac{Y_A}{P_A} - \kappa_7 P_A^{\theta}Y_A^{\frac{\theta}{\sigma-1}} \tag{A.38}$$

where $\kappa_7 = M\frac{D_A\bar{\alpha}}{2\gamma}(x)^{\frac{\theta}{1-\sigma}}\left[\frac{\sigma-1-\theta}{\theta+\sigma-1}+\frac{\theta}{\theta+2\sigma-2}\right]$. Let's further simplify the above:

$$W_A = \left(\chi\tilde{L}\right)^{\frac{\sigma\theta}{(\sigma-1)(1+\theta)}}(\kappa_2)^{\frac{1}{\theta+1}} - \kappa_7\left(\chi\tilde{L}\right)^{\frac{\theta\sigma}{(\sigma-1)(1+\theta)}}(\kappa_2)^{-\frac{\theta}{\theta+1}} =$$

$$= \left(\chi\tilde{L}\right)^{\frac{\sigma\theta}{(\sigma-1)(1+\theta)}}\left[(\kappa_2)^{\frac{1}{\theta+1}} - \kappa_7(\kappa_2)^{-\frac{\theta}{\theta+1}}\right] \tag{A.39}$$

Note that $W_A > 0$ always, since $\theta > \sigma - 1$. Welfare under free trade is:

$$W_{FT} = \frac{Y}{P} - M\int_{z^*}^{\infty}\frac{\gamma}{2}Var\left(\frac{\pi(z)}{P}\right)\theta z^{-\theta-1}dz =$$

$$= \frac{Y}{P} - M\int_{z^*}^{\infty}\frac{\gamma}{2}\left(Var(\alpha)\left(\frac{\pi_{HH}(z)}{P}\right)^2 + Var(\alpha)\left(\frac{\pi_{HF}(z)}{P}\right)^2 + 2\frac{\pi_{HF}(z)}{P}\frac{\pi_{HH}(z)}{P}Cov\left(\alpha_H,\alpha_F\right)\right)\theta z^{-\theta-1}dz$$

where $\pi_{ij}$are gross profits (since marketing costs are non-stochastic). By symmetry (and by absence of trade costs):

$$W_{FT} = \frac{Y}{P} - M\int_{z^*}^{\infty}\frac{\gamma}{2}\left(Var(\alpha)\left(\frac{\pi(z)}{P}\right)^2 + Var(\alpha)\left(\frac{\pi(z)}{P}\right)^2 + 2\left(\frac{\pi(z)}{P}\right)^2 Cov\left(\alpha_H,\alpha_F\right)\right)\theta z^{-\theta-1}dz =$$

$$= \frac{Y}{P} - M\gamma Var(\alpha)\left(1+\rho\right)\int_{z^*}^{\infty}\left(\frac{\pi(z)}{P}\right)^2 \theta z^{-\theta-1}dz =$$

$$= \frac{Y}{P} - MVar(\alpha)\left(1+\rho\right)\frac{D^2}{\gamma}\int_{z^*}^{\infty}\left(1-\left(\frac{z^*}{z}\right)^{\sigma-1}\right)^2 \theta z^{-\theta-1}dz =$$

$$= \frac{Y}{P} - MVar(\alpha)\left(1+\rho\right)\frac{D^2}{\gamma}\left(z^*\right)^{-\theta}\left(\frac{\sigma-1-\theta}{\theta+\sigma-1}+\frac{\theta}{\theta+2-2\sigma}\right) =$$

$$= \frac{Y}{P} - MVar(\alpha)\left(1+\rho\right)\frac{D^2}{\gamma}\left(\left(\frac{\sigma}{\sigma-1}\right)^{\sigma-1}\frac{fP^{1-\sigma}\sigma}{\bar{\alpha}Y}\right)^{-\frac{\theta}{\sigma-1}}\left(\frac{\sigma-1-\theta}{\theta+\sigma-1}+\frac{\theta}{\theta+2-2\sigma}\right) =$$

$$= \frac{Y}{P} - \kappa_8 P^{\theta} Y^{\frac{\theta}{\sigma-1}} \tag{A.40}$$

where $\kappa_8 = M\frac{1}{\gamma}\bar{\alpha}D_{FT}\left(x\right)^{\frac{\theta}{1-\sigma}}\left[\frac{\sigma-1-\theta}{\theta+\sigma-1}+\frac{\theta}{\theta+2\sigma-2}\right]$. Further simplify:

$$W_{FT} = \left(\chi\tilde{L}\right)^{1-\frac{\theta+1-\sigma}{(1-\sigma)(1+\theta)}}\left(\kappa_5\right)^{\frac{1}{\theta+1}} - \kappa_8 P^{\theta} Y^{\frac{\theta}{\sigma-1}} =$$

$$= \left(\chi\tilde{L}\right)^{\frac{\sigma\theta}{(\sigma-1)(1+\theta)}}\left[\left(\kappa_5\right)^{\frac{1}{\theta+1}} - \kappa_8\left(\kappa_5\right)^{-\frac{\theta}{\theta+1}}\right] \tag{A.41}$$

Using equations (A.39) and (A.41), welfare gains are:

$$\hat{W} = \frac{W_{FT}}{W_A} - 1 =$$

$$= \frac{\left(\chi\tilde{L}\right)^{\frac{\sigma\theta}{(\sigma-1)(1+\theta)}}\left[\left(\kappa_5\right)^{\frac{1}{\theta+1}} - \kappa_8\left(\kappa_5\right)^{-\frac{\theta}{\theta+1}}\right]}{\left(\chi\tilde{L}\right)^{\frac{\sigma\theta}{(\sigma-1)(1+\theta)}}\left[\left(\kappa_2\right)^{\frac{1}{\theta+1}} - \kappa_7\left(\kappa_2\right)^{-\frac{\theta}{\theta+1}}\right]} - 1 =$$

$$= \frac{\left(\kappa_5\right)^{\frac{1}{\theta+1}} - \kappa_8\left(\kappa_5\right)^{-\frac{\theta}{\theta+1}}}{\left(\kappa_2\right)^{\frac{1}{\theta+1}} - \kappa_7\left(\kappa_2\right)^{-\frac{\theta}{\theta+1}}} - 1 =$$

$$= \left(D_{FT}\right)^{-\frac{1}{\theta+1}}\xi - 1 \tag{A.42}$$

since I set $Var(\alpha) = \bar{\alpha} = 1$, and where $\xi \equiv \frac{\left(2\sigma\left(\frac{\sigma-1}{\theta+\sigma-1}\right)\right)^{\frac{1}{\theta+1}} - \left[\frac{\sigma-1-\theta}{\theta+\sigma-1}+\frac{\theta}{\theta+2\sigma-2}\right]\left(2\sigma\left(\frac{\sigma-1}{\theta+\sigma-1}\right)\right)^{-\frac{\theta}{\theta+1}}}{\left(\sigma\left(\frac{\sigma-1}{\theta+\sigma-1}\right)\right)^{\frac{1}{\theta+1}} - \frac{1}{2}\left[\frac{\sigma-1-\theta}{\theta+\sigma-1}+\frac{\theta}{\theta+2\sigma-2}\right]\left(\sigma\left(\frac{\sigma-1}{\theta+\sigma-1}\right)\right)^{-\frac{\theta}{\theta+1}}} > 1$.

For the second part of the proposition, consider trade shares:

$$\lambda_{ij} = \frac{M_i\bar{\alpha}\int_{z^*}^{\infty} q_{ij}(z)p_{ij}(z)\theta z^{-\theta-1}dz}{w\tilde{L}+\Pi} = \kappa_6 P_{FT}^{1+\theta} Y_{FT}^{\frac{\theta-\sigma+1}{\sigma-1}} \tag{A.43}$$

where $\kappa_6^{FT} = M\bar{\alpha}\frac{D_{FT}}{\gamma}\sigma\frac{\sigma-1}{\theta+\sigma-1}\left(x\right)^{\frac{\theta}{1-\sigma}}$. Note that $\kappa_6^{A} = M\bar{\alpha}\frac{D_{A}}{\gamma}\sigma\frac{\sigma-1}{\theta+\sigma-1}\left(x\right)^{\frac{\theta}{1-\sigma}}$. Substitute for Y and rearrange for $j = i$:

$$P = \left(\frac{\lambda_{jj}}{\kappa_9}\right)^{\frac{1}{\theta+1}} \tag{A.44}$$

where $\kappa_9 \equiv \kappa_6 \left(\chi\tilde{L}\right)^{\frac{\theta-\sigma+1}{1-\sigma}}$. Substitute this equation into welfare:

$$W_{FT} = \chi\tilde{L}\left(\frac{\lambda_{jj}}{\kappa_9}\right)^{-\frac{1}{\theta+1}} - \kappa_8\left(\frac{\lambda_{jj}}{\kappa_9}\right)^{\frac{\theta}{\theta+1}}\left(\chi\tilde{L}\right)^{\frac{\theta}{\sigma-1}} =$$

$$= \left(\chi\tilde{L}\right)^{\frac{-\sigma\theta+2(1+\theta-\sigma)}{(1-\sigma)(1+\theta)}}\left(\lambda_{jj}\right)^{-\frac{1}{\theta+1}}\left(\kappa_6\right)^{\frac{1}{\theta+1}} - \kappa_8\left(\lambda_{jj}\right)^{\frac{\theta}{\theta+1}}\left(\chi\tilde{L}\right)^{\frac{2\theta(\theta+1)-\sigma\theta}{(\sigma-1)(1+\theta)}}\left(\kappa_6\right)^{-\frac{\theta}{\theta+1}} \tag{A.45}$$

Similarly under autarky:

$$W_A = \frac{Y_A}{P_A} - \kappa_7 P_A^{\theta} Y_A^{\frac{\theta}{\sigma-1}} =$$

$$= \chi\tilde{L}\left(\frac{\lambda_{jj}}{\kappa_9}\right)^{-\frac{1}{\theta+1}} - \kappa_7\left(\frac{\lambda_{jj}}{\kappa_9}\right)^{\frac{\theta}{\theta+1}}\left(\chi\tilde{L}\right)^{\frac{\theta}{\sigma-1}} =$$

$$= \chi\tilde{L}\left(\lambda_{jj}\right)^{-\frac{1}{\theta+1}}\left(\kappa_6\left(\chi\tilde{L}\right)^{\frac{\theta-\sigma+1}{1-\sigma}}\right)^{\frac{1}{\theta+1}} - \kappa_7\left(\lambda_{jj}\right)^{\frac{\theta}{\theta+1}}\left(\kappa_6\left(\chi\tilde{L}\right)^{\frac{\theta-\sigma+1}{1-\sigma}}\right)^{-\frac{\theta}{\theta+1}}\left(\chi\tilde{L}\right)^{\frac{\theta}{\sigma-1}} =$$

$$= \left(\chi\tilde{L}\right)^{\frac{-\sigma\theta+2(1+\theta-\sigma)}{(1-\sigma)(1+\theta)}}\left(\lambda_{jj}\right)^{-\frac{1}{\theta+1}}\left(\kappa_6\right)^{\frac{1}{\theta+1}} - \kappa_7\left(\lambda_{jj}\right)^{\frac{\theta}{\theta+1}}\left(\kappa_6\right)^{-\frac{\theta}{\theta+1}}\left(\chi\tilde{L}\right)^{\frac{2\theta(\theta+1)-\sigma\theta}{(\sigma-1)(1+\theta)}} \tag{A.46}$$

Given the symmetry, with free trade $\lambda_{jj} = \frac{1}{2}$ in both models. In autarky instead, $\lambda_{jj} = 1$. Therefore the change in trade shares is the same across models, and we can use the ACR formula to compare welfare gains:

$$\tilde{W}_{ACR} = \left(\lambda_{jj}\right)^{-\frac{1}{\theta}} - 1 = \left(\frac{1}{2}\right)^{-\frac{1}{\theta}} - 1 \tag{A.47}$$

In my model instead welfare gains are:

$$\hat{W} = \frac{\left(\chi\tilde{L}\right)^{\frac{-\sigma\theta+2(1+\theta-\sigma)}{(1-\sigma)(1+\theta)}}\left(\frac{1}{2}\right)^{-\frac{1}{\theta+1}}\left(\kappa_6\right)^{\frac{1}{\theta+1}} - \kappa_8\left(\frac{1}{2}\right)^{\frac{\theta}{\theta+1}}\left(\chi\tilde{L}\right)^{\frac{2\theta(\theta+1)-\sigma\theta}{(\sigma-1)(1+\theta)}}\left(\kappa_6\right)^{-\frac{\theta}{\theta+1}}}{\left(\chi\tilde{L}\right)^{\frac{-\sigma\theta+2(1+\theta-\sigma)}{(1-\sigma)(1+\theta)}}\left(\kappa_6\right)^{\frac{1}{\theta+1}} - \kappa_7\left(\kappa_6\right)^{-\frac{\theta}{\theta+1}}\left(\chi\tilde{L}\right)^{\frac{2\theta(\theta+1)-\sigma\theta}{(\sigma-1)(1+\theta)}}} - 1$$

The welfare gains are higher in my model than in ACR as long as:

$$\frac{\left(\chi\tilde{L}\right)^{\frac{-\sigma\theta+2(1+\theta-\sigma)}{(1-\sigma)(1+\theta)}}\left(\frac{1}{2}\right)^{-\frac{1}{\theta+1}}\left(\kappa_6^{FT}\right)^{\frac{1}{\theta+1}} - \kappa_8\left(\frac{1}{2}\right)^{\frac{\theta}{\theta+1}}\left(\chi\tilde{L}\right)^{\frac{2\theta(\theta+1)-\sigma\theta}{(\sigma-1)(1+\theta)}}\left(\kappa_6^{FT}\right)^{-\frac{\theta}{\theta+1}}}{\left(\chi\tilde{L}\right)^{\frac{-\sigma\theta+2(1+\theta-\sigma)}{(1-\sigma)(1+\theta)}}\left(\kappa_6^{A}\right)^{\frac{1}{\theta+1}} - \kappa_7\left(\kappa_6^{A}\right)^{-\frac{\theta}{\theta+1}}\left(\chi\tilde{L}\right)^{\frac{2\theta(\theta+1)-\sigma\theta}{(\sigma-1)(1+\theta)}}} > \left(\frac{1}{2}\right)^{-\frac{1}{\theta}}$$

$$\phi\left[\left(D_{FT}\right)^{\frac{1}{\theta+1}}\left(\frac{1}{2}\right)^{-\frac{1}{\theta+1}} - \left(D_A\right)^{\frac{1}{\theta+1}}\left(\frac{1}{2}\right)^{-\frac{1}{\theta}}\right] > \left[\left(D_{FT}\right)^{\frac{1}{\theta+1}}\left(\frac{1}{2}\right)^{\frac{\theta}{\theta+1}} - \left(D_A\right)^{\frac{1}{\theta+1}}\left(\frac{1}{2}\right)^{\frac{\theta-1}{\theta}}\right]$$

$$\phi\left(\frac{1}{(1+\rho)}\right)^{\frac{1}{\theta+1}}\left(\frac{1}{2}\right)^{-\frac{1}{\theta+1}}-\phi\left(\frac{1}{2}\right)^{-\frac{1}{\theta}}>\left(\frac{1}{(1+\rho)}\right)^{\frac{1}{\theta+1}}\left(\frac{1}{2}\right)^{\frac{\theta}{\theta+1}}-\left(\frac{1}{2}\right)^{\frac{\theta-1}{\theta}}$$

$$\frac{\left(\frac{1}{2}\right)\left[\phi-\left(\frac{1}{2}\right)^{\frac{1}{\theta}}\right]^{\theta+1}}{\left[\phi-\left(\frac{1}{2}\right)\right]^{\theta+1}}-1>\rho \tag{A.48}$$

where $\phi=\frac{\left(\chi\bar{L}\right)^{2\left(1+\frac{\theta}{(1-\sigma)}\right)}\left(\sigma\frac{\sigma-1}{\theta+\sigma-1}\right)}{\left[\frac{\sigma-1-\theta}{\theta+\sigma-1}+\frac{\theta}{\theta+2\sigma-2}\right]}$. ■

A.3.7. Covariance estimation. I first prove that, if the shocks are i.i.d. over time and their mean is zero, computing the covariance stacking together all observations for products p and time t is equivalent to computing a covariance across products for each year t and taking the average across the years.

To save notation, define $X\equiv\Delta\tilde{\alpha}_x$ and $Y\equiv\Delta\tilde{\alpha}_y$, where x and y are any two destinations. The covariance between X and Y, computed stacking together the observed $\Delta^t\tilde{\alpha}_{xp}$, is:

$$Cov(X,Y)=\frac{1}{T\cdot P}\sum_{k=1}^{T\cdot P}\left(y_k-\bar{y}\right)\left(x_k-\bar{x}\right) \tag{A.49}$$

where x_k (y_k) is the observed change in the log of the shock in destination x (y) for k, where k is a pair of product p and year t. Since $\bar{x}\equiv E[\Delta\tilde{\alpha}_x]=0$ and $\bar{y}\equiv E[\Delta\tilde{\alpha}_p]=0$, the above becomes:

$$Cov(X,Y)=\frac{1}{T\cdot P}\sum_{k=1}^{T\cdot P}y_kx_k \tag{A.50}$$

If instead I compute the covariance for each year, this equals:

$$Cov(X^t,Y^t)=\frac{1}{P}\sum_{p=1}^{P}y_p^tx_p^t \tag{A.51}$$

where x_p^t (y_p^t) is the observed change in the log of the shock in destination x (y) in year t and product p. The average across years of this covariance is simply:

$$\frac{1}{T}\sum_{t=1}^{T}Cov(X^t,Y^t)=\frac{1}{T}\sum_{t=1}^{T}\frac{1}{P}\sum_{p=1}^{P}y_p^tx_p^t=$$

$$=\frac{1}{T\cdot P}\sum_{t=1}^{T}\sum_{p=1}^{P}y_p^tx_p^t=\frac{1}{T\cdot P}\sum_{k=1}^{T\cdot P}y_kx_k \tag{A.52}$$

by the associative property. Therefore, equation (A.50) is equivalent to equation (A.52).

Given an estimate of the covariance matrix of the *log-changes* of the shocks, I first recover the covariance matrix of the *log* of the shocks, using the fact that, for all i and j:

$$\begin{aligned} Cov\left(\Delta\tilde{\alpha}_j, \Delta\tilde{\alpha}_i\right) &= Cov\left(\tilde{\alpha}_{jt} - \tilde{\alpha}_{jt-1}, \tilde{\alpha}_{it} - \tilde{\alpha}_{it-1}\right) \\ &= Cov\left(\tilde{\alpha}_{jt}, \tilde{\alpha}_{it}\right) - Cov\left(\tilde{\alpha}_{jt}, \tilde{\alpha}_{it-1}\right) - Cov\left(\tilde{\alpha}_{jt-1}, \tilde{\alpha}_{it}\right) + Cov\left(\tilde{\alpha}_{jt-1}, \tilde{\alpha}_{it-1}\right) \\ &= 2Cov\left(\tilde{\alpha}_j, \tilde{\alpha}_i\right) \end{aligned}$$

where the last inequality is implied by the i.i.d. assumption, i.e. $Cov\left(\tilde{\alpha}_{jt-1}, \tilde{\alpha}_{it}\right) = 0$.

Given a covariance matrix of the *log* of the shocks, I can recover the covariance matrix of the *level* of the shocks as follows. For any pair of destinations $X \equiv \tilde{\alpha}_x$ and $Y \equiv \tilde{\alpha}_y$, the pairwise covariance is:

$$Cov\left(X, Y\right) = Cov\left(e^{\tilde{X}}, e^{\tilde{Y}}\right) = E\left[e^{\tilde{X}} e^{\tilde{Y}}\right] - E[e^{\tilde{X}}]E[e^{\tilde{Y}}] =$$

$$= E\left[e^{\tilde{Z}}\right] - E[e^{\tilde{X}}]E[e^{\tilde{Y}}]$$

where $\tilde{Z} = \tilde{X} + \tilde{Y}$ is the sum of two normally distributed variables, and has mean $E[\tilde{Z}] = E[\tilde{X}] + E[\tilde{Y}] = 0$ and variance $Var(\tilde{Z}) = Var(\tilde{X}) + Var(\tilde{Y}) + 2Cov(\tilde{X}, \tilde{Y})$. Note that I have already obtained $Var(\tilde{X})$, $Var(\tilde{Y})$ and $Cov(\tilde{X}, \tilde{Y})$ in the previous step. Then, by the moment generating function of the normal distribution:

$$E\left[e^{j}\right] = e^{E[j] + \frac{1}{2}Var(j)}$$

for $j = \tilde{Z}, \tilde{X}, \tilde{Y}$. Plugging these back I can derive the covariance of the level of the shocks:

$$Cov\left(X, Y\right) = e^{\frac{1}{2}Var(\tilde{Z})} - e^{\frac{1}{2}Var(\tilde{X}) + \frac{1}{2}Var(\tilde{Y})} =$$

$$= e^{\frac{1}{2}\left(Var(\tilde{X}) + Var(\tilde{Y}) + 2Cov(\tilde{X}, \tilde{Y})\right)} - e^{\frac{1}{2}\left(Var(\tilde{X}) + Var(\tilde{Y})\right)}$$

Country	Fraction of exports in 2005	Number of exporters in 2005	Diversification Index
Australia	.44 %	266	2.04 (0.33)
Austria	.52 %	367	1.7 (0.19)
Belgium-Lux.	2.64 %	949	2.12 (0.2)
Brazil	.71 %	302	1.59 (0.3)
Canada	.61 %	533	1.97 (0.24)
Chile	.27 %	74	1.34 (0.57)
China	.41 %	184	0.88 (0.24)
Czech Republic	.18 %	211	1.74 (0.42)
Denmark	.96 %	572	1.71 (0.18)
Finland	.68 %	366	1.52 (0.22)
France	13.83 %	1971	2.48 (0.18)
Germany	7.9 %	1283	2.04 (0.16)
Greece	.6 %	386	1.61 (0.19)
Hungary	.25 %	189	0.77 (0.44)
Ireland	.83 %	436	1.85 (0.31)
Israel	.3 %	213	1.74 (0.37)
Italy	3.83 %	897	1.51 (0.16)
Japan	.31 %	300	1.57 (0.23)
Rep. of Korea	.1 %	112	0.87 (0.26)
Malaysia	.02 %	55	0.86 (0.49)
Mexico	.21 %	187	0.96 (0.31)
Morocco	.65 %	286	1.80 (0.4)
Netherlands	4.82 %	954	1.82 (0.17)
Norway	.34 %	370	1.85 (0.28)
Poland	.48 %	241	1.12 (0.23)
Romania	.24 %	167	0.58 (0.44)
Russia	.34 %	164	1.56 (0.7)
Singapore	.12 %	100	1.12 (0.25)
South Africa	.4 %	195	1.33 (0.25)
Spain	29 %	2420	2.75 (0.21)
Sweden	1.19 %	597	1.87 (0.22)
Turkey	.69 %	221	0.67 (0.18)
United Kingdom	9.90 %	1294	1.96 (0.15)
United States	6.89 %	931	2.24 (0.23)
Total	90.56 %	4,821	

Notes: The fourth column reports the estimated Diversification Indices, with the standard errors in parenthesis.

TABLE B.1. List of destinations in the sample

Appendix B: Tables and Figures

	(1)	(2)	(3)	(4)
Dep. Variable	Prob. of entering	Prob. of entering	Log of exports	Log of exports
Method	L. S.	Probit	L. S.	Heckman
Log of D_j	0.102***	0.563***	1.130***	0.892***
	(0.005)	(0.033)	(0.139)	(0.165)
Log of GDP	0.074***	0.263***	0.648***	0.631***
	(0.002)	(0.010)	(0.039)	(0.061)
Log of Distance	-0.048***	-0.293***	-0.273*	-0.285*
	(0.004)	(0.032)	(0.143)	(0.158)
Firm f.e.	YES	NO	YES	NO
# of controls	13	13	13	12
Obs.	125,346	125,346	15,369	15,369
R-squared	0.124	0.145	0.103	0.105

Notes: In Columns 1 and 2 the dependent variable is an indicator equals to 1 if a firm from Portugal enters market j, and equal 0 otherwise. In Columns 3 and 4 the dependent variable is the log of sales of a Portuguese firm to market j. All data are for 2005. Additional not reported controls are: dummies for trade agreement with Portugal, contiguity, common language, colonial links, common currency, common legal origins, WTO membership, log of openness (trade/GDP), export and import duties as a fraction of trade, remoteness. Column 4 reports only the second stage of a Heckman 2SLS procedure, where the excluded variable is the dummy for common language. Clustered standard errors are shown in parenthesis (*** p<0.01, ** p<0.05, * p<0.1).

TABLE B.2. Firm-level trade patterns and risk

	(1)	(2)
Dep. Variable	Prob. of entering	Prob. of entering
Method	L. S.	Probit
Log of D_j	0.021***	0.196***
	(0.003)	(0.044)
Log of GDP	0.023***	0.186***
	(0.001)	(0.015)
Log of Distance	-0.025***	0.368***
	(0.003)	(0.045)
Firm f.e.	YES	NO
# of controls	13	13
Obs.	114,272	114,272
R-squared	0.028	0.015

Notes: In Columns 1 and 2 the dependent variable is an indicator equals to 1 if a firm from Portugal enters market *j for the first time* in 2005, and equal 0 otherwise. Additional not reported controls are: dummies for trade agreement with Portugal, contiguity, common language, colonial links, common currency, common legal origins, WTO membership, log of openness (trade/GDP), export and import duties as a fraction of trade, remoteness. All data are for 2005. Clustered standard errors are shown in parenthesis (*** p<0.01, ** p<0.05, * p<0.1).

TABLE B.3. Firm-level trade patterns and risk, II

	(1)	(2)
Dep. Variable	Log of bilateral trade flows	Bilateral trade flows
Method	L. S.	PPML
Log of D_j	0.255**	0.362***
	(0.093)	(0.099)
Log of GDP	1.123***	1.123***
	(0.032)	(0.038)
Log of Distance	-0.964*	-0.697***
	(0.051)	(0.065)
Source f.e.	YES	YES
# of controls	13	13
Obs.	1,225	1,225
R-squared	0.904	0.950

Notes: In Columns 1 and 2 the dependent variable is the log of bilateral sales between from country i to j. Data is for the 35 countries in the sample, for 2005, from Comtrade and WIOD. Additional not reported controls are: dummies for bilateral trade agreement, contiguity, common language, colonial links, common currency, common legal origins, WTO membership, as well as log of openness (trade/GDP), export and import duties as a fraction of trade, remoteness of destination j. The R^2 shown in Column 2 is the pseudo-R^2. Clustered standard errors are shown in parenthesis (*** p<0.01, ** p<0.05, * p<0.1).

TABLE B.4. Aggregate trade patterns and risk

	(1)	(2)	(3)	(4)
Dep. Variable	Prob. of entering	Prob. of entering	Log of exports	Log of exports
Method	L. S.	L. S.	Heckman	Heckman
Variance	-0.04***		-0.333***	
	(0.001)		(0.059)	
Average covar.		-0.021***		-0.14***
		(0.000)		(0.029)
Firm f.e.	YES	YES	NO	NO
# of controls	13	13	12	12
Obs.	125,346	125,346	15,369	15,369
R-squared	0.125	0.125	0.105	0.103

Notes: In Columns 1-2 the dependent variable is an indicator equals to 1 if a firm from Portugal enters market j, and equal 0 otherwise. In Columns 3-4 the dependent variable is the log of sales of a Portuguese firm to market j. All data are for 2005. Variance is the estimated demand variance of a destination, while Average covariance is the unweighted average of the covariances of a destination with all other countries. Additional not reported controls are: log of GDP, log of distance from Portugal, dummies for trade agreement with Portugal, contiguity, common language, colonial links, common currency, common legal origins, WTO membership, log of openness (trade/GDP), export and import duties as a fraction of trade, remoteness. Columns 3-4 report only the second stage of a Heckman 2SLS procedure, where the excluded variable is the dummy for common language. Clustered standard errors are shown in parenthesis (*** p<0.01, ** p<0.05, * p<0.1).

TABLE B.5. Firm-level trade patterns and risk, III

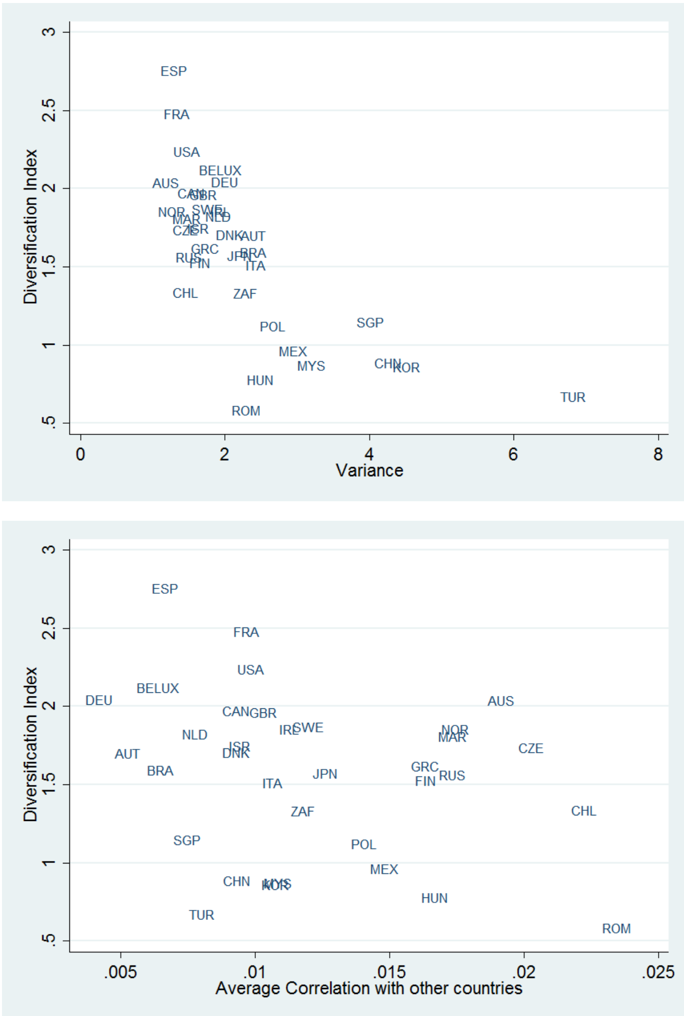
Dep. Variable	Average profits
Variance of profits	0.0046***
	(0.0001)
Observations	1,316
R-squared	0.547

Notes: The table regresses the the average profits of Portuguese exporters on their variance. Both statistics are computed using yearly data from 1995 to 2004 for firms exporting for more than 5 years. Robust standard errors are shown in parenthesis (*** p<0.01, ** p<0.05, * p<0.1).

TABLE B.6. Risk aversion

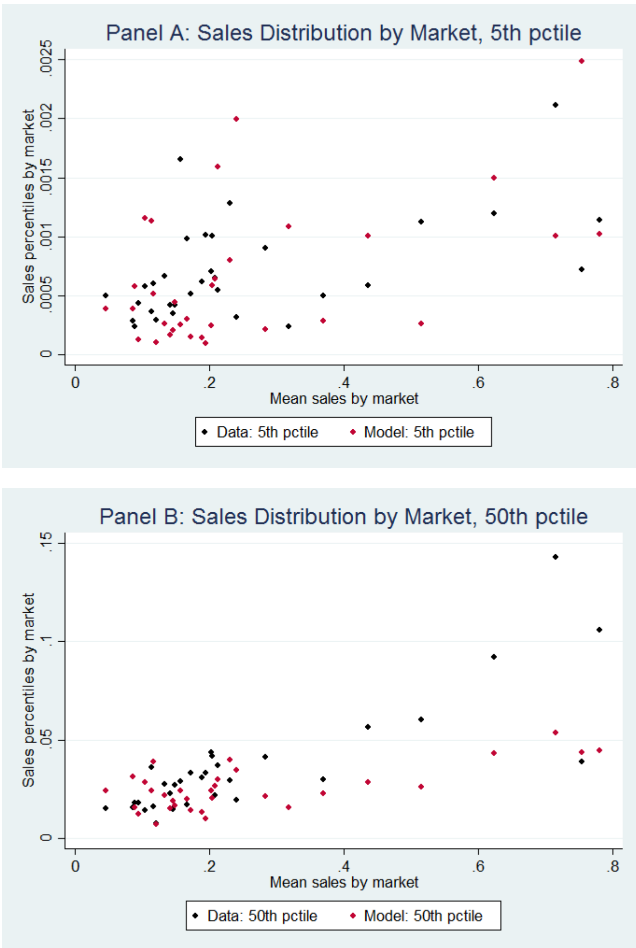
Parameter	θ	χ	$\tilde{f}$	κ_0	κ_1	κ_2	κ_3	κ_4
Value	5.286	0.776	0.008	0.683	0.187	-0.002	-0.063	≈ 0

TABLE B.7. Calibrated parameters



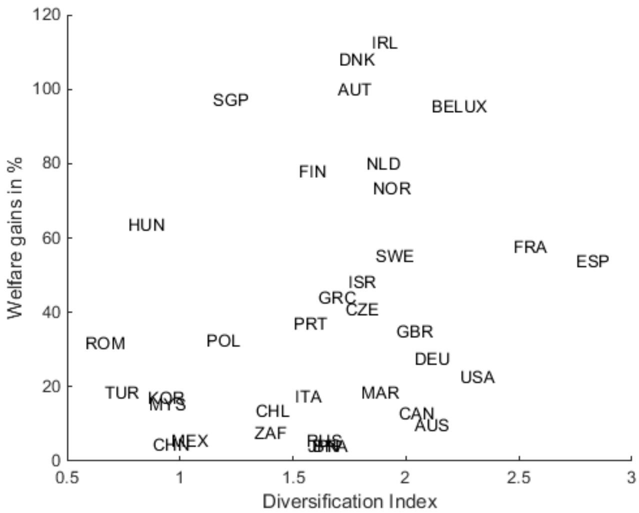
Notes: The figure at the top plots the estimated Diversification Index of the destinations in the sample against the corresponding demand variance. The figure at the bottom, instead, plots the Diversification Index against the corresponding average correlation of demand with all other countries.

FIGURE B.1: Diversification Index and its components



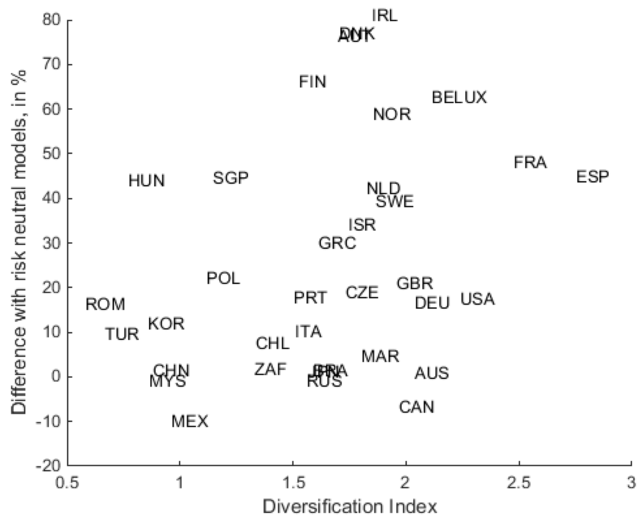
Notes: The figure at the top plots the simulated and the actual values of the 5th percentile sales to each market against actual mean Portuguese sales in that market. The figure at the bottom, instead, plots the median sales percentile.

FIGURE B.2: Sales distribution by market



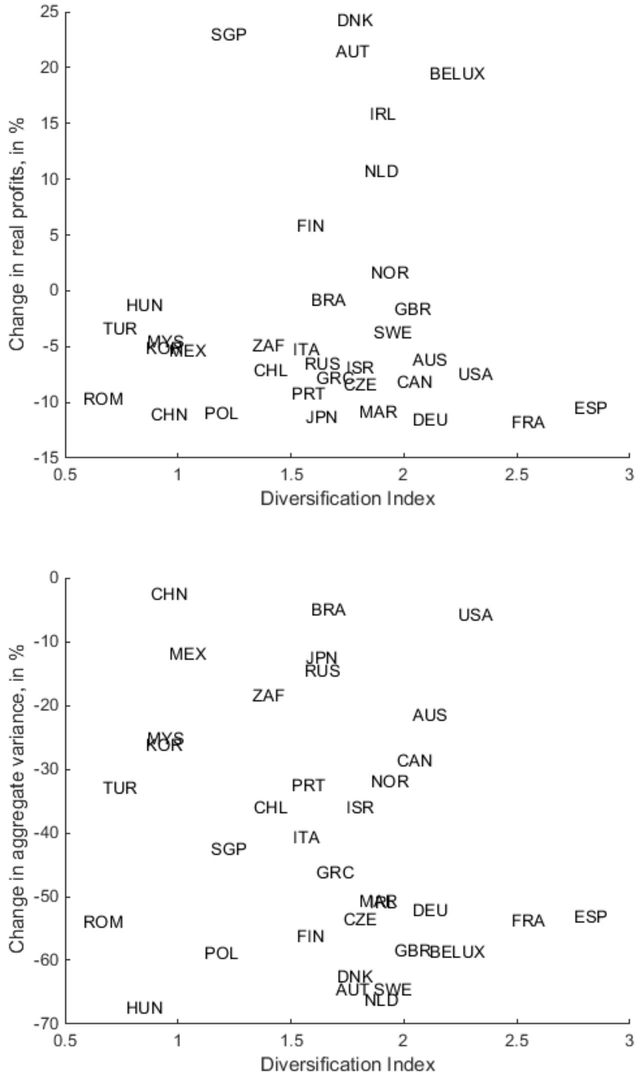
Notes: The figure plots the percentage change in welfare after moving from autarky to the calibrated equilibrium. The variable on the x-axis is the Diversification Index, the country-level measure of risk-return.

FIGURE B.3: Welfare gains from trade



Notes: The figure plots the difference between the welfare gains predicted by my model and those predicted by ACR. The variable on the x-axis is D, the country-level measure of risk-return.

FIGURE B.4: Welfare gains from trade vs risk neutral models



Notes: The figure at the top plots the change in real profits after moving from autarky to the calibrated equilibrium. The figure at the bottom, instead, plots the change in the aggregate variance of real profits.

FIGURE B.5: Decomposition of entrepreneurs' welfare gains

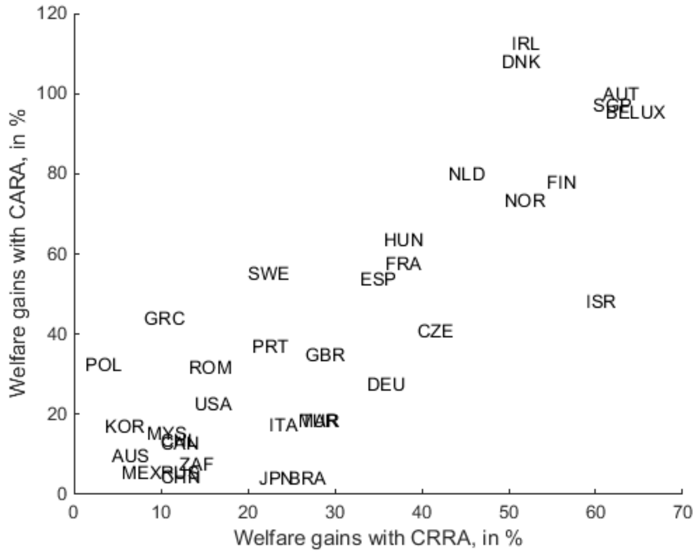


FIGURE B.6: Welfare gains from trade, CARA vs CRRA

WORKING PAPERS

2015

1|15 Unpleasant debt dynamics: can fiscal consolidations raise debt ratios?
Gabriela Castro | Ricardo M. Félix | Paulo Júlio | José R. Maria

2|15 Macroeconomic forecasting starting from survey nowcasts
João Valle e Azevedo | Inês Gonçalves

3|15 Capital regulation in a macroeconomic model with three layers of default
Laurent Clerc | Alexis Derviz | Caterina Mendicino | Stephane Moyen | Kalin Nikolov | Livio Stracca | Javier Suarez | Alexandros P. Vardoulakis

4|15 Expectation-driven cycles: time-varying effects
Antonello D'Agostino | Caterina Mendicino

5|15 Seriously strengthening the tax-benefit link
Pedro Portugal | Pedro S. Raposo

6|15 Unions and collective bargaining in the wake of the great recession
John T. Addison | Pedro Portugal | Hugo Vilares

7|15 Covariate-augmented unit root tests with mixed-frequency data
Cláudia Duarte

8|15 Financial fragmentation shocks
Gabriela Castro | José R. Maria | Paulo Júlio | Ricardo M. Félix

9|15 Central bank interventions, demand for collateral, and sovereign borrowing cost
Luís Fonseca | Matteo Crosignani | Miguel Faria-e-Castro

10|15 Income smoothing mechanisms after labor market transitions
Nuno Alves | Carlos Martins

11|15 Decomposing the wage losses of displaced workers: the role of the reallocation of workers into firms and job titles
Anabela Carneiro | Pedro Raposo | Pedro Portugal

12|15 Sources of the union wage gap: results from high-dimensional fixed effects regression models
John T. Addison | Pedro Portugal | Hugo Vilares

13|15 Assessing european firms' exports and productivity distributions: the compnet trade module
Antoine Berthou | Emmanuel Dhyne | Matteo Bugamelli | Ana-Maria Cazacu | Calin-Vlad Demian | Peter Harasztosi | Tibor Lalinsky | Jaanika Meriküll | Filippo Oropallo | Ana Cristina Soares

14|15 A new regression-based tail index estimator: an application to exchange rates
João Nicolau | Paulo M. M. Rodrigues

15|15 The effect of bank shocks on firm-level and aggregate investment
João Amador | Arne J. Nagengast

16|15 Networks of value added trade
João Amador | Sónia Cabral

17|15 House prices: bubbles, exuberance or something else? Evidence from euro area countries
Rita Fradique Lourenço | Paulo M. M. Rodrigues

2016

1|16 A mixed frequency approach to forecast private consumption with ATM/POS data
Cláudia Duarte | Paulo M. M. Rodrigues | António Rua

2|16 Monetary developments and expansionary fiscal consolidations: evidence from the EMU
António Afonso | Luís Martins

3|16 Output and unemployment, Portugal, 2008–2012
José R. Maria

4|16 Productivity and organization in portuguese firms
Lorenzo Caliendo | Luca David Opromolla | Giordano Mion | Esteban Rossi-Hansberg

5|16 Residual-augmented IVX predictive regression
Matei Demetrescu | Paulo M. M. Rodrigues

6|16 Understanding the public sector pay gap
Maria M. Campos | Evangelia Papapetrou | Domenico Depalo Javier J. Pérez | Roberto Ramos

7|16 Sorry, we're closed: loan conditions when bank branches close and firms transfer to another bank
Diana Bonfim | Gil Nogueira | Steven Ongena

8|16 The effect of quantitative easing on lending conditions
Laura Blattner | Luísa Farinha | Gil Nogueira

9|16 Market integration and the persistence of electricity prices
João Pedro Pereira | Vasco Pesquita | Paulo M. M. Rodrigues | António Rua

10|16 EAGLE-FLI | A macroeconomic model of banking and financial interdependence in the euro area
N. Bokan | A. Gerali | S. Gomes | P. Jacquinot | M. Pisani

11|16 Temporary contracts' transitions: the role of training and institutions
Sara Serra

12|16 A wavelet-based multivariate multiscale approach for forecasting
António Rua

13|16 Forecasting banking crises with dynamic panel probit models
António Antunes | Diana Bonfim | Nuno Monteiro | Paulo M. M. Rodrigues

14|16 A tale of two sectors: why is misallocation higher in services than in manufacturing?
Daniel A. Dias | Carlos Robalo Marques | Christine Richmond

15|16 The unsecured interbank money market: a description of the Portuguese case
Sofia Saldanha

16|16 Leverage and risk weighted capital requirements
Leonardo Gambacorta | Sudipto Karmakar

17|16 Surviving the perfect storm: the role of the lender of last resort
Nuno Alves | Diana Bonfim | Carla Soares

18|16 Public debt expansions and the dynamics of the household borrowing constraint
António Antunes | Valerio Ercolani

2017