UNIVERSITÀ DEGLI STUDI FIRENZE

DISEI
DIPARTIMENTO DI SCIENZE PER L'ECONOMIA E L'IMPRESA

Working Papers - Economics

Behind the International Trade Network: The Role of Heterogeneity and Financial Frictions

Elisa Grugni and Giorgio Ricchiuti

Working Paper N. 26/2024

DISEI, Università degli Studi di Firenze
Via delle Pandette 9, 50127 Firenze (Italia) www.disei.unifi.it

Behind the International Trade Network: the Role of Heterogeneity and Financial Frictions

Elisa Grugni[a,b] Giorgio Ricchiuti[c,d]

Version 1.0

[a] *Università Cattolica del Sacro Cuore, Milano*;
[b] *Universitat Autònoma de Barcelona (ICTA-UAB), Spain*;
[c] *Università degli Studi di Firenze*;
[d] *Complexity Lab in Economics (CLE), Università Cattolica del Sacro Cuore*

Abstract

Modern economies exhibit deeply integrated and synchronized networks among heterogeneous agents. This paper focuses on the trade network and seeks to unravel the mechanisms that underpin its emergence and evolution. To this end, we develop a multi-country general equilibrium model of trade that incorporates firms and countries heterogeneity as well as asymmetric information and financial frictions. Within this framework, the export decisions of firms give rise to an international trade network that mirrors the structure of real-world trade flows. Thus, the model, by encompassing both within and between country heterogeneity, facilitates the investigation of a range of stylized facts pertaining to firm exporting behavior and globalization. The resulting model allows to study the effects of financial shocks on trade flows and their network-based spillovers. The introduction of a credit market in a trade model provides novel insights on the influence of monetary and financial factors on trade patterns.

Keywords: trade, productivity, net worth, financial frictions, network analysis
JEL codes: F11, F12
Corresponding author: elisa.grugni@unicatt.it
Acknowledgment: We thank all the participants to the 1st Summer School in International Economics, organized by the Journal of International Economics, University of Crete, for their feedback and fruitful conversations. An earlier version of this paper was presented at the 26th Annual WEHIA Conference, University of Primorska, Koper; the 29th CEF conference, Université Côte d'Azur in Nice; A.M.A.S.E.S. XLVII, Università degli studi Milano - Bicocca. We are grateful to the participants for their helpful comments and suggestions which led to a considerable improvement of the paper. We also thank Gabriele Tedeschi for useful comments on an earlier version, which allowed us to improve the quality of the analysis, and to Luca Lodi, who provided insights on the estimation of trade costs. The usual disclaimer applies.

This work has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 956107, "Economic Policy in Complex Environments (EPOC)".

1 Introduction

Modern economies exhibit deeply integrated and synchronized networks, wherein heterogeneous agents - be they countries or firms - engage through a complex web of global interconnections. The endogenous evolution of these networks represents a significant source of real-world shock amplification. Among these, the network of trade flows is of paramount relevance. Trade is, indeed, the channel through which growth and prosperity are transmitted between countries. However it may pose a threat to economic stability as it may convey international contagion[1]. Thus, we aim at disentangling the mechanisms that drive trade flows and at analyzing how shocks spread throughout linkages among countries. Uncovering these dynamics is pivotal for identifying the primary drivers of trade and for designing policies that mitigate the potentially disruptive effects of shocks that can ripple through the network.

Financial factors play a crucial role within this background. In the aftermath of the *Great Financial Crisis*, the deep nexus between finance and the real economy became glaring, as did the role of international contagion in transmitting and amplifying local shocks. It was, indeed, a *sudden financial arrest* (Caballero, 2010), which caused a massive damage to the real economy with international trade being the most affected. The existence of extensively interwoven trade and financial networks boosted, indeed, the *Great Trade Collapse* (Baldwin, 2009) that ensued in the wake of the Financial Crisis. This paper investigates the relationship between financial factors and trade flows, spanning from microeconomic theory of international trade to the aggregate effects of firm-level decisions. The aim is to provide novel insights into how financial instability may reshape global trade networks.

The empirical literature on the impact of financial factors on international trade is extensive. Although it was already evident that exporters benefit from better financial wealth (see, for instance, Greenaway and Kneller, 2007), the existence of a tight relationship between corporate finance and trade flows became ineluctable in the wake of the global financial crisis, when the financial distress led to a trade collapse. Chor and Manova (2012) study the shrink in international trade that followed the 2007-2008 crisis, showing that tighter credit constraints on exporters were an important channel through which the crisis hindered trade relationships. Its effects were, indeed, higher in less financially sound economies and in industries more reliant on external finance. Becker et al. (2013) empirically show that developed financial systems facilitate exports. This line of research has expanded to establish a robust connection between firm-level financial characteristics and export decisions, both empirically and theoretically (see, among others, Minetti and Zhu, 2011, Manova, 2008, Caggese and Cuñat, 2013, Kohn et al., 2022). Credit constraints have been shown to influence both the intensive (Paravisini et al., 2015) and the extensive margins of trade (Muûls, 2015), acting as trade barriers that shape the overall structure of international networks. Moreover, the financial accelerator mechanism may amplify the network-based spillovers of shocks and policies. For instance, Demir et al. (2020) demonstrate that supply-side shocks can propagate through production networks, with heightened effects in financially fragile contexts, while di Giovanni and Rogers (2022) highlight how international trade linkages can transmit monetary policy shifts from the U.S. to other countries. Similarly, Basco et al. (2024) present evidence that financial crises impact the network structure of multinational enterprises and that financial frictions play a pivotal role in the adjustments to the shocks.

While the empirical research highlights the critical role of financial frictions in an interconnected

[1]Australia's Minister for Trade, Simon Crean, in Baldwin (2009).

global economy, a theoretical framework capable of predicting network-based spillovers - amplified by microfounded financial frictions in trade - is, to the best of our knowledge, still missing. However, developing such a model is essential for a comprehensive understanding of the global propagation of shocks and policies. Notably, as pointed out by Antràs (2023), the trade literature has largely overlooked the effects of monetary factors on international trade dynamics. At the same time, it is important to emphasize that trade is inherently a networked activity - a characteristic that, while often neglected in microfounded models of international trade, has significant implications for policy outcomes and shocks propagation. To address these dual gaps, we adopt a network-based perspective, which allows to elucidate the complex and non-linear effects of national policies on international outcomes.

Hence, the paper has two main objectives. First, we develop a model that captures key real-world features of trade networks. Second, we exploit this framework to conduct policy analysis, simulating comparative scenarios to understand the cross-border impacts of financial shocks. The ultimate goal is to provide policymakers with insights on how monetary actions and shocks propagate through trade linkages. To this end, we build a static general equilibrium trade model in the spirit of Melitz (2003), characterized by heterogeneity across and within countries, thereby allowing for asymmetric trade flows. This novel approach enables the analysis of micro-level trade decisions alongside system-wide dynamics, allowing to examine the cross-border spillovers of monetary policies within a networked framework. Rising to the challenge posed by Antràs (2023), we study how financial factors influences global trade, particularly its effects on the network structure of trade relationships. Notably, the model is employed to analyze the effects of interest rates on trade participation, affecting both domestic and foreign market frontiers and thereby reshaping the structure of the trade network.

The model has been calibrated on stylized facts about trade and exporting firms. Our findings confirm the pivotal role of financial factors in influencing trade patterns. Financial frictions affect both the extensive and at the intensive margin of trade, as extensively shown in the empirical literature. Furthermore, financial frictions exert a crucial impact on the topology of the trade network, affecting its density and degree distribution. Asymmetric information in the credit market shapes the emergence of the trade network, which, in turn, determines the effects of implemented policies and shocks, in terms of aggregate outcomes and spillovers. This analysis shows that the same shock may have different aggregate impacts in interlinked economies, depending on the relative importance of the hit country within the network. Indeed, we find that the effects and the magnitude of an interest rate hike are contingent upon the centrality of the country in which it occurs. Specifically, the more central the country is, the higher the effect of the shock on world economic outcomes (GDP, trade flows) will be and it will most likely boost feedback on the network topology.

The rest of the paper is organized as follows. Section 2 provides a brief overview of the literature to which the paper connects. Section 3 presents the theoretical model. Section 4 discusses the main results and the experiments. Section 5 concludes the paper and provides suggestions for future research.

2 Related literature

The paper proposes a static general equilibrium model with heterogeneous firms, aligning with the foundations of the *New-New Trade Theory.* Since the pioneering work of Melitz (2003), substantial research has examined modes of internationalization, incorporating productivity heterogeneity and market frictions. A focused area within this research addresses financial factors in firms' internationalization strategies (see, among others, Kohn et al., 2016, Kohn et al., 2020, Bergin et al. (2021)). In this context, Manova (2013) introduces a model with heterogeneous firms subject to collateral constraints, while Chaney (2016) explores how liquidity constraints limit firms' exporting choices. Along the same line of research, Crinò and Ogliari (2017) study how financial frictions affect trade, through their impact on product quality.

These studies consider both fixed and variable exporting costs, with exporters facing higher production costs and tighter credit constraints when serving foreign markets. Feenstra et al. (2014) expands on this by embedding asymmetric information into the Melitz (2003) framework, proposing that exporters encounter stricter credit rationing due to higher interest rates linked to extended debt repayment periods. Interest rates and firm-level exporting decisions are further studied in Assenza et al. (2016), who explain deviations from the productivity-export premium theory (Bernard et al., 1995) by introducing both financial soundness and productivity heterogeneity among firms. Building on Assenza et al. (2016), our model proposes a general equilibrium framework where two layers of firm heterogeneity drive the endogenous formation of the international trade network; distinctively, we apply a micro-founded asymmetric information setting, akin to Feenstra et al. (2014).

Furthermore, we explore the intersection of financial frictions and monetary policies within a Melitz model framework, a relatively novel domain in New-New Trade Theory. While research linking trade and interest rates exists, such as in Antràs (2023), who study trade in a two-country model with firm heterogeneity and time-dependent production cycles (following the Austrian approach of Boehm-Bawerk (1896)), our model differs by adopting a multi-country approach that considers both inter- and intra-country heterogeneity. This setup enables us to examine heterogeneous, network-based spillovers often overlooked in symmetric models. Multi-country Melitz models, such as Helpman et al. (2008) and Yeaple (2009), typically focus on country-pair relationships, whereas our model examines the structure of an entire system of interconnected firms and countries.

The proposed framework aims to bridge the *New-New Trade Theory* of firm heterogeneity with the *Old Trade Theory* of comparative advantage. We propose a model in which both firms' heterogeneity and country-specific factors, especially financial robustness, shape the international trade network, with firms borrowing from national banking systems. This model extends work by Kletzer and Bardhan (1987), who augment the *Heckscher-Ohlin-Samuelson* model to show that credit market frictions affect comparative costs, favoring financially developed countries. However, unlike their model, we incorporate firm-level financial heterogeneity alongside country characteristics.

Our research also contributes to literature on the microeconomic origins of macroeconomic outcomes, notably Acemoglu et al. (2012) and Carvalho (2014), who first showed how sectoral linkages can propagate microeconomic shocks into aggregate fluctuations. Subsequent work, such as Barrot and Sauvagnat (2016) and Baqaee and Farhi (2020), models production networks using input-output analysis to assess disruptions, while Baqaee and Rubbo (2022) examines microeconomic shock transmission through general equilibrium. In the context of international linkages, studies like Taschereau-Dumouchel (2020) and Devereux et al. (2020) underscore the importance of network structure in propagating economic and policy shocks globally. Research on monetary policy in networked economies, as in La'O and Tahbaz-Salehi (2022), further highlights the role of input-output linkages across sectors and countries.

In contrast to much of the production network literature, which focuses on sectoral connections, we examine firm-level perspectives on shock propagation and the evolution of trade patterns. Our model, therefore, offers a unique contribution by blending financial frictions with the dynamics of international trade and firm-level heterogeneity, establishing a bridge between these intersecting areas of research and embodying the *Financial Accelerator View* of macroeconomic fluctuations through real shocks in a global trade network.

3 Theoretical framework

We build a multi-country static general equilibrium model of international trade à la Melitz where firms face exporting decisions, choosing between N_c heterogeneous countries. Each country is populated by N_f firms, that differ in the level of productivity (φ_i) and net worth (a_i), creating a dual dimension of heterogeneity. The interplay between these two firm-specific characteristics serves as a potential source of competitive advantage, shaping pricing strategies and production decisions.

Given their initial endowments of productivity and net worth, alongside market demand conditions, firms borrow liquidity from banks to finance production. Under asymmetric information, as in Feenstra et al. (2014), banks cannot directly observe the true productivity levels of borrowers. Consequently, they design loan and interest rate schedules contingent on the productivity levels reported by firms. Firms, in turn, strategically declare their productivity to maximize profits. With the ensuing loan, firms determine which markets to serve based on the zero-profit cutoff condition, exporting to those markets (domestic or foreign) where profits are non-negative. Importantly, banks establish loan terms ex ante, and firms subsequently self-select into exporting activities and adjust production accordingly. Once revenues are realized, firms repay loans and interest to the bank. Following Feenstra et al. (2014), a critical assumption is that revenue realization is delayed for exports due to longer shipment times. The sequence of events is depicted in Figure 1.

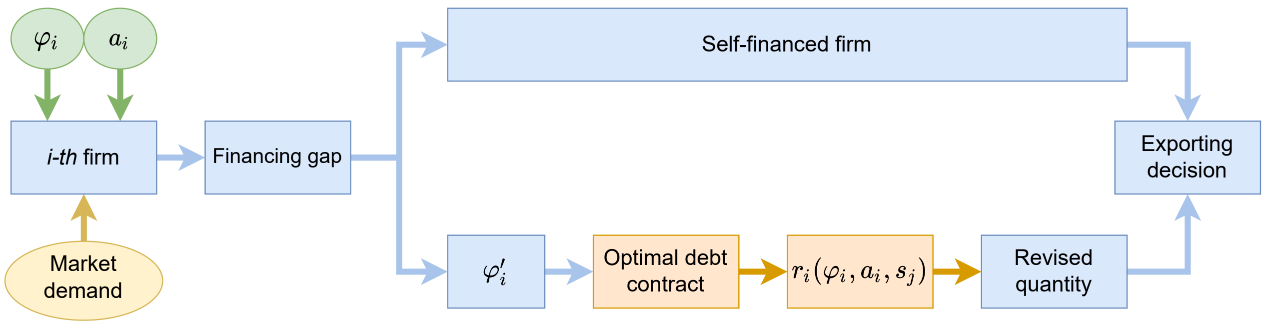


Figure 1: Sequence of events.

3.1 Households and firms

Each of the N_c countries in the world (indexed with $j = 1, 2, ..., N_c$) is populated by a set, $Z^j = Z$, of homogeneous households and $N_f^j = N_f$ firms, each of them producing a differentiated variety, $i = 1, 2, ..., N_f$.[2] In line with the *Dixit-Stiglitz* setting, the representative household's, z, utility

[2]Henceforth, superscripts shall denote the country, whereas subscripts shall indicate the firm.

function coincides with the CES aggregator of the quantities of each variety consumed, q_{iz} :

$$U_z^j = \left(\tilde{N^j}^{\frac{1}{1-\sigma}} \sum_{i=1}^{\tilde{N^j}} (q_{iz})^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{1}$$

where $\tilde{N^j}$ is the equilibrium availability of varieties in an open economy, endogenously determined, which corresponds to the number of firms selling to market j. The latter is given by the sum of local producers, N_D^j, and the sum of foreign firms located in each $k \neq j$ country and exporting to the market j, N_E^k, such that: $\tilde{N^j} = N_D^j + \sum_{k=1}^{N_c-1} N_E^k$. The quantity of the *i-th* variety, q_{iz}, consumed by each z household, is the result of the following constrained maximization problem:

$$\max_{q_i z} \quad \left(\tilde{N^j}^{\frac{1}{1-\sigma}} \sum_{i=1}^{\tilde{N^j}} (q_{iz})^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{2a}$$

$$\text{s.t.} \quad \sum_{i=1}^{\tilde{N^j}} p_i q_{iz} \leq R_z = w^j l_z + \Pi_z^j, \tag{2b}$$

$$\sum_{i=1}^{\tilde{N^j}} p_i q_{iz} = \tilde{P^j} C_z \tag{2c}$$

where R_z denotes resources available to household - the wage bill, $w^j l_z$, and profits earned from firms' owning, Π_z - and $C_z = U_z$ is total consumption. Solving household's maximization problem and summing over the total population of households, we derive the market demand for the *i-th* variety in country j:

$$q_i^j = \left(\frac{p_i^j}{\tilde{P^j}} \right)^{-\sigma} \frac{\tilde{Q^j}}{\tilde{N^j}} \tag{3}$$

where $\tilde{P^j}$ is the equilibrium price index of country j in an open economy, which accounts for the price charged by the N_D^j domestic producers, p_i^j, and the price of the *m-th* variety produced in country $k \neq j$ and sold to j, p_m^j:

$$\tilde{P^j} = \left[\frac{1}{\tilde{N^j}} \left(\sum_{i}^{N_D^j} p_i^{j\,(1-\sigma)} + \sum_{k=1}^{N_c-1} \sum_{m=1}^{N_E^k} p_m^{j\;(1-\sigma)} \right) \right]^{\frac{1}{1-\sigma}} \tag{4}$$

Similarly, $\tilde{Q^j}$ is real GDP in the *j-th* country, as the inflation-adjusted sum of the value of all goods and services locally produced and sold by the N_D^j domestic producers, q_i^j, or shipped to the *k-th* foreign market by the N_E^j domestic exporters, q_i^k:

$$\tilde{Q^j} = \frac{\sum_{i=1}^{N_D^j} q_i^j p_i^j + \sum_{i=1}^{N_E^j} \sum_{k=1}^{N_c-1} q_i^k p_i^k}{\tilde{P^j}} \tag{5}$$

To meet market demand, the *i-th* firm produces according to a technology, which is linear in labor, l_i. Hence, the labor demand is:

$$l_i = \frac{q_i}{\varphi_i} \tag{6}$$

where q_i is the quantity produced. Firms face a perfectly elastic supply of labor at a given nominal

wage, $w^j = 1$, which represents the variable cost of production borne by firm i: $w^j l_i$. [3]
Moreover, firms pay a fixed upfront cost for each market they serve, F^k. Consistently with the related literature (see, for instance, Melitz, 2003), we will assume that fixed costs of foreign selling are higher than the ones required for domestic sales, F^j. In addition, firms face iceberg costs, τ, connected to the sales activity, which reflects shipping fees, insurance and other costs related to the geographical distance between the domestic country j, in which the production takes place, and one of the k countries, where output is sold. Iceberg costs are normalized to 1 for domestic sales, $\tau^{jj} = 1$, while exporting involves higher costs ($\tau^{jk} > \tau^{jj}$ for $k \neq j$), reflecting the additional expenses associated with longer shipment distances. As extensively demonstrated in the trade literature (Anderson, 1979), countries with greater proximity - both geographically and culturally - are more likely to engage in trade. Greater distances between trading partners, on the other hand, result in longer shipment times and extended lags between production and the realization of sales. This temporal dimension of trade costs has important implications for working capital requirements, which increase with international shipments (see Feenstra et al., 2014).

Hence, total production costs for the *i-th* firm are:

$$PC(\varphi_i) = \frac{q_i}{\varphi_i}\tau^{jk} + F \tag{7}$$

To undertake production, firms require working capital, sourced either from internal equity or external bank loans. In a context of asymmetric information, a financing hierarchy emerges, as outlined in the *Pecking Order Theory* (Myers and Majluf, 1984), whereby internal funds should be primarily employed, since they entail the lowest cost. Accordingly, production costs are first financed through the firm's internal wealth (net worth), and only when these are insufficient the firm resort to bank loans. We posit that firms employ a constant fraction of their net worth, a_i, to produce for each of the N_c market they may serve. Thus, firms are divided in $n = N_c$ divisions, each of them specialized in the production for a specific country, domestic or foreign. The division of each firm i devoted to the production for the *k-th* market can dispose of internal resources up to a maximum of $a_i^k = \frac{a_i}{n}$. If internal funds are sufficient to cover production costs, the division is self-financed and any surplus funds are lost[4]. Conversely, if internal funds fall short, a positive financing gap arises, prompting the firm to seek external financing from a bank. This approach aligns closely with Feenstra et al. (2014), who assume firms finance a fixed proportion of production costs through bank loans.[5]

Hence, the loan demand of firm i to serve the generic *k-th* country (with $k = j$ being the domestic market and $k \neq j$ the foreign ones) is:

$$M^k(\varphi_i, a_i) = PC^k(\varphi_i) - a_i^k = \frac{q_i^k}{\varphi_i}\tau^{jk} + F^k - a_i^k \tag{8}$$

Each division operates independently in deciding whether to serve a foreign market and sets production accordingly. In a multi-country model, this means that the *i-th* firm requests separate

[3]The nominal wage has been normalized to 1 and it will be omitted in the following to easy the notation.

[4]From a managerial perspective, the Chief Financial Officer, responsible for implementing the firm's financial strategy, pre-allocates the budget for each division in the preceding period. Thus, we rule out the possibility of reallocation of resources among divisions.

[5]Importantly, our framework does not impose an a priori greater reliance on external financing for exporters, as in Assenza et al. (2016), since all divisions are allocated identical initial budgets. However, exporters face higher upfront costs, which, ceteris paribus, lead to a greater need for external funds.

loans for each market served. Consequently, the firm's total exposure to the banking system is the sum of the loans obtained by its individual divisions:

$$M(\varphi_i) = \sum_{k=1}^{N_c} \left(\frac{q_i^k}{\varphi_i} \tau^{jk} + F^k - a_i^k \right) \tag{9}$$

The firm applies for loans from the national banking system, uncertain whether its entire request will be granted. Due to asymmetric information, the bank is unable to observe the actual productivity level of firm i, φ_i, and it will design a loans schedule, $M(\varphi_i')$ and interest payments, $I(\varphi_i') = r_i M(\varphi_i')$, contingent on firm's announced productivity level, φ_i'. The contract designed by the bank should induce the firms to revel the true productivity level. Notice that asymmetric information regards only the firm-specific level of productivity. We assume that the bank knows firm's net worth, a_i, through its balance sheets. As a result, the bank determines the loan schedule solely as a function of the declared productivity level, $M(\varphi_i')$, taking net worth as given.

The firm sets the price to maximize profits, given the market demand and the loans schedule allotted by the bank, which, in turn, determines the interest rate. The overall profits of firm i will be given by the sum of all the profits realized in all the markets served: $\pi_i = \pi_i^{jj} + \sum_{k=1}^{N_c-1} \pi_i^{jk}$.

Due to the additive nature of the profit function, the maximization problem can be decomposed and solved separately for each market. Consequently, each division of the firm independently maximizes its profits, ensuring that the firm's total profit is also maximized. Focusing on the division of firm i serving market k, the optimization problem involves determining the price and the declared level of productivity that solve the following constrained maximization:

$$\max_{p_i^k,\, \varphi_i'} \quad \pi_i^k = {p^k}_i {q^k}_i - \left(\frac{q_i^k}{\varphi_i} \tau^{jk} + F^k \right) - r_i^k M(\varphi_i') \tag{10a}$$

$$\text{s.t.} \qquad q_i^k = \left(\frac{{p^k}_i}{\tilde{P}^k}\right)^{-\sigma} \frac{\tilde{Q}^k}{\tilde{N}^k}, \tag{10b}$$

$$\pi_i^k(\varphi_i, \varphi_i) > \pi_i^k(\varphi_i, \varphi_i'), \tag{10c}$$

$$\pi_i^k(\varphi_i, \varphi_i) > 0, \tag{10d}$$

$$M^k(\varphi_i') \geq \frac{q_i^k}{\varphi_i} \tau^{kj} + F_k - a_i^k \tag{10e}$$

where (10b) is the market demand for the i-th variety; (10c) ensures the revelation principle for the firm: profits must be greater when revealing the true level of productivity. They must also be positive according to (10d). Furthermore, the loan schedule under asymmetric information (10e) ensures that the loans extended by the bank to the firm declaring a productivity φ_i' should, at least, cover the financing gap. This happens whenever the firm declares a level of productivity which is lower than the true one: $\varphi_i' < \varphi_i$. In equilibrium, constraint (10e) must be binding; otherwise, the firm would incur higher interest payments by borrowing more than necessary. Since (10e) is binding, the quantity produced is a function of the loans schedule $M(\varphi_i')$:

$$q_i^k = (M(\varphi_i') - F^k + a_i^k) \frac{\varphi_i}{\tau^{jk}} \tag{11}$$

By substituting (11) and the inverse demand function obtained from (10b), we get:

$$\pi_i(\varphi_i, \varphi_i') = \left(\frac{\tilde{N^k}}{\tilde{Q^k}}\right)^{\frac{-1}{\sigma}} \tilde{P^k} \left[(M(\varphi_i') - F^k + a_i^k) \frac{\varphi_i}{\tau^{jk}} \right]^{\frac{\sigma-1}{\sigma}} - a_i^k - (1 + r_i^k) M(\varphi_i') \tag{12}$$

If we take the FOC wrt φ_i' under the revelation principle, we can find the declared level of productivity that maximizes firm's profits:

$$\frac{\partial \pi(\varphi_i, \varphi_i')}{\partial \varphi_i'} |_{\varphi_i' = \varphi_i} = 0$$

$$M'(\varphi_i) \left[\tilde{P^k} \frac{\sigma - 1}{\sigma} \left(\frac{\tilde{Q^k}}{\tilde{N^k}}\right)^{\frac{1}{\sigma}} \left(\frac{\varphi_i}{\tau^{jj}}\right)^{\frac{\sigma-1}{\sigma}} (M(\varphi_i) - F^k + a_i^k)^{\frac{-1}{\sigma}} \right] - (1 + r_i^k) M'(\varphi_i) = 0$$

If we rearrange we get:

$$\begin{aligned} &\Rightarrow r_i^k = \Phi(\varphi_i, M(\varphi_i)) - 1 \\ &where \quad \Phi(\varphi_i, M(\varphi_i)) = \tilde{P^k} \frac{\sigma - 1}{\sigma} \left(\frac{\tilde{Q^k}}{\tilde{N^k}}\right)^{\frac{1}{\sigma}} \left(\frac{\varphi_i}{\tau^{jk}}\right)^{\frac{\sigma-1}{\sigma}} (M^k(\varphi_i) - F^k + a_i^k)^{\frac{-1}{\sigma}} \end{aligned} \tag{13}$$

Equation (13) is the *incentive-compatibility condition* for firm i, that the bank should take into account when determining the loans schedule. This is the firm's demand for loans under asymmetric information; the bank takes it as given when maximizing its profits. Moreover, from the firm's maximization problem we get the optimal price charged by the *i-th* firm in the domestic market:

$$p_i^k = \frac{\sigma}{\sigma - 1} \frac{\tau^{jk}}{\varphi_i} (1 + r_i^k) \tag{14}$$

The firm will enter the *k-th* market if the participation constraint is satisfied, i.e. if profits are positive. Hence, we can determine the productivity threshold, $\bar{\varphi}_i^k$, that, given the firm-specific net worth a_i and the market fundamentals, $\tilde{N^k}, \tilde{P^k}, \tilde{Q^k}$, ensures positive profits for the firm producing for the *k-th* market.

$$\varphi_i \geq \bar{\varphi}_i^k(a_i, \tilde{P^k}, \tilde{Q^k}, \tilde{N^k}) = \Omega \tau^{jk} \left(\frac{\tilde{Q^k}}{\tilde{N^k}}\right)^{\frac{\sigma-1}{\sigma}} \left(\frac{1}{\tilde{P^k}}\right)^{\frac{\sigma}{\sigma-1}} \left[F^k (1 + r_i^k)^{\sigma} - a_i^k r_i^k (1 + r_i^k)^{(\sigma-1)} \right]^{\frac{\sigma}{\sigma-1}} \tag{15}$$

where $\Omega = \sigma^{\frac{\sigma}{\sigma-1}} (\sigma - 1)^{-1}$. Notice that this threshold is firm-specific as it depends on the net worth. In fact, we can map the population of firms onto the productivity-net worth plane, identifying the combinations of these two variables that enable firms to enter each market. The threshold is also influenced by the characteristics of the market, including the aggregate price index, as well as the market's size, measured by real GDP and the number of competitors. For example, countries with higher GDP levels could attract low productive firms, as the threshold for profitable market entry is laxer. Conversely, economies with more efficient producers will feature a lower aggregate price index, making it more difficult for foreign competitors to access the market.

It is worth highlighting that, under the assumption that $F^k > F^j$ and $\tau^{jk} > \tau^{jj}$, the participation constraint for the foreign market lies always above the participation constraint of the domestic market, ceteris paribus, as in the Melitz model. However, if countries are heterogeneous, economic fundamentals play a crucial role in determining the firm's production structure. For instance, some firms that are unable to enter the domestic market due to low efficiency relative to local competitors may still be able to serve a foreign market with lower efficiency barriers, either due to higher internal demand or a higher aggregate price index.

3.2 Banks

Firms borrow working capital from the monopolistic national bank, which sets the interests repayments to maximize profits. Bank's total revenues are given by the sum of the interests collected on loans while total costs are given by the opportunity cost of lending to the firm. The latter is computed as the interests the bank would have gotten if the funds lent to the firm, $M(\varphi_i)$, would have been employed in a risk free asset paying an interest rate i^j, for τ periods. The distance between countries represented by this parameter also reflects the time elapsed between production and realized revenues, thus indicating the maturity of debt. It follows that loans to exporting firms are characterized by longer maturity. The interest rate paid by the alternative asset, i^j, entails the the risk free interest rate, i^j_{rf}, and a country-specific spread, s^j, reflecting the riskiness of the sovereign.

The bank maximizes profits, choosing the interest rate charged to the *i-th* firm, under the incentive compatibility constraint of the borrower:

$$\max_{r_i} \quad \sum_{i}^{N_j} \sum_{k}^{N_c} \Big(r_i^k M^k(\varphi_i) - i^j \tau^{jk} M^k(\varphi_i) \Big) \tag{16a}$$

$$\text{s.t.} \quad r_i^k = \Phi(\varphi_i, M^k(\varphi_i)) - 1 \tag{16b}$$

where N_j is the number of firm in country j, serving either the domestic market ($k = j$) and the foreign countries ($k = 1, 2, ..., (N_c - 1) \neq j$).

Given the additivity of the profits function, we can separately solve the maximization problem for each division-firm[6]:

$$\max_{r_i^k} \quad r_i^k M^k(\varphi_i) - i^j \tau^{jk} M^k(\varphi_i) \tag{17a}$$

$$\text{s.t.} \quad r_i^k = \Phi^k(\varphi_i, M(\varphi_i)) - 1 \tag{17b}$$

where: $\Phi^k(\varphi_i, M^k(\varphi_i)) = \tilde{P^k} \frac{\sigma-1}{\sigma} \left(\frac{\tilde{Q^k}}{\tilde{N^k}}\right)^{\frac{1}{\sigma}} \left(\frac{\varphi_i}{\tau^{jk}}\right)^{\frac{\sigma-1}{\sigma}} (M^k(\varphi_i) - F^k + a_i^k)^{\frac{-1}{\sigma}}$ AND $M^k(\varphi_i) - F^k + a_i^k > 0$.

From (17b), we get firm's demand of loans as a function of the interest rate:

$$r_i^k(M^k(\varphi_i)) = B(\tilde{P^k}, \tilde{Q^k}, \tilde{N^k}, \varphi_i)(M^k(\varphi_i) - F^k + a_i^k)^{\frac{-1}{\sigma}} - 1$$

where:

$$B(\tilde{P^k}, \tilde{Q^k}, \tilde{N^k}, \varphi_i) = \tilde{P^k} \frac{\sigma - 1}{\sigma} \left(\frac{\tilde{Q^k}}{\tilde{N^k}}\right)^{\frac{1}{\sigma}} \left(\frac{\varphi_i}{\tau^{jk}}\right)^{\frac{\sigma-1}{\sigma}}$$

[6]It is worth noticing that the firm will sign a contract for each k market she serves, paying differentiated interest rate, depending on the destination.

and the direct loan demand function:

$$M^k(\varphi_i) = \left(\frac{B(\tilde{P^k}, \tilde{Q^k}, \tilde{N^k}, \varphi_i)}{1 + r_i^k}\right)^{\sigma} - a_i^k + F^k. \tag{18}$$

By substituting (18) into the bank's maximization problem, the optimal interest rate is derived as:

$$\begin{aligned}
&\pi^B = \left(r_i^k - i^j\tau^{jk}\right)\left(\left(\frac{B(\tilde{P^k}, \tilde{Q^k}, \tilde{N^k}, \varphi_i)}{1 + r_i^k}\right)^{\sigma} - a_i^k + F^k\right)\\
&\frac{\partial \pi^B}{\partial r_i^k} = 0\\
&\left(\left(\frac{B(\tilde{P^k}, \tilde{Q^k}, \tilde{N^k}, \varphi_i)}{1 + r_i^k}\right)^{\sigma} - a_i^k + F^k\right) + \left(r_i^k - i^j\tau^{jk}\right)\left(B(\tilde{P^k}, \tilde{Q^k}, \tilde{N^k}, \varphi_i)^{\sigma}(-\sigma)(\frac{1}{1 + r_i^k})^{\sigma+1}\right) = 0\\
&\left(\frac{B(\tilde{P^k}, \tilde{Q^k}, \tilde{N^k}, \varphi_i)}{1 + r_i^k}\right)^{\sigma}\left[1 - (r_i^k - i^j\tau^{jk})\sigma(\frac{1}{1 + r_i^k})\right] = a_i^k - F^k
\end{aligned} \tag{19}$$

Equation 19 has an implicit solution and must be solved computationally. Then, given the interest rate charged by the bank, r_i^{k*}, the loans schedule is determined from the direct demand function (Equation 18) and the quantity produced is set accordingly (Equation 11). A credit constraint endogenously emerges. The presence of asymmetric information in the market for loans gives rise to financial frictions and ultimately results in the emergence of constrained firms that are unable to achieve their first best. In this case, they will borrow as much as they can, $\bar{M} = M(r_i^{k*})$, and reschedule the quantity produced depending on the availability of funds: $q_i^k = (\bar{M} - F^k + a_i^k)\frac{\varphi_i}{\tau^{jk}} < q_i^{k*}$

3.3 International trade network

Macroeconomic variables are computed from the bottom-up, aggregating the results of firm-level interactions. Specifically, by summing up the quantity sold by the N_E^j exporters of country j to the *k-th* market, we get the unilateral flows of trade among the two entities, X^{jk}, such as:

$$X^{jk} = \sum_{i=1}^{N_E^j} \mathbb{1}(\varphi_i \geq \bar{\varphi_i^k}) q_i^k \tag{20}$$

where $\mathbb{1}(\varphi_i \geq \bar{\varphi_i^k})$ is an indicator equal to 1 if the productivity of the firm is greater than the participation threshold. Each country-pair unilateral flows of trade populates the following adjacency matrix, G:

$$G = \begin{pmatrix} 0 & X^{12} & X^{13} & \cdots & X^{1N_c} \\ X^{21} & 0 & X^{23} & \cdots & X^{2N_c} \\ X^{31} & X^{32} & 0 & \cdots & X^{3N_c} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ X^{N_c1} & X^{N_c2} & X^{N_c3} & \cdots & 0 \end{pmatrix}$$

which represents the international trade network. Note that in a homogeneous country framework, the adjacency matrix of a directed network would have been symmetric, whereas in the real world countries are characterized by unbalanced trade flows. The latter are, indeed, determined by countries' intrinsic characteristics which makes firm willing to serve them at different extent. Consequently, the international trade network that emerges from firms' exporting decisions is asymmetric, encompassing unbalanced and zero trade flows.

4 Results

The model presented does not have a closed-form solution. It is, therefore, necessary to undertake computational analysis. To this end, some of the parameters employed are derive from the existing literature while the remaining ones are calibrate with real data. Given the model's calibration, we first demonstrate how it reproduces key stylized facts from the literature, and then conduct experiments to examine the effects of network-based spillovers on the outcomes of financial shocks.

4.1 Calibration

The baseline version of the model is run for 30 countries[7], each of them populated by 1000 firms. We consider two alternative specification of the baseline model:

- Symmetric and homogeneous countries (**1st scenario**). They are characterized by the same set of firms, in terms of productivity and net worth distribution and they are identical in their fundamental characteristics, i.e. bilateral distance and financial soundness.
- Heterogeneous Countries (**2nd scenario**). Countries are populated by the same set of firms but they are heterogeneous both in terms of geographical distances (τ_{jk}) and financial soundness. Countries' financial robustness is proxied by the level of sovereign spread.

Parameters employed in the simulations are summarized in Table 1. Some of the parameters have been taken from the relevant literature. For instance, we follow the plant-level empirical analysis of Bernard et al. (2003) to set the elasticity of substitution among varieties: $\sigma = 3.8$. Based on this value, Balistreri et al. (2011) estimate the distribution of firm's productivity being a Pareto with shape parameter $a = 4.5$ and minimum $b = 0.2$. The Pareto assumption is by far the most common distributional assumption made in the heterogeneous-firm literature and, for this reason, we employ the same distribution for firm's net worth. In this regard, Axtell (2001) proved that U.S. firms size follow a Zipf law distribution; we relate to this funding by adopting a Pareto distribution of firms' net worth, with shape parameter close to 1.

In the second scenario, we allow for geographical heterogeneity among countries. Thereby each country-pair is assigned with a specific iceberg costs, τ^{jk}, while domestic selling is assumed to be friction-less. The resulting matrix of geographical distances is symmetric. We employ the *ESCAP-World Bank Trade Cost Database* to compute the related distribution of iceberg costs. According to our estimation, overall iceberg costs in the manufacturing sector are distributed following a lognormal distribution, such that $\tau \sim Lnorm(5.66, 0.51^2)$. Consequently, in each Monte Carlo simulation, a random adjacency matrix of iceberg costs is drawn from it.

[7]The thirty biggest countries in 2019 were responsible for 80% of total exports, with a considerable heterogeneity in their international participation (top 10% of exporters are responsible for almost half of the flows). For this reason - and to avoid excessive computational burden - we believe that it is sufficient to consider 30 countries. Nonetheless, robustness checks have been computed on the number of countries and results are summarized in the Appendix B.

Table 1: Numerical values of parameters in the alternative scenarios

Parameter	Description	1st	2nd
N_f	Number of Firms per country	1.000	1.000
N_c	Number of Countries	30	30
σ	Elasticity of substitution	3.8	3.8
w	Real wage	1	1
i^j	Risk Free Interest Rate	0.02	0.02
s^j	Sovereign Spread	0.0231	$Lnorm(-4.10, 0.82^2)$
τ^{jj}	Iceberg costs domestic production	1	1
τ^{jk}	Iceberg costs of exporting	3.7	$Lnorm(5.66, 0.51^2)$
F^j	Fixed Costs of domestic production	0.5	0.5
F^k	Fixed costs of exporting	2	$f(\tau^{jk})$

Furthermore, we introduce financial heterogeneity among countries, proxied by different levels of sovereign spread on the risk-free rate. In this regard, Gilchrist et al. (2022) construct bond-level sovereign spreads for dollar denominated bonds issued by over 50 countries from 1995 to 2020. Their database unrevealed an average credit spread of 231 basis points, indicating that most countries in the sample exhibit a premium relative to U.S. Treasury securities, with a standard deviation of 225 basis point. Therefore, we construct our measure of countries' financial soundness to match this the empirical evidence. To this end, countries' spread are drawn from a log-normal distribution with the desired mean and standard deviation, such that $s^j \sim Lognorm(-4.10, 0.82^2)$.

The remaining few parameters are calibrated to meet stylized facts in the international trade literature, presented in the next section.

4.2 Simulations meet Stylized Facts

Increasing availability of firm-level data has allowed to identify some stylized facts on firm's international activity (Eaton et al., 2004). Results of the simulations - in both scenarios, with and without financial frictions - are compared with a number of them, both at the micro and at the macro level, to calibrate the model. Results are summarized in Table 2.

Firstly, it has been possible to detect the characteristics that drive export market participation. Bernard et al. (2007) show that exporters are larger and more productive (**SF1**) than domestic firms, suggesting the existence of an *export productivity premium* (Bernard et al., 1995). Namely, exporters have an *a priori* advantage that leads to self-selection into international trade activity: exporters are more productive because only the most efficient firms are able to overcome the costs related to global market participation. This empirical regularity is confirmed by the simulated model: exporters are always characterized by a stricter participation threshold and, in turn, higher average productivity, in line with the Melitz framework. Notwithstanding the self-selection mechanism, empirical evidence still document the coexistence of highly productive non-exporters and low productive exporters (see, for instance, Bernard et al., 2003 and Melitz and Trefler, 2012); namely, data show an overlapping distribution of the productivity of exporting and non-exporting firms (**SF2**). By embedding a second layer of firms' heterogeneity, i.e. differences in net worth, the theoretical model discussed above is able to reproduce this empirical regularity in both scenarios, even though the effect of financial heterogeneity is more pronounced when it coexists with differences in interest rate spreads. Figure 2 depicts the kernell density of domestic and exporting firms' productivity in the first (Figure 2a)

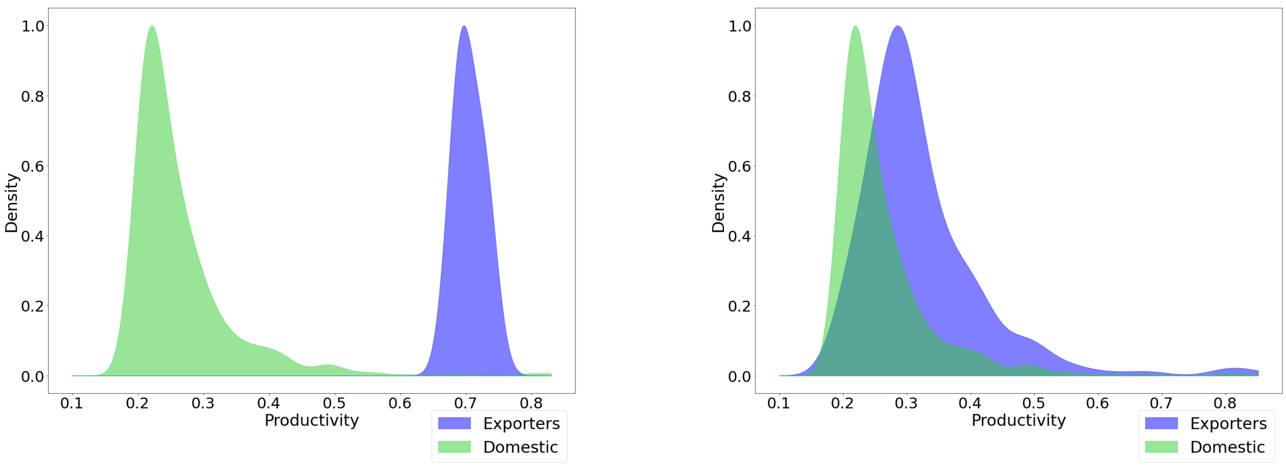
Table 2: Stylized facts with and without financial frictions

		Without financial frictions		With financial frictions	
SF	**Stylized Fact**	**1st**	**2nd**	**1st**	**2nd**
SF1	Domestic productivity threshold	0.2000	0.2000	0.2000	0.2000
		(0)	(0.0000)	(0)	(0.00001)
SF1	Exporters productivity threshold	0.4372	0.2068	0.6849	0.2094
		(0)	(0.0146)	(0)	(0.0182)
SF1	Average domestic productivity	0.2618	0.2618	0.2641	0.2702
		(0)	(0.0142)	(0)	(0.0142)
SF1	Average exporters productivity	0.5585	0.2731	0.6849	0.3680
		(0)	(0.0239)	(0)	(0.0684)
SF2	Overlapping productivity distribution				
SF3	Share of exporting firms	3.38%	46.21%	0.1%	22.73%
		(0)	(0.0766)	(0)	(0.1444)
SF4	Exported output share per firm	19.16%	54.26%	1.12%	34.61%
		(0)	(0.1171)	(0)	(0.1548)
SF5	Average export destinations	100%	17.35%	100%	10%
		(0)	(0.05095)	(0)	(0.0372)
SF6	Export share of top 10% exporters	30.17%	54.98%	1.12%	54.70%
		(0)	(0.0494)	(0)	(0.0685)
SF7	Countries' export share	3.33%	3.33%	3.33%	3.33%
		(0)	(0.0166)	(0)	(0.0250)
SF8	Network Density	1	0.9035	1	0.6598
SF9	Disassortativity	-	-0.10	-	-0.0815
SF10	Average Betweenness	0.0667	0.1203	0.0667	0.1060
		(0)		(0)	(0.0366)

and second scenario (Figure 2b). Exporters consistently have higher productivity than non exporting firms (**SF1**) but only in presence of countries' heterogeneity the distributions reveal an overlapping area, as detected in real data. This is due to the fact that the productivity threshold is decreasing in firm's financial soundness: even firms' characterized by relatively lower level of productivity may end up exporting, if they are initially endowed with high internal finance. Indeed, even if they are less efficient than other firms, facing higher marginal production costs, they can benefits from lower interest rates on loans that decrease the total financial costs and the overall individual price.

The simulated model shows that exporting is a relatively rare activity and only a small fraction of firms enter the international market. The empirical counterpart of this results is provided, for instance, by Eaton et al. (2004), which establish key features of exporters behavior by exploiting granular data on French firms. According to their empirical analysis, in 1986, only 17.4% of French firms were exporters (**SF3**) [8]. Furthermore, most firms export little (**SF4**) and to few markets (**SF5**). They show that the modal French exporter ships to only one foreign destination and just 19.7% of manufacturing firms served more than 10 markets. In a subsequent work, Chaney (2014) finds that French firms export, on average, to between 3.50 (in 1992) and 3.62 (in 1986) different foreign countries. The intensive margin of trade is, as well, weak with respect to domestic sales. In 1986,

[8] While the share of exporting firms may vary depending on industries and countries, the percentage generally fluctuates around this value. For instance, in 2002, 18% of American manufacturing firms exported[9] while the share of exporting Italian firms was 14.6% in 2003 (Bottazzi et al., 2014).



(a) Homogeneous countries (1st scenario)

(b) Heterogeneous countries (2nd scenario)

Figure 2: Productivity distribution of domestic firms and exporters.
Note: For both scenarios - homogeneous countries (left panel) and heterogeneous countries (right panel) - we depict the productivity distribution of domestic (green) and exporting (blue) firms in one representative simulation.

France exported 21.6% of total manufacturing product (Eaton et al., 2004) while the share shrinks to 10.3% for USA (Bernard et al., 1995).

The model is also able to reproduce the presence of the so-called "happy few" (Mayer and Ottaviano, 2008). Indeed, while the majority of firms' exporting activity is limited, some exporters emerge as "superstars" in international trade. Namely, largest exporters account for a disproportionate share of the traded volumes (**SF6**). For instance, in 2020, large U.S. exporters accounted for over two-thirds of the export value[10].

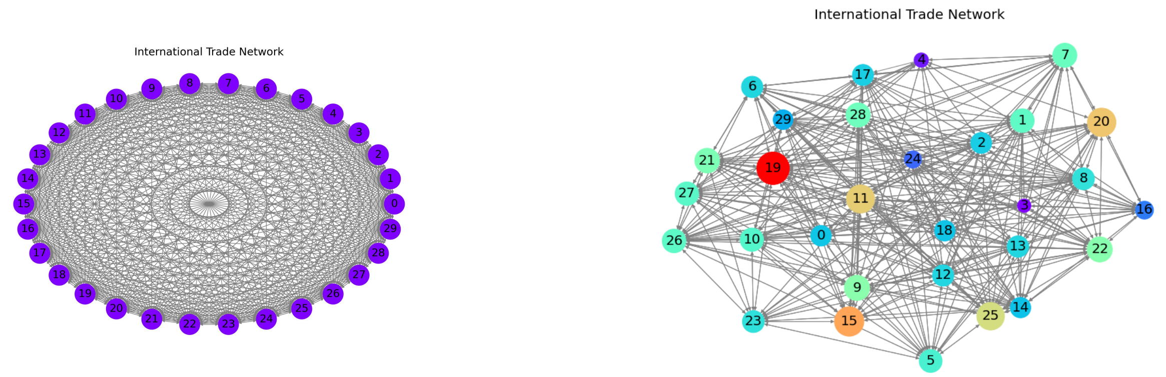
All the above-mentioned empirical findings led the way to the emergence and the establishment of *New-New Trade Theory* (see Melitz and Redding, 2014 and Redding, 2022 for an encompassing review of the literature). Nevertheless, new empirical regularities on international trade, coming from the adoption of complex network theory, point toward the need of a new perspective in international economics. Applying network analysis to trade flows yield, indeed, new insights and stylized facts concerning countries exposure to the global economy. These findings highlight a great heterogeneity among countries (**SF7**), which can not be explained by the traditional assumptions of the "Old", "New" and "New-New" trade theory (De Benedictis and Tajoli, 2011). For instance, Serrano and Boguná (2003) showed that international flows recreate a complex network, characterized by the scale-free and small-world properties. In the last decades, many researchers studied the topological properties of the world trade network (see Garlaschelli and Loffredo, 2004 and Kali and Reyes, 2007 among others), finding complex structures which cannot be explained using the traditional frameworks. In this regard, Schweitzer et al. (2009) advocate for new approaches able to capture the systemic complexity of economic networks, that can serve as a way to enrich established paradigms in economic theory.

De Benedictis and Tajoli (2011) use data on aggregate bilateral imports to study the evolution of the global trade network over the second half of the twentieth century. They show that trade tends to be concentrated among a subgroup of countries and a small percentage of the total number of exchanges account for a disproportionate share of the overall trade. Larger countries play a key role in the international context, being characterized by a greater number of partners. Furthermore, they

[10] U.S. Census Bureau, "A Profile of U.S. Importing and Exporting Companies, 2019-2020".

show that the world trade network is not regular nor complete. In line with their paper, we employ the *BACI Database (CEPII)* for the 2019[11], to reconstruct and analyze the evolution of the world trade network. The empirical regularities detected in real data are further employed to validate the accuracy of our theoretical framework. Notably, the world trade network in 2019 was characterized by a density[12] of 0.64 (**SF8**), a disassortative nature (**SF9**) and a betwenness centralization of 0.025 (**SF10**).

Network statistics have been computed for the simulated model under both scenarios and findings suggest the urge of accounting for both within and between heterogeneity to properly capture real world properties. The first scenario encompasses symmetric and homogeneous countries, populated by heterogeneous firms. This is the economy depicted by Melitz (2003), in which firms trade and aggregate flows among countries depend on micro-level decisions. Results at the firm-level are consistent with the main findings in the New-New Trade Theory. However, countries' symmetry leads to the same exporting share. This result is not consistent with empirical evidences on heterogeneous participation to international trade. Notably, if countries are homogeneous and characterized by the same distribution of agents, aggregate variables at the national level are the same for all countries in equilibrium. The ex-post network is regular and fully connected (see Figure 3).



(a) Homogeneous countries (1st scenario)

(b) Heterogeneous countries (2nd scenario)

Figure 3: Simulated international trade network
Note: Each node is a country and links are trade flows among country-pairs. Different colors are associated with different level of GDP while the size of each node reflects export participation.

Financial frictions play a critical role in shaping trade dynamics. Under the assumption of perfect information in the loan market (Table 2, first panel), all firms can access credit at the national risk-free rate, defined as the monetary policy rate adjusted for the government spread. In this scenario, the simulated network is fully connected, thereby indicating that financial frictions exert an influence on the extensive margin of trade. Introducing asymmetric information in the loan market significantly reduces the share of exporting firms. Firms in weaker financial positions face prohibitively high interest rates, limiting their access to external finance and excluding them from international markets. As a result, the productivity threshold for exporting firms increases, implying that only the most productive firms can compete in the global economy, characterized by financial frictions. Financial frictions also impact the intensive margin of trade in both scenarios. Specifically, the share of output

[11]The year 2019 was selected as the reference point for this study due to the significant temporal distance from the Great Trade Collapse and economic distress of 2008-2009. Additionally, the results were not influenced by the aftermath of the global pandemic of 2020 and the subsequent period of geopolitical instability.

[12]Network density is the ratio of actual connections to the maximum possible connections in a network, indicating the level of interconnectedness among nodes.

exported per firm (**SF4**) and the average number of destination markets served (**SF5**) decline in the presence of financial frictions. Limited access to funds under asymmetric information affects all firms, constraining their ability to expand into new markets or scale up existing operations. Consequently, financial frictions act as a barrier to economic activity. Figure 4 illustrates the percentage deviations in aggregate variables resulting from the introduction of financial frictions in the loan market.

By considering multiple layers of heterogeneity - both within and between countries - coupled with financial frictions, the theoretical model proposed is able to replicate all the above mentioned stylized facts.

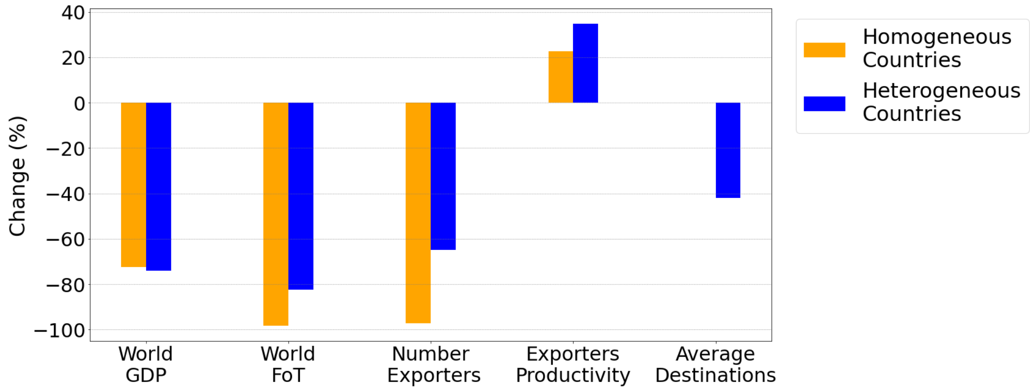


Figure 4: Effect of financial frictions.
Note:The figure presents the percentage change in main aggregate variables with respect to the frictionless case, for both the first scenario, comprising homogeneous countries (in orange), and the second scenario, comprising heterogeneous countries (in blue).

4.3 Financial distress

Once calibrated to meet stylized facts both at the micro and at the macro level, the model has been employed to evaluate the effects of financial shocks on the networked economy. Namely, a deterioration of financial conditions, i.e. an increase in the sovereign spread, is induced in the most and least central countries. In order to identify the main players, alternative centrality measures have been tested[13]. Since most of them lead to the identification of the same hubs - except for betweenness centrality - we will focus the discussion on *out-degree*[14], because it can be seen as a measure of the influence of the node in the network; definitions and results of alternative centrality measures are presented in the Appendix.

A shock to the most central country (left panel of Table 3) leads to a reduction in the overall flow of trade (FoT), even when the shocked node is excluded from the analysis. This is due to the fact that the contraction of aggregate demand in the affected country hinders the activities of foreign firms. As a result, the average share of exporters shrinks. Notwithstanding the impact on trade, foreign countries tend to benefit from increased domestic activity. This outcome is paired with the rise in the average number of domestic producers, boosted by the reduced competition coming from importers located in the affected country. However, the presence of less efficient domestic firms has the effect of increasing the overall average price index. Notice that this result is reversed when the

[13] Alternative centrality measures may lead to the identification of different nodes as hubs in certain networks, even if a correlation among them is observed (Krackhardt, 1990).

[14] Out-degree measures the centrality of a node considering the number of out-going links. In our case, it accounts flows originated from country i towards its trade partners.

statistic accounts for the shocked country. This can be attributed to the fact that least productive firms in the shocked country can not access the market anymore, due to increased financial costs.

The withdrawal of a key actor results in a shift in the relative importance of remaining countries within the network, which, in turn, leads to an increase in network density. This results could seem counter intuitive, since, in principle, removing the most central node would decrease network density because it erases a large number of connections, reducing the network's overall connectedness. [15] Nevertheless, the recorded increase in density is due to the fact that a shock hitting the node with the greatest number of out-going links boosts a reorganization of the structure in favor of other nodes, which increases their number of connections. Average out-degree, indeed, increases by 0.2% for the remaining countries.

The impact of the shock on aggregate variables is less pronounced when the affected country is peripheral in the network. In this case, economic activities record a slight slowdown, with a tight decrease in aggregate GDP and flows of trade.

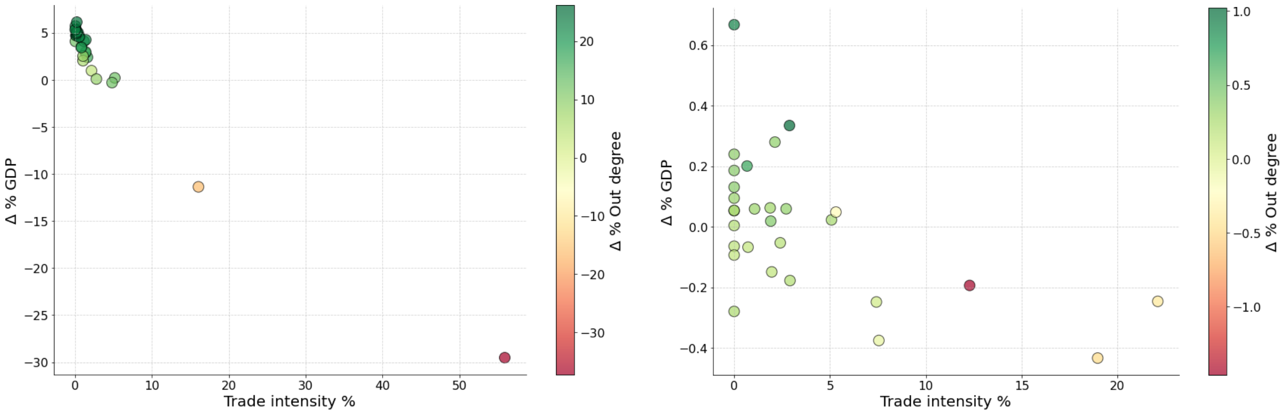
Table 3: Aggregate effects of an increase in the sovereign spread of the most (left panel) and least (right panel) central country in terms of out-degree.
Note: Aggregate variables, along with their corresponding percentage change, are calculated for the entire economy (denoted as *Total*) and for all countries except for the one that has been subjected to a shock (denoted as *Without shocked*).

	Shock to the most central		Shock to the least central	
	Total	Without shocked	Total	Without shocked
Δ GDP	-4,64%	1,04%	-1,06%	-0,05%
Δ P	-0,10%	0,76%	0,01%	0,02%
Δ FoT	-12,92%	-4,93%	-0,19%	-0,03%
Δ Domestics	-1,76%	1,73%	-1,35%	0,00%
Δ Exporters	-9,62%	-3,01%	0,01%	0,13%
Δ Density	1,57%	1,39%	0,52%	0,52%

Overall, countries that strongly rely on trade relationships with the shocked country are the most affected. By considering the distribution of the shocks, in Figure 5 we show the correlation between trade intensities and GDP variations when the shocked country is a central hub (Figure 5a) or at the periphery (Figure 5b). In the former, a strong negative correlation (-0.97) is evident between the intensity of the trade relationship and the loss recorded by foreign actors. This indicates that countries trading more with the affected country are experiencing greater losses, both in terms of GDP and their position within the network. The correlation is less evident when considering the impact of a shock on the periphery of the network. In this latter case, countries are only marginally affected, and it is not possible to discern a clear pattern.

It is important to note that the heterogeneity in outcomes observed following the shock would have been entirely overlooked in a framework with symmetric countries. To illustrate this point, the same experiment was conducted under the first scenario, which features heterogeneous firms but assumes symmetric and homogeneous countries. The results, presented in Table 4, reveal starkly different aggregate outcomes. In a world of homogeneous countries, the shock has only minimal effects on average GDP and the price index. Moreover, the network remains fully connected in the aftermath of the shock, and there is no distinction between the impact of a shock to the center versus the periphery of the network, as all countries exert identical influence under homogeneity.

[15] This remains true if we consider the most central node in terms of betweenness centrality (Table 5).



(a) Shock to the most central country

(b) Shock to the most peripheral country

Figure 5: Correlation between trade intensity and GDP variations
Note: For each experiment, the figure depicts the percentage change in GDP of each country after the shock to the most (or least) central one, in relation with the trade intensity with the shocked country. Trade intensity is defined as the relative value of exports toward that country with respect to total exports.

Table 4: Aggregate effects of an increase in the sovereign spread of the most (left panel) and least (right panel) central country in terms of out-degree when countries are homogeneous.
Note: Aggregate variables, along with their corresponding percentage change, are calculated for the entire economy (denoted as *Total*) and for all countries except for the one that has been subjected to a shock (denoted as *Without shocked*).

	Shock to the most central		Shock to the least central	
	Total	Without shocked	Total	Without shocked
Δ GDP	-2,63%	0,01%	-2,63%	0,01%
Δ P	0,31%	-0,05 %	0,31%	-0,05 %
Δ FoT	8,80 %	4,34 %	8,80 %	4,34
Δ Domestics	-	-	-	-
Δ Exporters	96,66%	100%	96,66%	100%
Δ Density	-	-	-	-

5 Conclusion

We rely on a microeconomic approach, focusing on how firms endogenously form a trade network based on their intrinsic characteristics and the environment surrounding them, to study aggregate trade flows and macroeconomic consequences of localized shocks. y bridging microeconomic foundations with macroeconomic phenomena, we demonstrate that productivity differences alone are insufficient to explain the substantial heterogeneity in firms' and countries' exposure to international markets. Additional factors, such as financial soundness at both the firm and country levels, geographic characteristics, and asymmetric information, play a pivotal role in shaping the structure of the international trade network. Incorporating these elements enables the model to replicate established stylized facts while offering new insights into the global trade system, particularly through the lens of network analysis. The resulting trade network exhibits scale-free properties, closely mirroring the empirical structure observed in real-world data.

The model conceptualizes the economy as a network, allowing for an analysis of how localized shocks - such as a deterioration in a country's financial conditions - propagate across the system. Results show that the transmission of shocks depends critically on the network's structure and the centrality of the affected country within it. Shocks to a central hub lead to significant aggregate disruptions, strongly affecting trading partners and propagating throughout the network. Conversely, shocks to peripheral nodes have limited effects on both trading partners and aggregate outcomes, highlighting the asymmetric influence of actors in the global economy.

We believe this framework represents a promising starting point for future developments. A key avenue for further work is the empirical validation of the model, which we aim to pursue in subsequent studies. Additionally, some simplifying assumptions, such as the fixed markup derived from the original Melitz model, warrant revisiting in light of advances in the literature (e.g., Melitz and Ottaviano (2008)). While we retained the original formulation in this paper to maintain focus and avoid unnecessary complexity, relaxing such assumptions could enrich the analysis and broaden the model's applicability.

References

Acemoglu, D., V. M. Carvalho, A. Ozdaglar, and A. Tahbaz-Salehi (2012): "The network origins of aggregate fluctuations," *Econometrica*, 80, 1977–2016.

Anderson, J. E. (1979): "A theoretical foundation for the gravity equation," *The American Economic Review*, 69, 106–116.

Antràs, P. (2023): "Interest Rates and World Trade: An'Austrian'Perspective," Tech. rep., National Bureau of Economic Research.

Assenza, T., D. Delli Gatti, J. Grazzini, and G. Ricchiuti (2016): "Heterogeneous Firms and International Trade: The role of productivity and financial fragility," *Available at SSRN 2813984*.

Axtell, R. L. (2001): "Zipf distribution of US firm sizes," *Science*, 293, 1818–1820.

Baldwin, R. (2009): "The collapse of global trade, murky protectionism, and the crisis: Recommendations for the G20," *A VoxEU.org Publication*.

Balistreri, E. J., R. H. Hillberry, and T. F. Rutherford (2011): "Structural estimation and solution of international trade models with heterogeneous firms," *Journal of International Economics*, 83, 95–108.

Baqaee, D. and E. Farhi (2020): "Supply and demand in disaggregated Keynesian economies with an application to the Covid-19 crisis," Tech. rep., National Bureau of Economic Research.

Baqaee, D. and E. Rubbo (2022): "Micro Propagation and Macro Aggregation," .

Barrot, J.-N. and J. Sauvagnat (2016): "Input specificity and the propagation of idiosyncratic shocks in production networks," *The Quarterly Journal of Economics*, 131, 1543–1592.

Basco, S., G. Felice, B. Merlevede, and M. Mestieri (2024): "Financial crises and the global supply network: Evidence from multinational enterprises," *Journal of International Economics*, 152, 103983.

Becker, B., J. Chen, and D. Greenberg (2013): "Financial development, fixed costs, and international trade," *The Review of Corporate Finance Studies*, 2, 1–28.

Bergin, P. R., L. Feng, and C.-Y. Lin (2021): "Trade and firm financing," *Journal of International Economics*, 131, 103461.

Bernard, A. B., J. Eaton, J. B. Jensen, and S. Kortum (2003): "Plants and productivity in international trade," *American Economic Review*, 93, 1268–1290.

Bernard, A. B., J. B. Jensen, and R. Z. Lawrence (1995): "Exporters, jobs, and wages in US manufacturing: 1976-1987," *Brookings papers on economic activity. Microeconomics*, 1995, 67–119.

Bernard, A. B., J. B. Jensen, S. J. Redding, and P. K. Schott (2007): "Firms in international trade," *Journal of Economic Perspectives*, 21, 105–130.

Boehm-Bawerk, E. v. (1896): "The Positive Theory of Capital and Its Critics," *The Quarterly Journal of Economics*, 10, 121–155.

Bottazzi, G., A. Secchi, and F. Tamagni (2014): "Financial constraints and firm dynamics," *Small Business Economics*, 42, 99–116.

Caballero, R. J. (2010): "Sudden financial arrest," *IMF Economic Review*, 58, 6–36.

Caggese, A. and V. Cuñat (2013): "Financing constraints, firm dynamics, export decisions, and aggregate productivity," *Review of Economic Dynamics*, 16, 177–193.

Carvalho, V. M. (2014): "From micro to macro via production networks," *Journal of Economic Perspectives*, 28, 23–48.

Chaney, T. (2014): "The network structure of international trade," *American Economic Review*, 104, 3600–3634.

——— (2016): "Liquidity constrained exporters," *Journal of Economic Dynamics and Control*, 72, 141–154.

Chor, D. and K. Manova (2012): "Off the cliff and back? Credit conditions and international trade during the global financial crisis," *Journal of international economics*, 87, 117–133.

Crinò, R. and L. Ogliari (2017): "Financial imperfections, product quality, and international trade," *Journal of International Economics*, 104, 63–84.

De Benedictis, L. and L. Tajoli (2011): "The world trade network," *The World Economy*, 34, 1417–1454.

Demir, B., B. Javorcik, T. K. Michalski, and E. Ors (2020): "Financial constraints and propagation of shocks in production networks," *The Review of Economics and Statistics*, 1–46.

Devereux, M. B., K. Gente, and C. Yu (2020): "Production networks and international fiscal spillovers," Tech. rep., National Bureau of Economic Research.

di Giovanni, J. and J. H. Rogers (2022): "The Impact of US Monetary Policy on Foreign Firms," *FRB of New York Staff Report*.

Eaton, J., S. Kortum, and F. Kramarz (2004): "Dissecting trade: Firms, industries, and export destinations," *American Economic Review*, 94, 150–154.

Feenstra, R. C., Z. Li, and M. Yu (2014): "Exports and credit constraints under incomplete information: Theory and evidence from China," *Review of Economics and Statistics*, 96, 729–744.

Garlaschelli, D. and M. I. Loffredo (2004): "Patterns of link reciprocity in directed networks," *Physical review letters*, 93, 268701.

Gilchrist, S., B. Wei, V. Z. Yue, and E. Zakrajšek (2022): "Sovereign risk and financial risk," *Journal of International Economics*, 136, 103603.

Greenaway, D. and R. Kneller (2007): "Firm heterogeneity, exporting and foreign direct investment," *The Economic Journal*, 117, F134–F161.

Helpman, E., M. Melitz, and Y. Rubinstein (2008): "Estimating trade flows: Trading partners and trading volumes," *The quarterly journal of economics*, 123, 441–487.

Kali, R. and J. Reyes (2007): "The architecture of globalization: a network approach to international economic integration," *Journal of International Business Studies*, 38, 595–620.

Kletzer, K. and P. Bardhan (1987): "Credit markets and patterns of international trade," *Journal of Development Economics*, 27, 57–70.

Kohn, D., F. Leibovici, and M. Szkup (2016): "Financial frictions and new exporter dynamics," *International Economic Review*, 57, 453–486.

——— (2020): "Financial frictions and export dynamics in large devaluations," *Journal of International Economics*, 122, 103257.

——— (2022): "Financial Frictions and International Trade: A Review," *Oxford Research Encyclopedia of Economics and Finance*.

Krackhardt, D. (1990): "Assessing the political landscape: Structure, cognition, and power in organizations," *Administrative science quarterly*, 342–369.

La'O, J. and A. Tahbaz-Salehi (2022): "Optimal Monetary Policy in Production Networks," *Econometrica*, 90, 1295–1336.

Manova, K. (2008): "Credit constraints, equity market liberalizations and international trade," *Journal of International Economics*, 76, 33–47.

——— (2013): "Credit constraints, heterogeneous firms, and international trade," *Review of Economic Studies*, 80, 711–744.

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

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

Melitz, M. J. and G. I. Ottaviano (2008): "Market size, trade, and productivity," *The Review of Economic Studies*, 75, 295–316.

Melitz, M. J. and S. J. Redding (2014): "Heterogeneous firms and trade," *Handbook of International Economics*, 4, 1–54.

Melitz, M. J. and D. Trefler (2012): "Gains from trade when firms matter," *Journal of Economic Perspectives*, 26, 91–118.

Minetti, R. and S. C. Zhu (2011): "Credit constraints and firm export: Microeconomic evidence from Italy," *Journal of International Economics*, 83, 109–125.

Muûls, M. (2015): "Exporters, importers and credit constraints," *Journal of International Economics*, 95, 333–343.

Myers, S. C. and N. S. Majluf (1984): "Corporate financing and investment decisions when firms have information that investors do not have," *Journal of Financial Economics*, 13, 187–221.

Paravisini, D., V. Rappoport, P. Schnabl, and D. Wolfenzon (2015): "Dissecting the effect of credit supply on trade: Evidence from matched credit-export data," *The Review of Economic Studies*, 82, 333–359.

Redding, S. J. (2022): "Trade and geography," *Handbook of International Economics*, 5, 147–217.

Schweitzer, F., G. Fagiolo, D. Sornette, F. Vega-Redondo, A. Vespignani, and D. R. White (2009): "Economic networks: The new challenges," *Science*, 325, 422–425.

Serrano, M. A. and M. Boguná (2003): "Topology of the world trade web," *Physical Review E*, 68, 015101.

Taschereau-Dumouchel, M. (2020): "Cascades and fluctuations in an economy with an endogenous production network," *Available at SSRN 3115854*.

Yeaple, S. R. (2009): "Firm heterogeneity and the structure of US multinational activity," *Journal of International Economics*, 78, 206–215.

A Appendix

Experiments have been performed considering alternative specifications of network centrality. Namely, we identified the most (and least) central countries in terms of *betweenness centrality*[16], *eigenvector centrality*[17], *PageRank*[18], *In and Out Degree*. Under all these alternative definitions of centrality, the same country has been identified as being the most (least) central in the network, except when considering betweenness centrality. Aggregate outcomes of the experiments are summarized in Table 5 for the most central and Table 6 for the least one.

	Betweenness		Eigenvector		Pagerank		In-degree	
	Total	Without shocked	Total	Without shocked	Total	Without shocked	Total	Without shocked
Δ GDP	-2,23%	0,18%	-4,64%	1,036%	-4,64%	1,036%	-4,64%	1,036%
Δ P	-0,35%	0,04%	-0,105%	0,76%	-0,105%	0,76%	-0,10%	0,76%
Δ FoT	-1,03%	-0,24%	-12,92%	-4,93%	-12,92%	-4,93%	-12,91%	-4,93%
Δ Domestics	-0,23%	0,11%	-1,76%	1,73%	-1,76%	1,73%	-1,76%	1,73%
Δ Exporters	-0,41%	0,41%	-9,62%	-3,01%	-9,62%	-3,01%	-9,62%	-3,01%
Δ Density	-0,17%	-0,17%	1,57%	1,57%	1,57%	1,57%	1,57%	1,57%

Table 5: Aggregate effects of a shock in the most central country

	Betweenness		Eigenvector		Pagerank		In-degree	
	Total	Without Shocked	Total	Without Shocked	Total	Without Shocked	Total	Without Shocked
Δ GDP	-3,63 %	0,58 %	-0,89%	0,008%	-0,89%	0,008%	-1,06%	-0,05%
Δ P	-0,33 %	0,42 %	-0,03%	-0,02%	-0,03%	-0,02%	0,01%	0,02%
Δ FoT	-6,63 %	-2,19 %	-0,29%	-0,08%	-0,29%	-0,08%	-0,19%	-0,03%
Δ Locals	-0,03 %	0,01 %	-1,35%	0,004%	-1,35%	0,004%	-1,35%	0,004%
Δ Exporters	-10,11 %	-3,88 %	0,01%	0,08%	0,01%	0,08%	0,01%	0,08%
Δ Density	0,35 %	0,35 %	0,52 %	0,52 %	0,52 %	0,52 %	0,52 %	0,52 %

Table 6: Aggregate effects of a shock in the least central country

[16]The betweenness centrality of a vertex i is the number of geodesic (shortest) paths between other vertices that run through i. Betweenness centrality captures the importance of a country in terms of connecting others, i.e. being a bridge between other nodes. The country with highest betweenness centrality is crucial intermediary in the network but this information seems to be not much relevant in our framework, since we are considering just flows of trade in final goods; it would become relevant if we study supply chains. This is pointed out also by Tajoli 2011.

[17]Eigenvector centrality is a global centrality measure stressing the importance of partners in order to determine the centrality of a node. Then, the eigenvector centrality of country i is computed as the sum of the eigenvector centralities of its neighbors. In general, countries with a high value of eigenvector centrality are the ones which are connected to many other well-connected countries.

[18]PageRank is a score assigned to each node aimed at capturing its importance, defined in terms of how many in-links from important partners the node has. For this reason, considering PageRank and Eigenvector Centrality brings the same results

B Robustness checks

We run the simulations considering 30 countries. In the empirical network of 2019, taken as a reference, the biggest 30 countries were responsible for 80% of trade flows. Furthermore, we run the simulations with various number of countries and, as depicted in Figure 6, increasing the number of countries would have not affected the structure of the network.

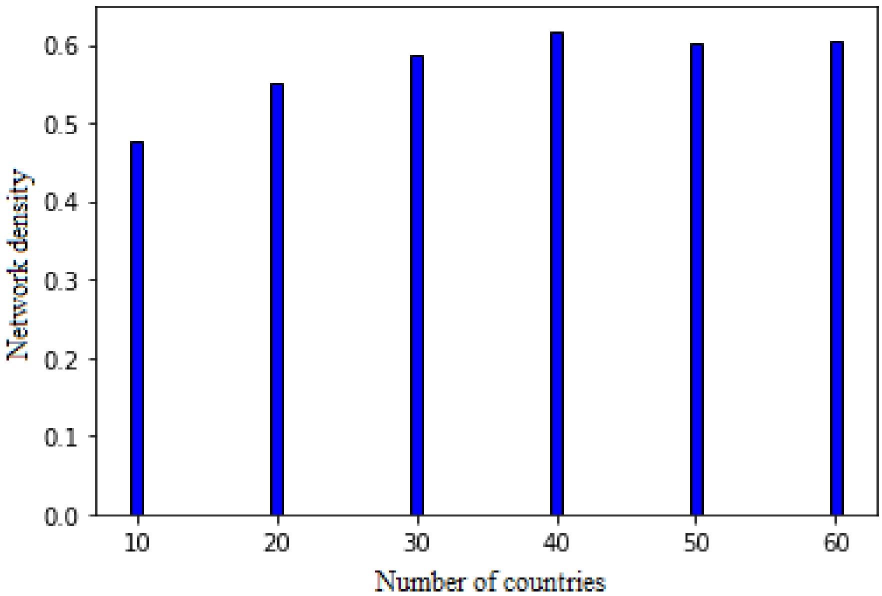


Figure 6: Network density with increasing number of countries.