Demand Shocks, Sector-level Externalities, and the Evolution of Comparative Advantage

D. Verdini

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Demand Shocks, Sector-level Externalities, and the Evolution of Comparative Advantage*

Daniele Verdini †

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Abstract

Does production size play any role in industrial productivity? And how important is its contribution to the evolution of comparative advantage over time? In this paper, I develop a multi-country multi-sector general equilibrium model of trade characterized by the presence of inter-temporal sector-level externalities. The model makes explicit the mechanism linking size and productivity and delivers at the equilibrium a dynamic gravity model of trade that can be empirically tested. I structurally estimate the dynamic scale parameter by exploiting exogenous demand shocks uncorrelated to any supply-side component of production. Results show that industrial production scale can be a potential source of comparative advantage, with an estimated average dynamic scale parameter of 0.18. However, potential gains are heterogeneous, with values ranging between 0.12 and 0.20 across different industries.

Keywords: International Trade, Dynamic Comparative Advantage, Sector-level Externality, Demand Shocks

JEL Classification: D62, F11

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†Contact: IRES, Université catholique de Louvain. *Email*: daniele.verdini@uclouvain.be

1 Introduction

A key insight in the theory of international trade is that countries tend to specialize relatively more in the production and export of those goods in which they are relatively more productive. The law of comparative advantage, as first formulated by Ricardo (1817), is a powerful predictive tool that received empirical validation in recent years (Bernhofen and Brown, 2004; Costinot and Donaldson, 2012). Nonetheless, it is silent on the underlying reasons explaining the disparities in the observable productivities. A running theme in this respect is that specialization might be favored by scaling up the level of production at the industry level, because of the presence of external economies of scale (Grossman and Rossi-Hansberg, 2010; Kucheryavyy, Lyn, and Rodríguez-Clare, 2016). However, the quantification and the distribution across sectors of such a scale effect is still at the centre of the enquiry.

To shed light on this matter, I develop a Ricardian general equilibrium model of trade characterized by endogenous productivity and dynamic sector-level technological spillovers. The aim is to link current production levels with future industrial productivity. The model allows to empirically disentangle the pure productivity effect from the dynamic scale effect. With respect to the previous literature, in which productivity is assumed to be constant (Krugman, 1980; Melitz, 2003) or parametric (Eaton and Kortum, 2002; Chaney, 2008), in this framework sector-level productivity results from the interaction between past sector-level production and the magnitude of the scale parameter. By breaking the simultaneity of the adjustment, the model allows to directly test the mechanism at play. Although being static in all the other aspects, I rely upon this inter-temporal feature of the model to directly inquire about the dynamic consequences of a change in the sector-level trade pattern on its productivity evolution. In order to do so, I structurally estimate the dynamic scale parameter using the dynamic gravity model resulting from the equilibrium conditions.

The identification strategy builds on the insights from the empirical literature of economic geography. Davis and Weinstein (2002) disentangle the role of *natural* comparative advantage, unrelated to the scale of production, and the scale effect on the evolution of localization of activities. To identify the contribution of each source, they exploit the large war damages that Japanese cities withstood during the second world war and the response to these shocks. The intuition is that shocks are followed by a reversion to the mean if economies of scale are unimportant, while changes are permanent otherwise. I apply the same logic to an international trade context. To clarify the point, take as an example a period of strong currency valuation, or an economic crisis in the main export destination of a particular country. These events tend to have a direct impact on the demand addressed by the exporting sectors and are exogenous to the sector-level productivity. When a negative shock reduces the level of production, the consequence in the presence of economies of scales is the increase of the average cost of production, with a potential consequent hindering of the productivity rate. These insights are also related to a recent literature on the transmission of international shocks to domestic sales (Vannoorenberghe, 2012; Berman, Berthou, and Hericourt, 2015). Nevertheless, my paper focuses on industrial productivity and go beyond the short-run adjustment to study, instead, the medium-run dynamics.

This paper contributes to two different strands of the international trade literature. A long lasting tradition has inquired the determinants of relative productivity disparities, and whether they were related to purely technological differences (Eaton and Kortum, 2002; Costinot, Donaldson, and Kromunjer, 2012), differences in factor endowments (Romalis, 2004), differences in the quality of the institutions (Nunn, 2007; Manova, 2013), or rather the presence of external increasing returns to scale (Grossman and Rossi-Hansberg, 2010; Kucheryavyy, Lyn, and Rodríguez-Clare, 2016). Demand specific channels has also been explored, for example in Fieler (2011), where non-homothetic preferences are introduced in a Ricardian model à la Eaton and Kortum. The first contribution of the paper is to quantify the role played by one specific mechanism, namely the presence of external economies of scale at the industry level.

On the contrary, few attempts have been made to understand what determines overtime changes in the patterns of specialization. Among the many reasons to study the productivity distribution dynamics is the fact that a country's comparative advantage is far from being persistent and stable over time. Levchenko and Zhang (2016) find evidence of a systematic productivity catch-up within countries and over time of those sectors that are initially less productive, suggesting that either domestic or international technological spillovers might play a non-trivial role in enhancing productivity. Hanson, Lind, and Muendler (2016) document a continuous turnover in top exporting industries across countries. They find evidence that churning in export advantage is relatively fast, with more than half of top 5% exporting industries losing their position from the top of the ranking within a period of maximum two decades. Nonetheless, they also find evidence that the distribution of the relative productivity is preserved over time, suggesting that along a dissipation process, wearing away a country's established export capability, lays an endogenous innovation process offsetting the impact of the former. These studies propose a new set of stylized facts that is worth exploring, but remain agnostic about the economic mechanisms at play. Hence, the second contribution of the paper is to inquire the dynamic effect of scaling up industrial production on the evolution of the comparative advantage overtime.

Indeed, the trade literature has identified other channels that can account for such shifts. Costinot, Donaldson and Smith (2016) find evidence that changes in the natural environment are a source of productivity growth/decline. In their study, climate change, by modifying world crops yielding, reshapes countries relative productivities over time, hence the patterns of trade. Sampson (2018) focuses on the role of innovation, in particular by highlighting how R&D activities and knowledge spillovers contribute to shape the comparative advantage distribution. Another key mechanism trough which a country can gain a comparative advantage is learning-by-doing. The point was first made by Krugman (1987): allowing productivity to depend on an index of cumulative experience in production is equivalent to introduce dynamic increasing returns to scale, without altering the perfect competition market structure. Knowledge accumulation, hence, becomes the determinant of the long-run pattern of specialization. Redding (1999) extends Krugman's analysis to account for dynamic welfare evaluation, and identifies the necessary conditions allowing welfare-improving industrial policy to exist. In the same spirit, Young (1991) develops a general equilibrium growth model featuring bounded learning-by-doing along with national spillovers effects and analyzes the impact of free trade on developed and less developed countries' growth rates and welfare. The paper concludes that opening to international trade has positive effects on productivity and welfare in developed economies, while ambiguous effects on less developed countries' welfare. This results is driven by the shift of production to high-productive countries that follows from a trade liberalization, with the effect to dump developing countries' productivity growth, hence, raising a potential argument in favor of inward-oriented policies[1].

I find the dynamic scale parameter to range between 0.12 and 0.20, with an average magnitude of 0.18. The effect is characterized by persistence over time, meaning that potential current shocks can have an impact to the future levels of industrial productivity and output. This result is robust to different types of specifications, different definition of explanatory variables, the use of an instrumental variable strategy, and

[1]The case for (infant-)industry protection was first motivated by Graham (1923), and then developed by Ethier (1982). The idea is that the presence of an *ex ante* comparative advantage in an industry featuring diseconomies of scale might generate *ex post* welfare losses, hence protection of the comparative disadvantage sector would result in a higher level of welfare at the equilibrium. Melitz (2005) formulates a two-country model featuring bounded learning-by-doing and product differentiation to evaluate the effect of different trade policy on total welfare. From an empirical perspective, Juhász (2015) exploits the heterogeneity of a trade barrier shock, that hit the French regional cotton industry at the beginning of the nineteenth century as a consequence of the Napoleonic Blockade, to explain the subsequent cotton industry take-off in the most exposed regions. She examines as well the long-run effects of the temporary trade protection, finding evidence for a persistent pattern of specialization in the cotton industry even after the end of the blockade. These findings are in line with the idea that industry protection might be able to drive the patterns of specialization.

to the use of different data sources. Contemporaneous research by Bartelme, Costinot, Donaldson and Rodríguez-Clare (2018) builds a non-parametric model to disentangle trade and scale elasticity. Using parametric restrictions, they estimate the sector-level scale elasticity to range between 0.07 and 0.25, with an average of 0.13, in line with my findings. They also perform a quantitative analysis to assess optimal industrial policy. Despite being methodologically very close to theirs, my paper adds a dynamic characterization of the impact of scaling up industrial production. This aspect becomes crucial for estimating the potential gains from optimal industrial policy.

The rest of the paper is organized as follows. Section 2 develops the theoretical model and highlights its predictions in linking productivity growth and demand shocks. Section 3 describes the empirical methodology and the data. Section 4 presents the results, and section 5 concludes.

2 A Trade Model with Endogenous Productivity

I consider a world economy, at any point in time t, with N countries indexed by s and d, referring respectively to sources and destinations, and I sectors indexed by i. Each country is endowed with a fixed amount of L_{dt} units of labor, which is assumed to be inelastically supplied and immobile across countries, but perfectly mobile between sectors, therefore factor price equalization holds across sectors and the wage rate can be expressed as w_{dt}. Since labor is the only factor of production, total income in country d is simply given by: $Y_{dt} = w_{dt}L_{dt}$. Trade is assumed to be balanced.

2.1 Demand Side

Preferences are symmetric across countries and represented by a two tier utility function for each representative consumer in destination d at any time t. The first tier is a Cobb-Douglas aggregator over the i sectors, while the second tier a CES aggregator across all the Armington varieties s.

To give an intuition about the demand structure, let us consider a simple two-sector (*textile* and *footwear*), two-country model (*Belgium* and *France*). The representative consumers in Belgium and France will allocate a Cobb-Douglas share of their income to the purchase of both textile and footwear, then they will split their income shares in order to buy a positive quantity of Belgian and French varieties of both textile and footwear, due to the fact that French and Belgian products are perceived as differentiated. Mathematically, this preference structure takes the following form:

$$U_{dt} = \prod_{i=1}^{I} \left[\sum_{s=1}^{N} \beta_{isdt}^{\frac{1}{\sigma_i}} c_{isdt}^{\frac{\sigma_i - 1}{\sigma_i}} \right]^{\mu_{idt} \frac{\sigma_i}{\sigma_i - 1}} \qquad \sum_{i=1}^{I} \mu_{idt} = 1, \quad \sum_{s=1}^{N} \beta_{isdt} = 1, \tag{1}$$

where c_{isdt} represents the consumption of variety s in sector i in country d at time t, β_{isdt} is an idiosyncratic demand shifter incorporating both quality and consumer tastes, μ_{idt} is the Cobb-Douglas expenditure share, and $\sigma_i > 1$ is the sector-level elasticity of substitution between varieties. Such a specification ensures that a share of the bundle consumed is produced domestically, while the rest is imported[2]. The budget constraint faced by the consumer is:

$$Y_{dt} \equiv w_{dt} L_{dt} = \sum_{i=1}^{I} \sum_{s=1}^{N} p_{isdt} c_{isdt}. \tag{2}$$

The utility function, U_{dt}, is weakly separable, hence it is possible to find the optimal demand by applying a two stage budgeting procedure. Given the Cobb-Douglas structure, the representative consumer devotes a share μ_{idt} of real income to each sector:

$$M_{idt} = \frac{\mu_{idt} Y_{dt}}{P_{idt}}, \ \forall i \in I, \tag{3}$$

where the price index associated to the bundle of consumption in sector i, for destination country d, at time t is given by $P_{idt} = \left(\sum_{s=1}^{N} \beta_{isdt} p_{isdt}^{1-\sigma_i} \right)^{\frac{1}{1-\sigma_i}}$.

The lower-tier maximization regards the choice of the sector-level consumption bundle and it takes into account the income partition derived from first-stage. The problem can be expressed as follows:

$$\max_{c_{isdt}} \left[\sum_{s=1}^{N} \beta_{isdt}^{\frac{1}{\sigma_i}} c_{isdt}^{\frac{\sigma_i - 1}{\sigma_i}} \right]^{\frac{\sigma_i}{\sigma_i - 1}} \quad s.t. \quad \mu_{idt} Y_{dt} - \sum_{s=1}^{N} p_{isdt} c_{isdt} = 0. \tag{4}$$

[2] I assume that σ_i is the only elasticity at play, hence, conversely from Feenstra, Luck, Obstfeld, and Russ (2014), consumers do not perceived domestic varieties as better substitutes with respect to foreign ones. Nevertheless, the demand function, U_{dt}, allows to consider any foreign product s less attractive as long as the parametrization implies $\beta_{isdt} < \beta_{iddt}$

and it is solved by:

$$c_{isdt} = \beta_{isdt}\mu_{idt}Y_{dt}\frac{p_{isdt}^{-\sigma_i}}{P_{idt}^{1-\sigma_i}}. \tag{5}$$

2.2 Production Side

We assume each country s and sector i to be populated by many firms perfectly competing to target both the domestic and the foreign markets. Firms incur a shipping cost reflected in the iceberg trade cost $\tau_{sdt} > 1$, interpreted as the quantity of good i necessary to be produced in s that allows one unit of product to arrive to the destination market d, at time t. We also assume that the arbitrage-free condition $\tau_{sdt} \leq \tau_{sjt}\tau_{jdt}$ holds, ensuring that shipping from country s to country d cannot be cheaper by funneling the good through any third country j.

In any country, the sector-level production function features a Ricardian component, A_{ist}, characterizing the exogenous differences at the level of technology across industries and countries, and an intertemporal scale component characterizing the relationship between the current level of productivity and the past levels of production in the same sector. I define these *dynamic external economies of scale* as $\varphi(Q_{ist-1})$, being twicely differentiable and concave, so that $\varphi'(\cdot) > 0$ and $\varphi''(\cdot) < 0$. Total production of sector i in country s at time t is given by:

$$Q_{ist} = A_{ist}\,\varphi(Q_{ist-1})L_{ist}, \tag{6}$$

where $L_{ist} = \sum_{d=1}^{N} L_{isdt}$ identifies the amount of labor employed in sector i, in country s, at time t. Indeed, productivity gains are not destination specific, as any production gain (loss) due to an increase (decrease) of export to any destination country d indirectly improves (hinders) the capability of the sector to compete in all the other $N-1$ destinations.

There justification for the existence of dynamic external economies of scale is twofold: the first one is in continuity with the long-lasting tradition considering localized spillovers as a source of productivity advantage. The so-called Marshallian externalities can be very different in nature, the literature identifies three categories: input market externalities, labor market externalities, and knowledge externalities. With respect to the classic configuration, in this setting the twist is to include an adjustment friction delaying the realization of the gains to the subsequent period. The second way is to draw a parallel between dynamic external economies of scale and learning-by-doing, acknowledging the fact that the former is isomorphic to the latter in any classic growth model with sector-level learning. I will leave the interpretation of this assumption open hereafter, however, I will assume that this type of dynamic spillover is sector and source country specific (*i.e.* international spillovers are not taken into account) and take one period to realise. This latter assumption will be sufficient to create a testable dynamic structure.

To bring the model to the data, it is necessary to parametrize the dynamic externality function $\varphi(Q_{ist-1})$. Due to the lack of empirical investigations about the possible shapes of the sector-level externalities, I will follow the literature[3] in assuming the exponential form, with ψ_i being the driving elasticity:

$$\varphi(Q_{ist-1}) = Q_{ist-1}^{\psi_i}, \tag{7}$$

where the dynamic scale elasticity, $0 \leq \psi_i \leq 1$, is sector specific.

At time t a firm in sector i located in country s faces both domestic and foreign demand, hence, profit maximization reads:

$$\max_{q_{isdt}} \quad \Pi_{ist} = \sum_{d=1}^{N} \left[p_{isdt} q_{isdt} - \frac{\tau_{sdt} w_{st}}{A_{ist} Q_{ist-1}^{\psi_i}} q_{isdt} \right]. \tag{8}$$

Assuming that each firm breaks even in any destination market d[4], the FOC of the profit maximization reads:

$$p_{isdt} = \frac{w_{st} \tau_{sdt}}{A_{ist} Q_{ist-1}^{\psi_i}}. \tag{9}$$

The optimal price charged by firms, p_{isdt}, must equal the marginal cost of production and delivering, which is made of two distinct components: the former one is the standard component given by the interaction of trade costs and the country specific cost of production, $w_{st}\tau_{sdt}/A_{ist}$; the second characterizes the efficiency gains realised by the sector-level scale of production, $1/Q_{ist-1}^{\psi_i}$.

2.3 Competitive Equilibrium

The amount of output sold by firms in sector i and country s to destination d at time t at equilibrium is retrieved by substituting the optimal price, Eq. (9), and the

[3] see Kucheryavyy, Lyn, and Rodríguez-Clare (2016) and Bartelme, Costinot, Donaldson, and Rodríguez-Clare (2018)

[4] This assumption rules out the possibility for an industry to compensate losses in some of the destination markets by making large profit margins in others.

price index into the representative consumer demand, Eq. (5). For the good market equilibrium condition to hold, it must be that:

$$q_{isdt} = \frac{\beta_{isdt}\tau_{sdt}^{-\sigma_i}\Phi_{ist}^{-\sigma_i}}{\sum_{\zeta=1}^{N}\beta_{i\zeta dt}\tau_{i\zeta dt}^{1-\sigma_i}\Phi_{i\zeta t}^{1-\sigma_i}}\mu_{idt}Y_{dt}, \tag{10}$$

where:

$$\Phi_{ist} = \frac{w_{st}}{A_{ist}Q_{ist-1}^{\psi_i}}. \tag{11}$$

The price parameter, Φ_{ist}, measures the competitiveness of firms competing in sector i and country s at time t, and it summarizes, for each period, three productivity determinants (i) the level of technology in sector i and country s, (ii) the level of production costs in country s, and (iii) the gains from the scale of production achieved in sector i and country s the previous period.

To relate the model to the standard quantitative literature, I define the expenditure function of destination country d at time t towards variety s in sector i, which is obtained by multiplying both sides of the Marshallian demand, in Eq. (5), evaluated at the optimal level of c_{isdt} and p_{isdt}:

$$X_{isdt} = \frac{\beta_{isdt}\tau_{sdt}^{1-\sigma_i}\Phi_{ist}^{1-\sigma_i}}{\sum_{\zeta=1}^{N}\beta_{i\zeta dt}\tau_{i\zeta dt}^{1-\sigma_i}\Phi_{i\zeta t}^{1-\sigma_i}}\mu_{idt}Y_{dt}. \tag{12}$$

The price index at the equilibrium price takes the following form:

$$P_{idt} = \left\{\sum_{s=1}^{N}\beta_{isdt}\left[\frac{w_{st}\tau_{sdt}}{A_{ist}Q_{ist-1}^{\psi_i}}\right]^{1-\sigma_i}\right\}^{\frac{1}{1-\sigma_i}}. \tag{13}$$

Eq. (12) has the standard gravity-type form recurring in the international trade literature, and can be interpreted as follows: destination country d's expenditure for variety s in sector i at time t is directly proportional to the share of total income spent by d in sector i, $\mu_{idt}Y_{dt}$, the idiosyncratic variety shifter, β_{isdt}, and it is inversely proportional to the price parameter, Φ_{ist}, the trade cost, τ_{sdt}, and the multilateral resistance term. These relationships follow from the fact that both the price parameter and the iceberg trade cost enter with an elasticity of $1-\sigma_i$, which must be negative by assumption ($\sigma_i > 1$). The novelty stemming from Eq. (12) with respect to its counterparts in existing literature is its implicit dynamic structure, due to the functional form of the price parameter Φ_{ist}. To make it explicit, I will first manipulate Eq. (10) and then plug it back to Eq. (12). Exporter's total output in sector i is retrieved by multiply both sides of Eq. (10) by τ_{sdt} and then sum across all destination markets:

$$Q_{ist} \equiv \sum_{d=1}^{N} \tau_{sdt} q_{isdt} = \sum_{d=1}^{N} \frac{\beta_{isdt} \tau_{sdt}^{1-\sigma_i} \Phi_{ist}^{-\sigma_i}}{\sum_{\zeta=1}^{N} \beta_{i\zeta dt} \tau_{i\zeta dt}^{1-\sigma_i} \Phi_{i\zeta t}^{1-\sigma_i}} \mu_{idt} Y_{dt}$$
$$= \Phi_{ist}^{-1} X_{ist}. \tag{14}$$

At the equilibrium, the total production in sector i in country s, at time t, depends on the world demand destined to that market and the competitiveness of the source country in that sector. It is possible to solve Eq. (14) recursively by substituting Eq. (11) in it, so that the total output produced becomes a function of all its past realizations:

$$Q_{ist} = \frac{A_{ist}}{w_{st}} X_{ist} \; \Pi_{n=1}^{t} \left[\frac{A_{ist-n}}{w_{st-n}} X_{ist-n} \right]^{\psi_i^n} \underbrace{Q_{is0}^{-\psi_i^t}}_{\lim_{t\to\infty}=1}$$
$$= \frac{A_{ist}}{w_{st}} X_{ist} \; \Pi_{n=1}^{t} \left[\frac{A_{ist-n}}{w_{st-n}} X_{ist-n} \right]^{\psi_i^n}. \tag{15}$$

Eq. (15) is key to describe the dynamic effects of spillovers, it relates, in fact, the current level of total output to its previous one. With Eq. (11) and (15) at hand, it is possible to retrieve a dynamic specification for the gravity model. Let's substitute the two in Eq. (12) to get:

$$X_{isdt} = \frac{\beta_{isdt} \tau_{sdt}^{1-\sigma_i} \left(\frac{A_{ist}}{w_{st}}\right)^{\sigma_i - 1}}{\sum_{\zeta=1}^{N} \beta_{i\zeta dt} \tau_{i\zeta dt}^{1-\sigma_i} \Phi_{i\zeta t}^{1-\sigma_i}} \mu_{idt} Y_{dt} \; \Pi_{n=1}^{t} \left[\frac{A_{ist-n}}{w_{st-n}} X_{ist-n} \right]^{\psi_i^n (\sigma_i - 1)}. \tag{16}$$

Eq. (16) is the full-fledged dynamic (or path dependent) gravity model that will be later used to estimate the elasticity parameter, ψ_i. In such a specification, the dynamic scale elasticity, ψ_i, fades away the further in the past the level of production is considered[5]. This feature breaks the equilibrium indeterminacy curse driven by the interplay between the scale elasticity, ψ_i, and the elasticity of substitution, σ_i. In Grossman and Rossi-Hansberg (2010), for example, $\psi_i \sigma_i < 1$ must be assumed to hold in every sector i to ensure the existence of an unique equilibrium. Eq. (16) rules

[5]Due the fact that $0 \leq \psi_i \leq 1$, the impact of a four-period lagged level of production has a marginal contribution equal to its value to the power $\psi_i^4 \approx 0$. This example clarify that such structure mechanically downplay more periods that are more far in time.

out the need to introduce such an assumption.

It is now possible to compute the source country's total export flow at time t by summing up trade flows across all the destination countries d:

$$X_{ist} \equiv \sum_{d=1}^{N} X_{isdt} = \left(\frac{A_{ist}}{w_{st}}\right)^{\sigma_i - 1} \Lambda_{ist}\ \Pi_{n=1}^{t}\left[\frac{A_{ist-n}}{w_{st-n}} \sum_{d=1}^{N} X_{isdt-n}\right]^{\psi_i^n(\sigma_i-1)}, \tag{17}$$

where:

$$\Lambda_{ist} = \sum_{d=1}^{N} \frac{\beta_{isdt}\tau_{sdt}^{1-\sigma_i}\mu_{idt}Y_{dt}}{\sum_{\zeta=1}^{N}\beta_{i\zeta dt}\tau_{i\zeta dt}^{1-\sigma_i}\Phi_{i\zeta t}^{1-\sigma_i}}. \tag{18}$$

Eq. (18) is a measure of the real world demand directed to sector i in country s. Up to this point the analysis had considered wages, w_{st}, as given, however, to close the model, trade must be balanced ensuring that the equilibrium wage is correctly pinned down. It must hold that total labor income in country s equalizes world expenditure towards s at time t, hence by substituting Eq. (17) in the balance trade condition, after some manipulation one obtains:

$$w_{st} = L_{st}^{-\frac{1}{\sigma_i}}\left[\sum_{i=1}^{I} A_{ist}^{\sigma_i-1} Q_{ist-1}^{\psi_i}\Lambda_{ist}\right]^{\frac{1}{\sigma_i}}. \tag{19}$$

By dividing the equilibrium nominal wage by its relative price index, $P_{st} \equiv \sum_{i=1}^{I} P_{ist}$, we get the real wage in country s at time t, which will be used as a measure of total welfare:

$$W_{st} = \frac{L_{st}^{-\frac{1}{\sigma_i}}}{P_{st}}\left[\sum_{i=1}^{I} A_{ist}^{\sigma_i-1} Q_{ist-1}^{\psi_i}\Lambda_{ist}\right]^{\frac{1}{\sigma_i}}. \tag{20}$$

2.4 The Gravity Model of Trade

Eq. (16) takes the form of a gravity model of bilateral trade. Conversely to the standard specifications, it features a component of contemporaneous relationships and one linking past and current export, hence characterizing a dynamic structure of trade[6].

[6]The gravity model is by now considered the workhorse model in the literature of empirical international trade (Head and Mayer, 2013). However, dynamic considerations have been for the moment kept at the margin of the debate, although these were proven to be pivotal for the understanding of the determinants of trade flows, for example by Bun and Klaassen (2002) and Olivero and Yotov (2012)

Following Hanson, Lind, and Muendler (2016), it is possible to break down Eq. (16) in different components by log-linearizing it:

$$ln(X_{isdt}) = k_{ist} + m_{idt} + \sum_{n=1}^{t} \psi_i^n z_{ist-n} + (1-\sigma_i)\, ln(\tau_{sdt}) + ln(\beta_{isdt}). \qquad (21)$$

Eq. (21) takes into account all the determinants of bilateral trade derived from the model previously discussed.

The first term of the decomposition, $k_{ist} = (\sigma_i - 1)\, ln(A_{ist}/w_{st})$, is the *export capability* of country s in sector i at time t, and it summarizes all the sector-country-specific characteristics favoring its propensity to export. The second term is the *potential demand* from country d to sector i at time t:

$$m_{idt} = ln\left[\frac{\mu_{idt} Y_{dt}}{\sum_{\zeta=1}^{N} \beta_{i\zeta dt} \tau_{i\zeta dt}^{1-\sigma_i} \Phi_{i\zeta t}^{1-\sigma_i}}\right].$$

This term summarizes the role played by destination country d for bilateral trade, taking into account all the other competitors for that market (*i.e.* the multilateral resistance term). The third component is the one introducing an element of innovation with respect to the existing literature, since it summarizes the effect of past production in country s and sector i on the current level of trade:

$$z_{ist-n} = (\sigma_i - 1)\, ln\left[\frac{A_{ist-n}}{w_{st-n}} X_{ist-n}\right],$$

likewise, this term can be rewritten as follows:

$$z_{ist-n} = (\sigma_i - 1)\, ln\left[\frac{Q_{ist-n}}{Q_{ist-n-1}^{\psi_i^n}}\right].$$

The ratio between brackets can be interpreted as the additional fraction of production in the previous period concurring to the determination of present productivity. Eventually, the last terms of the equation, $ln(\tau_{sdt})$ and $ln(\beta_{isdt})$, are simply the linearized demand shifter and trade costs, with $1 - \sigma_i$ being the trade elasticity.

It must be noted that the spillover parameter, ψ_i, enters in Eq. (21) exponentiated to the power n. This means that the way the spillover parameter is assumed to behave in the intertemporal externality function matters for the empirical specification derived from the equilibrium condition. Assuming ψ_i to take the exponential form in Eq. (7) leads to a time structure of the parameter that is expected to decay exponentially over time. There is no need to impose such condition when bringing the empirical model to the data. Nonetheless, the finding of an exponential decay of ψ_i would result in a validation of the assumed structure.

3 Estimating the Gravity Model

Eq. (21) can be estimated in a stochastic setting, by allowing for an additive error term, ϵ_{isdt}, capturing any type of measurement error and unaccounted determinants. The log-transformation allows to consider the model linear in its parameters:

$$ln(X_{isdt}) = \delta_{ist} + \delta_{idt} + \sum_{n=1}^{t} \alpha_n z_{ist-n} + ln(\tau_{sdt}) + \epsilon_{isdt}, \tag{22}$$

where δ_{ist} and δ_{idt} are directional fixed effects, α_n is the sector-level dynamic scale coefficient, and $\tau_{sdt} = \exp[\mathbb{X}'_{sdt}\, \eta_m]$ sum up the vector of m covariates, $\mathbb{X}_{sdt}$, related to bilateral trade costs[7]. The error term ϵ_{isdt} is structurally interpreted as the idiosyncratic demand shock β_{isdt}, nonetheless, as already mentioned, such a residual might contain some noise due to any possible misspecification of the model. To identify the parameter of interest, ψ_i, I introduce additional assumptions that I will discuss in details below.

Bilateral trade costs, summarized in τ_{sdt}, and past trade flows are directly observed. The elasticity of substitution, σ_i, is taken from Broda and Weinstein (2006). The demand shifter, β_{isdt}, cannot be observed, furthermore it enters Eq. (21) both linearly in the fourth term and non-linearly in the potential demand. This is less of a problem if the number of source countries is big enough, in such case the marginal effect of β_{isdt} would be sufficiently small to not pose a threat for the identification strategy.

The problem with the identification lies in the non-observability of the Ricardian component A_{ist}. Moreover, existing sector-level productivity estimates cannot be used, due the fact that these are simultaneously determined by a technology-specific component and the overall scale of production at the sector level. Therefore, to disentangle the pure Ricardian component from the scale effect, I propose an IV strategy. Along with the IV approach, Appendix A discusses a reduced form estimation as a

[7]CEPII provides a set of time-invariant bilateral trade costs: bilateral distance ($dist$), the sharing of a geographical border ($border$), of the same language ($lang$), of a minority language ($lang\,9perc$), of colonial linkages in the past ($colony$, $after45\,colonial$) or in the present ($curr\,colonial$), of a common colonizer ($comm\,colonizer$), being the same country ($same\,country$), being in a regional trade agreement (RTA). I also rely on time-varying fixed effects to control for bilateral costs

robustness check.

3.1 Structural Estimation of the Gravity Model

By manipulating Eq. (17), it is possible to show:

$$X_{ist} = (A_{ist}/w_{st})^{\sigma_i - 1} Q_{ist-1}^{\psi_i(\sigma_i - 1)} \Lambda_{ist}. \tag{23}$$

Total production is made of a supply-specific and a demand-specific component:

$$Q_{ist} = \Phi_{ist}^{-\sigma_i} \sum_{d=1}^{N} \frac{\beta_{isdt} \tau_{sdt}^{1-\sigma_i} \mu_{idt} Y_{dt}}{\sum_{\zeta=1}^{N} \beta_{i\zeta dt} \tau_{i\zeta dt}^{1-\sigma_i} \Phi_{i\zeta t}^{1-\sigma_i}} = \Phi_{ist}^{-\sigma_i} \Lambda_{ist}. \tag{24}$$

In fact, while the price parameter Φ_{ist} summarizes all the information related to the labor market conditions and the industrial structure, Λ_{ist} refers to the world demand condition affecting total production. Since the supply side is serially correlated overtime, if one could exploit the variation coming only from Λ_{ist}, the identification of ψ_i would be unbiased.

One way to address this issue is to directly construct Λ_{ist}. However, this approach comes with the problem of finding appropriate counterparts in the data. Both β_{isdt} and μ_{idt} are not directly observable, and at best τ_{sdt} and Φ_{ist} would need a first round of estimations. For this reason, I will adopt an indirect approach to identify demand-driven variations: a structural *Bartik shock*. This strategy is adopted to take fully advantage of the longitudinal structure of trade data, and allows to effectively disentangle supply-side and demand-side variation, making it the best option for the identification of ψ_i. The Bartik shift-share instrument is a widely applied tool used to isolate demand shocks from supply shocks, it has been shown to be a reliable instrument to tackle endogeneity, and to be robust to microfoundations[8]. For the model previously developed, the Bartik shock has the following form:

$$\Lambda_{ist}^{Bartik} = \sum_{d=1}^{N} W_{isd} \hat{E}_{dt}, \tag{25}$$

where W_{isd} is the constant share of world demand directed to country s, in industry i, from destination d, and $\hat{E}_{dt}$ is the change in destination d total expenditure. Given the benchmark Bartik-type world demand shock, it is now possible to draw a parallel

[8]Some prominent studies exploiting a Bartik instrument are Card (2001) and Autor, Dorn, and Hanson (2013).

between the static Eq. (24) and the dynamic Eq. (25). Left aside the supply side part, the income component Y_{dt} can be easily linked to the shifting component $\hat{E}_{dt}$, while the remaining part of the summation to the constant share W_{isd}. Total income can be proxy by GDP, the issue is to choose a measure for W_{isd}. To construct the variable, I take the idiosyncratic demand component at time $t-1$:

$$\Lambda_{isdt-1} = \frac{\beta_{isdt-1}\tau_{sdt-1}^{1-\sigma_i}\mu_{idt-1}}{\sum_{\zeta=1}^{N}\beta_{i\zeta dt-1}\tau_{i\zeta dt-1}^{1-\sigma_i}\Phi_{i\zeta t-1}^{1-\sigma_i}} Y_{dt-1}. \tag{26}$$

As just discussed, none of the components of Eq. (26) can be directly observed, except for Y_{dt-1}. Nonetheless, it is possible to retrieve the remaining part of the equation by exploiting a particular *odds* specification[9]:

$$\frac{X_{isdt-1}}{X_{ist-1}} = \frac{\beta_{isdt-1}\tau_{sdt-1}^{1-\sigma_i}\mu_{idt-1}Y_{dt-1}}{\sum_{\zeta=1}^{N}\beta_{i\zeta dt-1}\tau_{i\zeta dt-1}^{1-\sigma_i}\Phi_{i\zeta t-1}^{1-\sigma_i}}\left[\sum_{d=1}^{N}\frac{\beta_{isdt-1}\tau_{sdt-1}^{1-\sigma_i}\mu_{idt-1}Y_{dt-1}}{\sum_{\zeta=1}^{N}\beta_{i\zeta dt-1}\tau_{i\zeta dt-1}^{1-\sigma_i}\Phi_{i\zeta t-1}^{1-\sigma_i}}\right]^{-1} \equiv \frac{\Lambda_{isdt-1}}{\Lambda_{ist-1}}. \tag{27}$$

Using X_{isdt-1}/X_{ist-1} as a substitute for Λ_{isdt-1} has the advantage to not impose any further assumption, it is immediately available from data on export, and it can be further manipulated to obtain the constant share to plug in the Bartik shock. By defining the variation over time of Y_{dt} as $\hat{Y}_{dt} = \partial log(Y_{dt})/\partial t$, it is possible to define the weighted idiosyncratic demand shock as follows:

$$\hat{D}_{isdt-1} = \frac{1}{\Lambda_{ist-1}}\frac{\beta_{isdt-1}\tau_{sdt-1}^{1-\sigma_i}\mu_{idt-1}}{\sum_{\zeta=1}^{N}\beta_{i\zeta dt-1}\tau_{i\zeta dt-1}^{1-\sigma_i}\Phi_{i\zeta t-1}^{1-\sigma_i}}\hat{Y}_{dt}, \tag{28}$$

where the weight is the inverse of the total world demand Λ_{ist-1}. Eventually, it is possible to sum up the weighted idiosyncratic demand shocks across all destinations ds to obtain a measure of the world demand shock:

$$\hat{D}_{ist-1} = \frac{1}{\Lambda_{ist-1}}\sum_{d=1}^{N}\frac{\beta_{isdt-1}\tau_{sdt-1}^{1-\sigma_i}\mu_{idt-1}}{\sum_{\zeta=1}^{N}\beta_{i\zeta dt-1}\tau_{i\zeta dt-1}^{1-\sigma_i}\Phi_{i\zeta t-1}^{1-\sigma_i}}\hat{Y}_{dt}. \tag{29}$$

Eq. (29) is a weighted structural Bartik shock, and will be used as an instrument for the change in the total level of production over time, $\hat{Q}_{ist}$, with two caveats. First, to avoid the simultaneity bias, I will lag the constant share by three periods[10]; second,

[9]See Head and Mayer (2013) for a discussion of the use the odds specification in the gravity model of trade literature.

[10]The time length of the database is such to undermine the size of the Nickell bias.

the presence of the weight, $1/\Lambda_{ist}$, will not hinder the identification strategy, since, on the one hand, this measure will be lagged, hence the risk of an autocorrelation bias will be attenuated, on the other hand, the assumption that past levels of demand and future demand shocks are not correlated is sufficient to avoid any upward or downward bias in the estimation of ψ_i. The Bartik instrument, $\hat{B}_{ist}$, reads:

$$\hat{B}_{ist} = \frac{1}{\Lambda_{ist-3}} \sum_{d=1}^{N} \frac{\beta_{isdt-3}\tau_{sdt-3}^{1-\sigma_i}\mu_{idt-3}}{\sum_{\zeta=1}^{N} \beta_{i\zeta dt-3}\tau_{i\zeta dt-3}^{1-\sigma_i}\Phi_{i\zeta t-3}^{1-\sigma_i}} \hat{Y}_{dt}. \tag{30}$$

Eq. (30) will be used in the first stage of a 2SLS estimation to capture the variation of total production changes coming from the world demand shocks, in the second step I will estimate the effect of the predicted total production variation, $\tilde{Q}_{ist}$, on the total trade flow variation, $\hat{X}_{ist}$. This structural procedure will identify ψ_i.

3.2 Data

Data are collected from different sources. The United Nation Statistics Division Database on Commodity Trade (COMTRADE) provides bilateral trade flows for the period between 1986 and 2015. Product classification is based on the Standard International Trade Classification (SITC), revision 2, at the 2-digit level. This level of disaggregation broadly identifies industries, which are reported in Appendix C. I consider import value, which are of the CIF (cost, insurance, and freight) type. For the sample of countries considered, I aggregate pre- and post-unification German trade data, and Belgium and Luxembourg[11] trade data to deal with respectively a unique time series data. Following Hanson, Lind, and Muendler (2016), I introduce a set of restrictions on the choice of the sample of importers and exporters. First, it is required that destination countries import a product in all years, so that coefficients on exporting-industries dummies are comparable over time. Second, it is necessary to consider only exporters shipping to overlapping groups of importing countries, in order to correctly identify destination-industries dummies. Overall, this strategy ensures that all importer and exporter fixed effects are separately identified. Combined, these restrictions leave 85 exporters, 55 importers, and 52 industries, which account for the 85% of overall world trade in the same period. This one is the sample used to estimate the baseline dynamic gravity equation.

Data for gravity control variables are retrieved by CEPII and consists of a set of dummy pair variables on the adjacency of the countries, the share of a common

[11] This expedient is necessary to uniquely identify and merge the gravity-type controls that are kept aggregated at the Belgium and Luxembourg level.

language and the existence of a colonial relationship. Egger and Larch (2008) provides data on regional trade agreements (RTA, hereafter) for the same period. In such database RTAs are defined according to four different, not mutually exclusive, classes: free trade agreements (FTA), customs unions (CU), economic integration agreements (EIA), and partial scope agreement (PS), however the subsequent gravity trade estimation will take into account only the existence of any of these different agreements between any two countries.

For implementing the IV strategy, I rely on the OECD Structural Analysis (STAN) Database that allows to match production and trade data at the sector level. STAN data used in the analysis span a period between 1990 to 2015 and are based on the International Standard Industrial Classification of all economic activities (ISIC), revision 4. For such a dataset, I use free on board (FOB) export trade data, this choice is justify by the fact that I can perform the estimation only on a small sample of exporters[12], for which both trade and production data are available. Similarly to what done for the COMTRADE database, a restriction will be imposed on exporter and importers, overall will be considered 23 exporters, 68 importers, and 26 industries, more information can be found in Appendix C.

4 Results

4.1 Baseline Estimation

Table 1 reports the first and second stage results of the 2SLS estimation discussed above: Column (1) shows a very strong first stage, with the Bartik variable, $\hat{B}_{ist-1}$, being significantly different from zero at the 1%, and the F test larger than 10, the commonly considered threshold. Column (2) reports the coefficient associated to the effect of the predicted change in total output on the change in trade flows, namely the average scale elasticity ψ, which is significant at the 1% and equal to 0.18.

Despite the dynamic nature, the magnitude of the scale parameter is close to static scale parameters estimated in the industrial organization literature: for example in Fuss and Gupta (1981), $\psi \approx 0.15$, or Paul, Morrison and Siegel (1999), $\psi \approx 0.25$. As regards to the trade literature, Antweiler and Trefler (2002) find only a modest effect of scale with a point estimate of $\psi \approx 0.05$, while preliminary results by Bartelme, Costinot, Donaldson, and Rodriguez-Clare (forthcoming) show estimates not far from the one of this paper, with $\psi \approx 0.13$. With respect to the IO literature, the main

[12]The subsample of OECD countries is composed by: Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Japan, Latvia, Mexico, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Sweden, Switzerland, USA.

Table 1: IV Estimation (ψ)

	$\hat{Q}_{ist-1}$	$\hat{X}_{ist}$
	I Stage 2SLS	II Stage 2SLS
	(1)	(2)
$\tilde{Q}_{ist-1}$		0.18***
		(0.08)
$\hat{B}_{ist-1}$	7.32e+07***	
	(1.43e+07)	
Observations	7,309	7,309
Prob > F	0.00	0.01
SW F stat	26.14	×
F-stat	57.54	×

Notes: The table reports the first and second stage of the estimated static gravity model using volumes of production. 2SLS is estimated using the STATA command **ivreg2**. Sanderson-Windmeijer (SW) F statistic is reported in the second last row. Standard errors are clustered at the industry-source level and are reported in parentheses. Figure D.1 in Appendix D shows the scatter plot of the first stage. ***p<0.01, **p<0.05, *p<0.1

contribution of this paper is a framework to estimate the sector level scale parameter without using data on output and input. The advantage of using trade rather than production data lays in the availability of the former for a large number of countries and industries. Indeed, it is reassuring that my estimates do not go far from those relying on detail sector-level production data.

4.2 Reduced Form Estimation

The reduced form approach aims at estimating the dynamic scale parameter, ψ_i, by exploiting a variant of Eq. (22). Appendix A discusses the main assumptions of this approach. The strategy is to estimate the export capabilities for each country at any time in the sample, and the subsequent use of these estimates to construct a measure of z_{ist-n}. With these variables at hand, it is possible to apply Least Square Dummy Variable estimation to retrieve ψ_i.

As shown in Eq. (22), the α_n correspond to the average dynamic externality parameters ψ^n, for all the n lagged periods. *A priori*, there is no rule of thumb for the choice of the number of lags to introduce in the model, therefore I will show results for different specifications for which I include a progressive number of lags,

Table 2: **Dynamic Gravity Reduced Form Estimate (ψ^n)**

	lnX_{ist}			
	OLS			
	(1)	(2)	(3)	(4)
z_{ist-1}	0.30***	0.19***	0.17***	0.17***
	(0.002)	(0.002)	(0.001)	(0.001)
z_{ist-2}		0.11***	0.06***	0.05***
		(0.002)	(0.001)	(0.001)
z_{ist-3}			0.07***	0.04***
			(0.001)	(0.001)
z_{ist-4}				0.05***
				(0.001)
Source × Destination × Time FE	✓	✓	✓	✓
Industry × Destination × Time FE	✓	✓	✓	✓
Source × Time FE	✓	✓	✓	✓
Observations	3,868,079	3,770,088	3,669,147	3,568,837
Adjusted R^2	0.73	0.73	0.73	0.73
Prob > F	0.00	0.00	0.00	0.00

Notes: The table reports LSDV estimates of the baseline model. Estimation relies on the STATA command **reghdfe** developed by Correia (2016). Standard errors are clustered at the industry-source level and are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1

up to four. Another aspect concerns the behavior of the distribution of ψ^n over time. By construction it is assumed to be exponentially shaped, but there is no anecdotal evidence that should make us be more inclined to expect a similar pattern in the series of coefficients estimated. I will show that, actually, the exponential assumption does not perform badly once tested with data.

For the reduced form estimation, I use the more exhaustive COMTRADE data. This will also provide a potential robustness check for the previous estimates. Table 2 displays the point estimates for the average ψ, using Least Squared Dummy Variable (LSDV) estimation. The four columns show the different specifications tested, in each one I control for the bilateral trade costs, and the previously discussed set of directional fixed effects. The coefficient of interest is the one associated to z_{ist-1}. In Column (1) it that takes a value of 0.30, but with the introduction of additional lagged variables the coefficient drops to 0.17[13]. Three aspects emerge from the estimation:

[13]Table A.1, in Appendix A, shows a more loose specification, for which the source-destination-year

Table 3: Gravity Model Estimates (Volumes of Production)

	$ln(X_{ist})$	X_{ist}
	LSDV	PPML
	(1)	(2)
$ln(Q_{ist-1})$	0.30***	0.28***
	(0.03)	(0.04)
Source × Time FE	✓	✓
Observations	536,790	664,484
Adjusted R^2	0.81	×
Prob > F	0.00	×

Notes: The table reports LSDV and PPML estimates of the static gravity model using volumes of production. LSDV is estimated using the STATA command **reghdfe** developed by Correia (2016), while PPML is estimated with **poi2hdfe**, developed by Guimarães (2014). Standard errors are clustered at the industry-source level and are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1

first, all the dynamic externality coefficients are positive, highly significant, and between zero and one, in line with the theory previously developed. Second, the effect features persistence over time, decaying more than linearly as the theory would imply, even though there is no intention to test for exponential decaying. Third, avoiding to consider the dynamics leads to an upward bias of the point estimates, as it is apparent from the comparison between Column (1) and Columns (2), (3), and (4).

Another way to check for the robustness of the results in Table 2 is to exploit the gravity equation in the log-linearized form of Eq. (23), using sector-level volumes of production to proxy for Q_{ist} and considering the total amount of export X_{ist}, instead of the bilateral trade flow X_{isdt}. Due to data availability, this exercise is carried out on the same database used for the IV estimation. To exploit data on the volumes of production and match them with trade data, in fact, it is necessary to use the OECD STAN database, as discussed in the data section.

Column (1) of Table 3 reports the coefficient for the average ψ_i using a LSDV estimation, while Column (2) reports the point estimate for the Poisson-Pseudo Maximum Likelihood (PPML) estimation. Reassuringly, the coefficient estimated does not different from the one previously estimated. To give a sense of the exercise, one should compare the two columns of Table 4 with only the first column of 1, since ex-

fixed effect is replaced by the bilateral controls provided by CEPII, but the results are in line with the previous estimate

Table 4: Dynamic Gravity Reduced Form Estimate (ψ_i)

Industry	LSDV	Adjusted R^2	Observations
Food	0.16***	0.75	417,721
	(0.008)		
Beverage & Tobacco	0.20***	0.82	67,292
	(0.018)		
Crude Materials	0.16***	0.70	371,976
	(0.001)		
Chemicals	0.19***	0.80	515,489
	(0.008)		
Manufactured Goods	0.18***	0.81	685,410
	(0.008)		
Machinery & Transport Equipment	0.12***	0.85	682,892
	(0.005)		
Miscellaneous Manufacturing	0.15***	0.86	619,205
	(0.008)		

Notes: The table reports the one-year-lag LSDV estimate of the baseline model, for the seven 1-digit SITC Rev.2 aggregate industries. For *Mineral fuels* and *Oils* industries size was not sufficient to identify the parameter of interest, hence these are omitted. Estimation relies on the STATA command **reghdfe** developed by Correia (2016). Standard errors are clustered at the industry-source level and are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1

ploiting volumes does not allow to perform a dynamic analysis. The intuition is that the current total level of production contains all the information of the past volumes of production.

Up to now, I showed results for an aggregate measure of the dynamic scale parameter. The aim is to provide evidences of heterogeneity of such a parameter across different industries. However, due to the dimensionality constraint imposed by the reduced form estimation, I don't have enough flexibility to estimate the 2-digit industry specific dynamic scale parameter. Nonetheless, it is possible to aggregate industries up to the 1-digit, and Table 3 reports the range of heterogeneous ψ_i for seven groups of aggregate of industries. Despite not being able at this stage to get at a more disaggregated level of analysis, it is possible to see that variation is present, given that estimated ψ_i range between 0.12 to 0.20. The industries featuring stronger dynamic externalities are beverage & tobacco, chemicals, and manufactured goods.

5 Conclusion

The international trade literature tends to focus strongly on the analysis of the source of comparative advantage from a static perspective. This paper explores a complementary and novel view on the subject by introducing explicit dynamic effects determining changes of the relative productivity over time. To this end, I develop a general equilibrium model of trade featuring three main characteristics *i*) world production differentiation at the industry level, according to an Armington structure *ii*) industry-level productivity as a combination of technological levels and scale of productions *iii*) dynamic gains from scaling up industry-level production. With such a model at hand, it is possible to derive at the equilibrium a dynamic gravity model of trade characterized by path-dependency, and structurally estimate it.

The second contribution of the paper is to provide an estimation strategy to consistently identify the scale parameter at the industry level, by controlling for any other supply-side confounding factor. This is achieved in two steps, at first by instrumenting the total volume of production by a Bartik shock, isolating the demand-driven source of variation, and then by inputting the predicted demand shock in the gravity model. Indeed, I find that scaling up can determine substantial dynamic productivity gains, depending on which industry is considered. In fact, I show that the dynamic scale parameter is heterogeneous across industries, with point estimates ranging between 0.12 and 0.20, and an average of 0.18.

In conclusion, this study aims at reviving the literature about the role and the relevance of industrial policy, by providing new empirical evidences of the relevance of external economies of scale. As a matter of fact, these findings point to a crucial policy implication: it might become optimal to pursue a protectionist industrial policy, when international demand conditions are particularly averse and therefore certain targeted industries might suffer consequences in the long run. The question is: what would be quantitatively the optimal response to a negative exogenous shock? I will leave such an open question for future research.

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A Reduced Form Estimation of the Gravity Model

This appendix proposes a different identification strategy for the dynamic scale parameter, ψ_i. As discussed in Section 3, the estimation of Eq. (21) would require to construct the dynamic scale variable, z_{ist-n}. However, the industry-level TFP, A_{ist}, and the average wage rate, w_{st}, are not directly available. One possibility is, hence, to estimate both by imposing strong assumptions about their behavior. The main idea is to follow a two step procedure affine to development accounting and proposed by Levchenko and Zhang (2016): at first one has to estimate the variable of interest using fixed effects; in the second step, it is possible to exploit data on all the additional variables to isolate the true values of of the variables of interest. This will be done for all the countries in the database.

The first aspect to consider is that by using fixed effects to estimate the stochastic version given by Eq. (22), it would not be possible to disentangle the source of variation coming from A_{ist} and z_{ist-n}. Hence, as a first order simplification, the strategy that is adopted relies on the estimation of the country-level productivity parameter k_{st}. In such a reduced form approach, the latter is equal to:

$$k_{st} = (\sigma - 1)\, ln(A_{st}/w_{st}),$$

where σ is the average elasticity of substitution across industries. Once imposed this structure on the econometric model, it becomes possible to jointly estimate A_{st} and w_{st} by exploiting a log-linearize version of Eq. (17):

$$ln(X_{ist}) = (\sigma_i - 1)\, ln(A_{ist}/w_{st}) + ln(\Lambda_{ist}) + \sum_{n=1}^{t} \psi_i^n z_{ist-n}.$$

where:

$$\Lambda_{ist} = \sum_{d=1}^{N} \frac{\beta_{isdt} \tau_{sdt}^{1-\sigma_i} \mu_{idt} Y_{dt}}{\sum_{\zeta=1}^{N} \beta_{i\zeta dt} \tau_{i\zeta dt}^{1-\sigma_i} \Phi_{i\zeta t}^{1-\sigma_i}},$$

and:

$$z_{ist-n} = (\sigma_i - 1)\, ln\left[\frac{A_{ist-n}}{w_{st-n}} X_{ist-n}\right].$$

I estimate the log total trade flows by employing Least Square Dummy Variable (LSDV) estimation of the following form:

$$ln(X_{ist}) = \delta_{st} + \delta_{is} + \delta_{it} + \epsilon_{ist},$$

where δ_{st} is the source country-year fixed effect capturing the role played by A_{st}/w_{st}, δ_{is} and δ_{it} are respectively the sector-year and sector-country fixed effects. A huge part of the variance is hence not capture in such a specification, nonetheless, it is not of importance for the estimation of δ_{st} as long as ϵ_{ist} and δ_{st} are orthogonal, as I here claim to be the case.

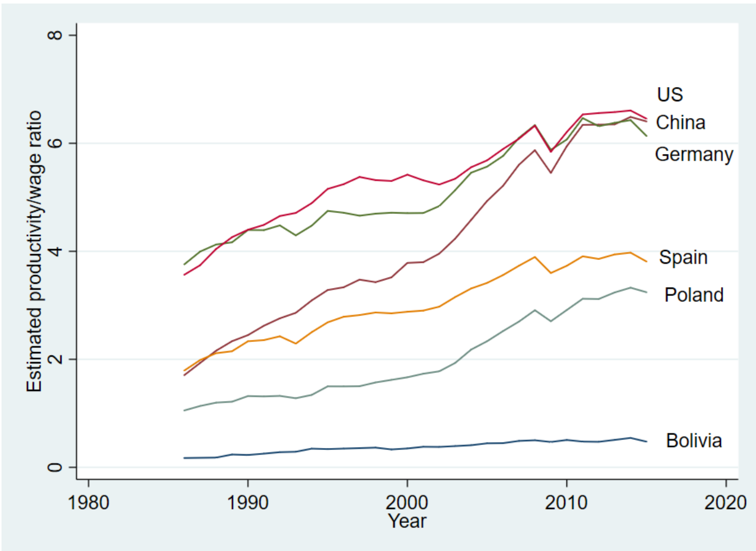
Since fixed effects are identified up to a reference group, for convenience I will fix the reference to be the US at the beginning of the period. The estimated source country-year fixed effect is hence given by:

$$\delta_{st} = (\sigma - 1)\frac{ln(A_{st}/w_{st})}{ln(A_{USt^{init}}/w_{USt^{init}})}.$$

This is very convenient, since it is simply possible to correct for the adjusted average elasticity of substitution $(\sigma - 1)$[14] and for the observable term $ln(w_{USt^{init}}/A_{USt^{init}})$ to retrieve $ln(A_{st}/w_{st})$. With the estimates of A_{st} and w_{st} at hand, it is possible to construct the dynamic scale variables $\tilde{z}_{ist-n}$, for different lagged periods, to estimate ψ_i from Eq. (22).

Figure 1 and 2 report the estimates of $ln(A_{st}/w_{st})$ for a small sample of countries. United States and Germany features the highest adjusted productivity through the period considered, followed by high income OECD countries like France and Italy[15]. China is characterized by a surge in adjusted productivity bringing it among the top at the end of the period. Similar upward trends, but smaller in magnitude, are shared by transition economies of the eastern European block, like Poland and Hungary, and emerging economies like Mexico and the Korean Republic. Eventually, lagging economies of South America and Africa, like Bolivia and Kenya, are found at the bottom of the ranking.

Figure A.1: Estimated Productivity/Wage Ratio I

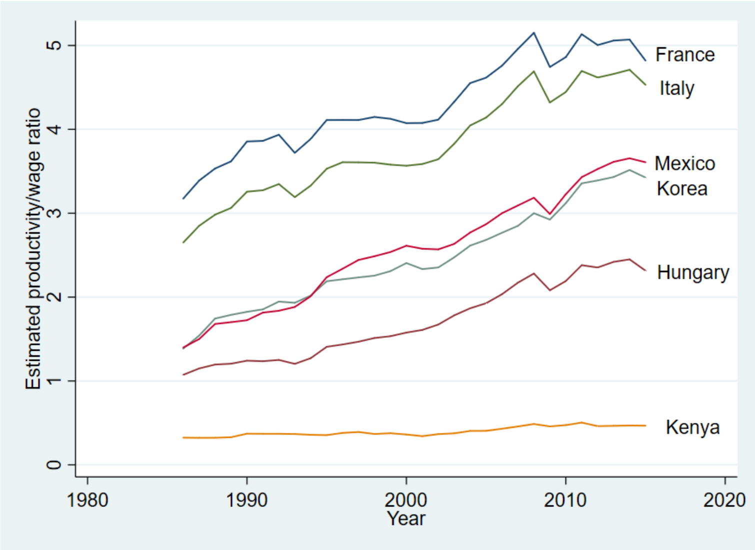


Notes: Estimated productivity/wage ratio between 1986 and 2015 for a sample of countries: Bolivia, China, Germany, Poland, Spain, United States. Confidence intervals are omitted for clarity.

[14]In controlling for a country-year fixed effect, I exploit the variation across sector that prevents to identify the industry specific elasticity of substitution σ_i. Nonetheless, the fixed effect will capture the measure of interest weighted by an average of such elasticity.

[15]Note the different scale of Figure 1 and 2.

Figure A.2: Estimated Productivity/Wage Ratio II



Notes: Estimated productivity/wage ratio between 1986 and 2015 for a sample of countries: France, Hungary, Italy, Kenya, Mexico, Rep. of Korea. Confidence intervals are omitted for clarity.

Estimation of Eq. (22) using $\tilde{z}_{ist-n}$ relies on three other assumptions: first, it requires β_{isdt} to be uncorrelated with the industry-destination-time fixed effect, this is due to the fact that the real potential demand is inversely related to the idiosyncratic demand shifter. This is a minor issue in this context, due to the fact that the number of source countries N is sufficiently large in the sample, although a country size granularity might prevent the law of large number to hold. Using the same reasoning, it is also necessary to assume orthogonality between A_{ist} and w_{st} with Λ_{ist}. The third assumption needed is the orthogonality of both the country-level productivity and the wages with its respective overtime components. This second assumption is much stronger, as Figure 1 and 2 show.

B Additional Robustness

Table B.1: Dynamic Gravity Estimates using CEPII Bilateral Controls

	$ln(X_{isdt})$			
	LSDV			
	(1)	(2)	(3)	(4)
z_{ist-1}	0.29***	0.19***	0.17***	0.16***
	(0.002)	(0.009)	(0.009)	(0.009)
z_{ist-2}		0.11***	0.06***	0.05***
		(0.007)	(0.009)	(0.001)
z_{ist-3}			0.07***	0.03***
			(0.007)	(0.001)
z_{ist-4}				0.05***
				(0.008)
Time Invariable Bilateral Controls (τ_{sd})	✓	✓	✓	✓
Source × Destination × Time FE	✓	✓	✓	✓
Source × Time FE	✓	✓	✓	✓
Observations	3,871,689	3,773,439	3,669,147	3,565,973
Adjusted R^2	0.70	0.70	0.70	0.70
Prob > F	0.00	0.00	0.00	0.00

Notes: The table reports LSDV estimates for an alternative specification of the baseline model using CEPII bilateral controls. Estimation relies on the STATA command **reghdfe** developed by Correia (2016). Heteroskedasticity-robust standard errors are reported in parentheses. ***p<0.01, **p<0.05, *p<0.1

C Tables

Table C.1: COMTRADE Database SITC, rev. 2, 2-digit industries

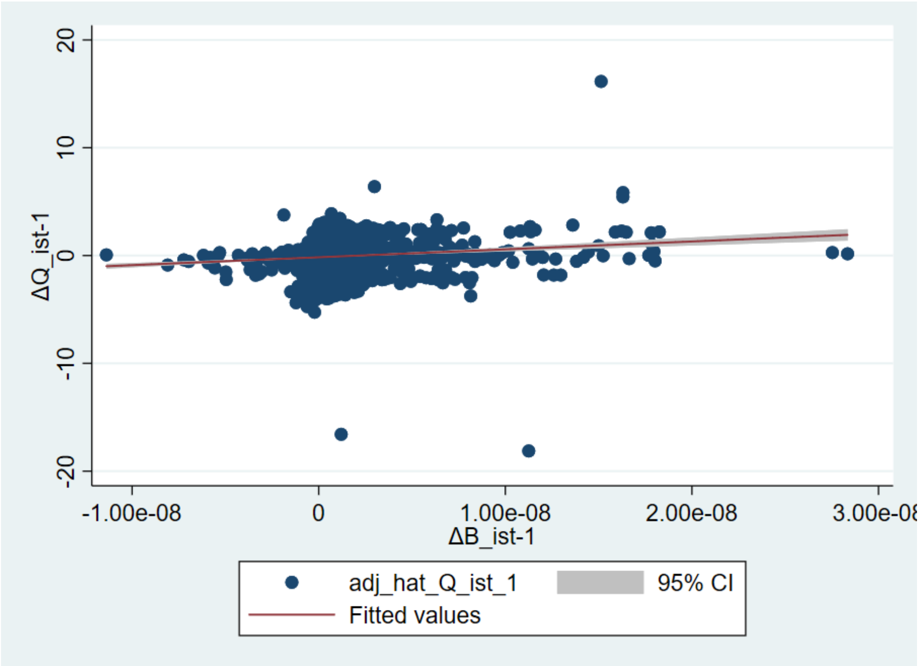
Industry (SITC Rev.2)	
Dairy products and birds' eggs (02)	Leather, leather manufactures, nes, and dressed furskins (61)
Fish, crustacean and molluscs, and preparations thereof (03)	Rubber Manufactures, nes (62)
Cereals and cereal preparations (04)	Cork and wood, cork manufactures (63)
Vegetables and fruit (05)	Paper, paperboard, and articles of pulp, of paper or of paperboard (64)
Sugar, sugar preparations and honey (06)	Textile yarn, fabrics, made-up articles, nes, and related products (65)
Coffee, tea, cocoa, spices, and manufactures thereof (07)	Non-metallic mineral manufactures, nes (66)
Feeding stuff for animals (not including unmilled cereals) (08)	Iron and steel (67)
Miscellaneous edible products and preparations (09)	Non-ferrous metals (68)
Beverages (11)	Manufactures of metals, nes (69)
Tobacco and tobacco manufactures (12)	Power generating machinery and equipment (71)
Crude rubber (including synthetic and reclaimed) (23)	Machinery specialized for particular industries (72)
Cork and wood (24)	Articles of apparel, accessories, knit or crochet (73)
Textile fibres (not wool tops) and their wastes (not in yarn) (26)	General industrial machinery and equipment, nes, and parts of, nes (74)
Crude fertilizer and crude minerals (27)	Office machines and automatic data processing equipment (75)
Metalliferous ores and metal scrap (28)	Telecommunications, sound recording and reproducing equipment (76)
Crude animal and vegetable materials, nes (29)	Electric machinery, apparatus and appliances, nes, and parts, nes (77)
Petroleum, petroleum products and related materials (33)	Road vehicles (78)
Fixed vegetables oils and fast (42)	Other transport equipment (79)
Animals and vegetables oils and fats, processed and waxed (43)	Sanitary, plumbing, heating, lighting fixtures and fittings, nes (81)
Organic chemicals (51)	Furniture and parts thereof (82)
Inorganic chemicals (52)	Travel goods, handbags and similar containers (83)
Dyeing, tanning, and colouring materials (53)	Articles of apparel and clothing accessories (84)
Medicinal and pharmaceutical products (54)	Footwear (85)
Oils and perfume materials: toilet and cleansing preparation (55)	Professional, scientific, controlling instruments, apparatus, nes (87)
Artificial resins and plastic materials, and cellulose esters etc. (58)	Photographic equipment and supplies, optical goods; watches, etc (88)
Chemical materials and products, nes (59)	Miscellaneous manufactured articles, nes (89)

Table C.2: STAN Database ISIC, rev. 4, 2-digit industries

Industry	ISIC Rev. 4
Crop and Animal Production, Hunting and Related Service Activities	D01
Forestry and Logging	D02
Fishing and Aquaculture	D03
Manufacturing of Food Products	D10
Manufacturing of Beverages	D11
Manufacturing of Tobacco Products	D12
Manufacturing of Textiles	D13
Manufacturing of Wearing Apparels	D14
Manufacturing of Leather and Related Products	D15
Manufacturing of Wood and Products of Wood	D16
Manufacturing of Paper and Paper Products	D17
Printing and Reproduction of Recorded Media	D18
Manufacturing of Coke and Refined Petroleum Products	D19
Manufacturing of Chemicals and Chemical Products	D20
Manufacturing of Pharmaceutical	D21
Manufacturing of Rubber and Plastic Products	D22
Manufacturing of Other Non-metallic Mineral Products	D23
Manufacturing of Basic Metal	D24
Manufacturing of Fabricated Metal Products	D25
Manufacturing of Computer, Electronic, and Optical Products	D26
Manufacturing of Electrical Equipment	D27
Manufacturing of Machinery and Equipment n.e.c.	D28
Manufacturing of Motor Vehicles, Trailers, and Semi Trails	D29
Manufacturing of Other Transport Equipment	D30
Manufacturing of Furniture	D31
Other Manufacturing	D32

D Figures

Figure D.1: First Stage IV Estimation



Notes: The figures reports the fitted line derived by regressing the Bartik instrument, $\hat{B}_{ist-1}$, on the volume of production $\hat{Q}_{ist-1}$. The grey band represents the confidence interval at the 95%.

Institut de Recherches Économiques et Sociales
Université catholique de Louvain

Place Montesquieu, 3
1348 Louvain-la-Neuve, Belgique

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