It takes (more than) a moment: Revisiting the link between firm productivity and aggregate exports.*

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Abstract

This paper examines empirically which features of productivity distributions are related to aggregate exports. It implicitly tests if the predictions of the standard trade model with heterogeneous firms la Melitz (2003), that, within a gravity framework, only the first moment of productivity distributions affect aggregate exports, are supported by the data. The empirical analysis, based on the Compnet data set for a sample of European countries and industries, provides robust support to the alternative view, that also higher moments of the productivity distributions are correlated to trade outcomes. In particular exports are larger the larger productivity dispersions and the larger the rightwards asymmetry towards the top tail of the distributions. These findings support the use of policies favoring allocative efficiency for promoting exports. The paper also carries out an application to see if asymmetry in productivity distributions has an influence on the impact of exchange rate shocks on exports. It finds that the elasticity of exports to exchange movements is lower the higher the asymmetry in productivity. Therefore the effectiveness in exchange rate movements in closing trade imbalances depends on several features of the underlying population of firms.

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1 Introduction

Translating the micro predictions of the trade theory with heterogeneous firms into their macro-aggregate outcomes and consequently into policy prescriptions is far from obvious. The "standard trade model" à la Melitz (2003) predicts that aggregate export outcomes are fully determined by the mean of the productivity distribution of its producers. If this is the case, policies aimed at boosting aggregate exports should focus on raising mean productivity, and therefore the whole productivity distribution. This, in principle, is at odds with the well-known evidence that the dominant share of aggregate exports is the outcome of the export activity of the most efficient firms. If the most productive firms generate the dominant share of exports, then also higher moments of the productivity distribution should be related to aggregate exports. And policy should target the rightward tail of the distribution, independently from the level of the mean. For example policies aimed at fostering allocative efficiency could be more effective in favoring the transition of firms towards the top percentiles of the distribution, hence boosting aggregate exports, rather than those supporting small medium enterprises, independently of their growth performance. The main aim of this paper is assessing empirically which features of productivity distributions are related to aggregate exports, and therefore implicitly testing if the predictions of the standard trade model à la Melitz (2003) are supported by the data. The first part derives theoretically a general aggregate demand function with heterogeneous producers. It then introduces the three underlying assumptions of the Melitz (2003) model: CES demand systems; a variable iceberg export cost and a fixed export cost; Pareto productivity distributions. And it derives a gravity equation that explains bilateral exports in terms of the competitiveness (capability) of the country of origin, the characteristics of the destination country and bilateral trade costs. The model shows that if the three underlying assumptions of the Melitz (2003) model hold, then the competitiveness of the country of origin is strictly determined by the first moment of the productivity distribution. This is the null hypothesis to be taken to the data. The empirical analysis is based on the Compnet data set, developed by the European system of central banks, which provides information on several features of firms populations at the industry/country/year level for a sample of several European countries, matched with trade data from the Eurostat/Comext data base. The empirical exercise is carried in two stages. First, a gravity equation is run to estimate the origin country fixed effect. This is implicitly a measure of competitiveness, netted out of importing country and country-pair specific characteristics. Second, it is checked whether and how this competitiveness measure is related to different moments of the productivity distributions. The paper finds strong and robust evidence rejecting the null hypothesis that only the first moments of the productivity distributions matter for aggregate exports. Exports are positively correlated to the first moments, but also to measures of dispersion and of asymmetry of the underlying productivity distributions. Especially, asymmetry explains a considerable share of the cross industry and country variance of the competitiveness measure. These results have two implications. From the theoretical point of view, that we need more general or different functional forms than those underlying the standard trade model of Melitz (2003) to explain aggregate bilateral exports. And from the policy perspective, that, for any given mean productivity, policies enhancing rightwards asymmetries in the productivity distributions are crucial for aggregate export growth. Of course also the first moment matters. But the descriptive evidence from the Compnet data base CompNet Task Force (2014), shows that there is a huge variance in productivity distributions across the Compnet sample countries, both in terms of their mean and dispersion measures. Dispersion and especially rightwards asymmetries are also key parameters that any policy aimed at fostering exports should not foresee. Given the importance of asymmetry and dispersion measures for explaining aggregate exports, the last part of this paper carries out an application, examining how far these features of the productivity distributions affect the aggregate impact of macro shocks on export. It focuses on exchange rate shocks. Other papers have already examined this issue (Berman et al., 2012; Di Mauro and Pappadà, 2014). This exercise essentially extends the paper by Berman et al. (2012), which is focused on French data only, to a cross country analysis. Consistently with their results, it also finds that the elasticity of exports to exchange rate shocks is lower the larger the asymmetry of the productivity distribution. According to Berman et al. (2012), several theoretical models with heterogeneous firms and pricing to market support this result, by showing that pricing to market strategies are more likely for high productivity firms. In this case exchange rate movements are less effective in correcting trade imbalances.

2 Theoretical Framework

Our aim is to investigate which features of the productivity distribution of a country's producers explain its aggregate exports. Specifically, we want to check whether the implications of the "standard model" with heterogeneous firms à la Melitz (2003) are supported by the data. As the model is well known, here we only provide a streamlined presentation. Further details can be found in the original paper and in recent surveys such as those by Costinot and Rodriguez-Clare (2014) and Head and Mayer (2014).

Consider an economy consisting of M countries indexed $m = 1, ..M$. The focus will be on the bilateral exports from an 'origin' country o to a 'destination' country d. In each country m there are a large number of monopolistically competitive producers N_m, each supplying a unique variety of a horizontally differentiated good with marginal cost c distributed according to a continuous cumulative density function $G_m(c)$ with support $[0, c_{mm}]$.

The associated productivity is $1/c$ and, therefore, the upper bound of the support c_{mm} identifies the marginal cost level of the lowest efficiency producers in m. With costly trade exporters from m to d are those producers in m that are at least as efficient as the lowest efficiency producers in d after taking trade cost into account. The lowest efficiency exporters from m to d have thus marginal cost $c_{md} < c_{dd}$, where the gap is due to the presence of trade costs. Accordingly the fraction of producers in m exporting to d is $G_m(c_{md})$, and their number is

$$N_{md}^x = N_m G_m(c_{md}). \tag{1}$$

This is the 'extensive margin' of trade from m to d. Using $x_{md}(c)$ to denote the value of exports from m to d for a producer with marginal cost c, the average value of exports per exporter from m to d can be written as

$$\overline{x}_{md} = \left[\int_0^{c_{md}} x_{md}(c) dG_m(c)\right] / G_m(c_{md}). \tag{2}$$

This is the 'intensive margin' of trade from m to d. Then, by definition, aggregate exports X_{md} are such that

$$X_{md} = N_{md}^x \overline{x}_{md} = N_m \left[\int_0^{c_{md}} x_{md}(c) dG_m(c)\right]. \tag{3}$$

While expressions (1), (2) and (3) have broad validity, Melitz (2003) makes two additional restrictive assumptions with a bearing on the functional form of $x_{md}(c)$ and the gap between c_{dd} and c_{md}. Most subsequent applications of Melitz's model also make the third restrictive assumption that productivity $1/c$ follows a specific distribution. When all three assumptions hold, we have what we call the the "standard model" of international trade with heterogeneous firms.

To understand what the three additional assumptions imply, it is useful to consider the general additive separable demand system studied by Zhelobodko et al. (2012). Specifically, let a mass L_d of identical consumers in country d share the following utility function

$$U_d = \int_0^{N_d^s} u(q_d(n))dn \tag{4}$$

which they maximize subject to the budget constraint

$$\int_0^{N_d^s} p_d(n)q_d(n)dn = y_d$$

where y_d is individual income, N_d^s is the number of sellers in d (including both local producers N_d and exporters from elsewhere N_{md}^x), $q_d(n)$ is consumption of the variety supplied by seller n, and $p_d(n)$ is its price. Utility maximization generates individual inverse demand

$$p_d(n) = \frac{u'(q_d(n))}{\int_0^{N_d^s} u'(q_d(n))q_d(n)dn} y_d$$

with associated individual expenditure

$$r_d(n) = p_d(n)q_d(n) = \frac{u'(q_d(n))q_d(n)}{\int_0^{N_d^s} u'(q_d(n))q_d(n)dn} y_d.$$

The value of exports from origin country o to destination country d for an exporter with marginal cost c can thus be stated as

$$x_{od}(c) = p_{od}(c)q_{od}(c)L_d = \frac{u'(q_{od}(c))q_{od}(c)}{\sum_{m=1}^{M} N_m \left[\int_0^{c_{md}} u'(q_{md}(c))q_{md}(c)dG_m(c)\right]} y_d L_d \tag{5}$$

with a corresponding value of aggregate exports equal to

$$X_{od} = \frac{N_o \int_0^{c_{od}} u'(q_{od}(c))q_{od}(c)dG_o(c)}{\sum_{m=1}^{M} N_m \left[\int_0^{c_{md}} u'(q_{md}(c))q_{md}(c)dG_m(c)\right]} y_d L_d \tag{6}$$

In line with Melitz (2003), the "standard model" assumes $u(q_d(n)) = (q_d(n))^{1-1/\sigma}$ so that (4) implies a CES demand system. It also assumes that there are two types of trade costs: an iceberg variable export cost $\tau_{md} > 1$ and a fixed export cost $f_{md} > 0$. Local sales incur a fixed production cost $f_{mm} > 0$ instead of the fixed export cost but no variable trade cost ($\tau_{dd} = 1$). The value of aggregate exports (6) then becomes

$$X'_{od} = \frac{\left[N_o G_o(c_{od})\right] \left(\overline{c}_{od}\right)^{1-\sigma} \left(\tau_{od}\right)^{1-\sigma}}{\left[\sum_{m=1}^{M} N_m G_m(c_{md})\right] \left(\overline{c}_d^s\right)^{1-\sigma}} y_d L_d \tag{7}$$

where $\overline{c}_{md}$ is the average (delivered) marginal cost of exporters from m to country d defined as

$$\overline{c}_{md} = \left[\int_0^{c_{md}} c^{1-\sigma} dG_m(c)/G_m(c_{md})\right]^{\frac{1}{1-\sigma}},$$

$\overline{c}_d^s$ is the average (delivered) marginal cost of all sellers to d defined as

$$\overline{c}_d^s = \left[\sum_{m=1}^{M} \frac{N_m}{N_d^s} \left(\overline{c}_{md}\right)^{1-\sigma} \left(\tau_{md}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}},$$

and $\sum_{m=1}^{M} N_m G_m(c_{md})$ is the total number of sellers N_d^s. Collecting country indices, (7) can be rewritten as

$$X'_{od} = N_o \; G_o\left(\frac{c_{dd}}{\tau_{od}}\left(\frac{f_{dd}}{f_{od}}\right)^{\frac{1}{\sigma-1}}\right) \left(\overline{c}_{od}\right)^{1-\sigma} \left(\tau_{od}\right)^{1-\sigma} \; \frac{y_d L_d}{N_d^s \left(\overline{c}_d^s\right)^{1-\sigma}} \tag{8}$$

given that we have

$$c_{od} = \frac{c_{dd}}{\tau_{od}} \left(\frac{f_{dd}}{f_{od}}\right)^{\frac{1}{\sigma-1}}$$

Lastly, the "standard model" assumes that productivity follows a Pareto distribution implying the cumulative density function of marginal cost $G_m(c) = (c/c_{mm})^k$ with $c \in [0, c_{mm}]$. Higher values of $k > 1$ increase the asymmetry of the distribution by shifting density towards the upper bound of the support c_{mm}. Under this third assumption, (8) can be further specified as

$$X''_{od} = N_o \left(\overline{c}_{oo}\right)^{-k} \; \left(f_{od}\right)^{1-\frac{k}{\sigma-1}} \left(\tau_{od}\right)^{-k} \; \frac{y_d L_d \left(\overline{c}_{dd}\right)^{1-\sigma+k} \left(f_{dd}\right)^{\frac{k}{\sigma-1}-1}}{N_d^s \left(\overline{c}_d^s\right)^{1-\sigma}} \tag{9}$$

This is a gravity equation that explains aggregate bilateral exports from origin country o to destination country d in terms of the 'capabilities' of country o as a supplier to all destinations $N_o \left(\overline{c}_{oo}\right)^{-k}$, the characteristics of destination country d that promote imports from all origins

$$y_d L_d \left(\overline{c}_{dd}\right)^{1-\sigma+k} \left(f_{dd}\right)^{\frac{k}{\sigma-1}-1} / N_d^s \left(\overline{c}_d^s\right)^{1-\sigma},$$

and bilateral trade costs due to crossing the border f_{od} and covering distance τ_{od} (Head and Mayer, 2014). For conciseness, we introduce the term 'competitiveness' of origin country o to refer to its 'capabilities' as a supplier to all destinations. Then (9) has the strong implication that the country's competitiveness $N_o (\bar{c}_{oo})^{-k}$ and thereby its aggregate exports to d depend only on the first moment $\bar{c}_{oo}$ of the productivity distribution of its producers but not on higher order moments.

In the next section we will bring this implication of the "standard model" to data in two steps. First, we will run gravity regressions based on (9) to estimate origin country fixed effects for a sample of Eurozone countries. These fixed effects will measure the 'competitiveness' of the sampled countries as suppliers, netting out importer-specific and country-pair-specific characteristics. Second, we will check whether the variation in the estimated origin country fixed effects is related to various moments of the distribution of firm productivity. Given (9), the null hypothesis of the "standard model" is that only the first moment of the productivity distribution should matter for competitiveness. The alternative hypothesis based on (6) is that higher moments should matter too. Rejection of the null hypothesis in favour of the alternative should, therefore, be interpreted as confutation of the CES-iceberg-Pareto restrictions imposed by the "standard model".[1]

3 Data

We use different data sources, in particular a novel database, named CompNet, that allows to take into account the heterogeneity in labor and total factor productivity within sectors and different European countries.

CompNet - The CompNet database has been developed by the European System of Central Banks (ESCB). Under the coordination of the European Central Bank, each National Central Bank has produced a set of sector- and year-level productivity indicators running the same routines on a national sample of firm-level data. Thus, the CompNet is a cross-country panel dataset that includes, by year and sector, harmonized and comparable information across countries (see CompNet Task Force, 2014) on: (i) inputs and output of the production function, (ii) productivity-related indicators such as labour productivity, total factor productivity (TFP); and (iii) allocative efficiency indicators, such as the Olley and Pakes (1996) covariance. The time coverage of the sample is generally the period 1995-2011, although important differences across countries remain given that some countries like Czech Republic, Hungary, Italy, Poland, Romania and Slovakia have data only from the early 2000s. Our

[1] These restrictions underpin the finding by Arkolakis et al. (2012) that several trade models share the same welfare properties.

CompNet database is an unbalanced panel of 2,382 observations with data for 11 European countries (Belgium, Czech Republic, Estonia, France, Germany, Hungary, Italy, Romania, Slovakia, Slovenia, and Spain), the period 1996-2011. We include all the manufacturing sectors at two digit level (NACE rev.2) with the exclusion of Tobacco (12), Printing and publishing (18), Coke and Petroleum (19). We also exclude observations for which the sectoral statistics are based on less than 10 firms. A more detailed description of the CompNet data and variables is provided in the Appendix, section A.

Eurostat/ComeExt - This database reports the values of exports (in Euros) for each EU country by 165 destination markets and 20 manufacturing sectors (CPA 2008 2 digit) over the period 1996-2011.[2] The export values are then deflated and expressed in PPP value at constant price for year 2000. Descriptive statistics of the ComExt data are reported in Table 1.

Other databases - The dyadic variables for the gravity model come from CEPII database. We include geographic distance, common border, common language, and former colony status. The historical series of the bilateral exchange rate (ER), to be used in section X, are collected from UNCTAD database. ER is defined in term of units of domestic (CompNet) currency for a unit of foreign currency, thus an increase in the ER indicates a devaluation of CompNet currencies.

4 Empirical Analysis

To test the main predictions of our theoretical model, we follow a two-stage approach. First, using a gravity-type model of trade, we calculate country-year-sector fixed effects for the sample of CompNet (exporting) countries: these fixed effects will measure the country's competitiveness in the international markets, i.e., net of importer- and bilateral-specific features. Second, we analyze if differences in such fixed effects are related not only to the average productivity but also to higher moments of the productivity distribution.

4.1 Gravity Estimation (Stage 1)

In the first stage, we estimate a gravity-type model on an unbalanced panel of 514,437 observations that includes all bilateral export flows from CompNet countries and 20 manufacturing sectors from 1996 to 2011. Following Head and Mayer (2014), our baseline specification is as follows:

[2]Notice that the first two digits of CPA 2008 coincide with the first two digits of NACE rev.2.

$$Log(Export)_{inst} = \alpha_{ist} + \beta Log(Tot.Import)_{nst} + \gamma_{in} + \epsilon_{inst} \quad (10)$$

where the dependent variable is the log of export (expressed in Euro PPP, 2005) by country of origin i, country of destination n, sector s, and year t. The term α_{ist} identifies the fixed effects of our interest, i.e., by country of origin, sector, and year). To control for differences across destination countries and sectors, while minimizing the computational burden, we include the total annual sectoral level of imports ($Tot.Import$) of the single destination country from the all the CompNet countries.[3] Finally, γ_{in} are the usual dyadic terms for the gravity equation, i.e., log of distance, common border, common language, former colony. Heteroschedasticity-Robust standard errors are always included.

Results from the baseline gravity model are reported in column 1 of Table 2. Not surprisingly, exports decrease with distance, while they increase with importing countrys demand (i.e, total imports) and when the exporting and importing country have a common border and share the same language; they increase also when the importing country has been a former colony of the exporting country. These results are fully confirmed when we restrict the sample to non-Eurozone destinations (column 2)[4] and when we include sector*year fixed effects to control for time-varying unobservable sectoral characteristics (column 3).

Using the estimated coefficients and the residuals of the above regressions, we then calculate the $\hat{\alpha}$ fixed effects. The estimated αs are highly correlated among the three specifications: correlation index between the values estimated in the first and second column is 0.98, the one between (Col. 1 and 2, Table 2), and of the first and the third column is 0.86 for the fixed affects from the augmented gravity (Col. 1 and 3, Table 2). The Table 3 reports the descriptive statistics for these effects. We observe that the most advanced European economies, such as Germany or France, show the highest values for the fixed effects, while smaller countries (e.g., Estonia or Romania) reports the lower ones. In addition, fixed effects are positively correlated with the sectoral trade balance (index of correlation equal to 0.30).[5] In light of this, we are quite confident that the estimated αs describe countries competitiveness in the international markets.

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[3] In formula, $Tot.Import_{nst} = \sum_{i=1}^{I} Export_{inst}$, i indicates each of the CompNet countries. Notice that, in this way, $Tot.Import$are measured at FOB prices.

[4] We consider as Euro countries the ones that adopted the Euro currency since 1999, plus Greece. As a result, we exclude from the gravity estimation the following destination countries: Austria, Belgium, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain.

[5] Trade balance is defined as the ratio between exports minus imports and exports plus imports. See Figure B.1, Section B, in the Appendix

4.2 Moments analysis (Stage 2)

In the second stage, we estimate the following specification for country i, sector s, and year t:

$$Comp.Ind._{ist} = a_0 + a_1 Asim_{ist-1} + a_2 Disp_{ist-1} + a_3 Mean_{ist-1} + D_n + D_s + D_t + e_{ist} \quad (11)$$

where the dependent variable is the competitiveness index ($Comp.Ind.$) as defined by the fixed effects estimated in the first stage. D_i, D_s, and D_t are dummy variables controlling, respectively, for exporting country, sector, and year time-invariant unobservable characteristics. $Mean$ is the average productivity level as computed from the CompNet database at the level of exporting country, sector and year. To identify whether higher moments of the productivity distributions affect a countrys exporting capacity, we include a measure of the asymmetry ($Asim.$) and one of the dispersion ($Disp.$) of the distribution. We compute all these measures using both labour productivity (LProd) and TFP data. All the explanatory variables are one-period lagged to minimize endogeneity concerns, a logarithmic transformation is applied to all the variables. Before moving to the results, we first describe in greater detail the asymmetry and dispersion indices.

Asymmetry - For each country-sector-year triple, we measure the asymmetry of productivity distribution as follows:

$$Asim_{ist} = \frac{Mean - Median}{st.dev.} \quad (12)$$

When $Asim.$ assumes positive (negative) values, i.e., when mean>median (mean<median), the productivity distribution is right-skewed (left-skewed). A higher asymmetry index is therefore signalling a fatter right tail of the distribution. The normalization of the asymmetry index for the standard deviation ($st.dev.$) is needed to allow comparability across countries and sectors.[6] As a robustness, we also measure asymmetry through a standard skewness index ($skew$).

Asymmetry As measures of productivity dispersion, we consider the following indicators: (i) the ratio of the 75th to the 25th percentile of the productivity distribution ($\mathbf{Disp}_{p75/p25}$), and (ii) the ratio of the 90th to 10th percentile of the productivity distribution ($\mathbf{Disp}_{p90/p10}$). Both ratios capture how

[6] Mean, median, and standard deviation are un-weighted moments computed on the firm-level data produced within the CompNet network.

much the productivity is dispersed in a country-sector-year. For example, a ratio $Disp_{p90/p10}$ equal to 2 means that the firm at the 90th percentile is twice more productive than a firm in the 10th percentile. Then, an increase in the ratios indicates that the tails of the distribution are more distant from the median, and the most productive firms (right part of the distribution) are relatively more productive than the less productive firms (left part of the distribution). For robustness purposes, we use also the standard deviation as alternative indicator of dispersion. Table 4 reports descriptive statistics for both the asymmetry indices and other variables in the estimation sample (CompNet database).[7]

4.3 Estimation Results

In this section, we present the estimation results using labour productivity. As shown in Table 5, the coefficient of average labour productivity is, as expected, always positive and statistically significant: in the spirit of Melitz-type models, higher average productivity is beneficial to a country's exporting capacity. Our novel analysis on asymmetry and dispersion reveals that a country-sector external competitiveness is also stronger when the productivity distribution is more asymmetric or right-skewed. Quantitatively, using the estimate of column 3, an increase of one standardized mean in the asymmetry index is associated to a competitiveness index 2.6 per cent higher. As basis of comparison, the effect of an increase of one standardized mean in the average labour productivity ($Mean(LProd)$) amounts to about 9 per cent the $Comp.Ind.$ (Col.5). While the estimated coefficient of asymmetry is quite stable across specifications, we find weaker and mixed results on dispersion: the coefficients of $Disp_{p90/p10}$ and $Disp_{p75/p25}$ are never statistically different from zero, the standard deviation's coefficient is instead positive and statistically significant.

To test the robustness of our results, we replicate the estimates in columns 7, 8, and 9 including $country*year$ dummies or $sector*year$ dummies. So doing, we aim at better controlling for exporting country-specific cyclical shocks across countries in the former case (Col. 1, 3, and 5), and sector-specific cyclical shocks in the latter (Col. 2, 4, and 6). The results, reported in Table 6, confirm by and large what found in the baseline specification. The only significant difference concerns the coefficient of the average productivity that is smaller or even weakly negative, indicating that average productivity and exporting competitiveness are somehow synchronized along the cycle.

The results above hold through when we use TFP instead of labour productivity. As shown in

[7] Correlations are reported in Table B.1 (Section B, in the Appendix

Table 7, we find that both average TFP and asymmetry have a positive effect on the competitiveness index. TFP dispersion has also a positive but negligible impact on the competitiveness. Quantitatively, the effect of asymmetry is analogous when using labour productivity or TFP. When we add $country * year$ dummies or $sector * year$ dummies to the specification of columns (7), (8), and (9), the main results are still valid (Table 8). In Section B in the Appendix, we show that the above results for both labour (Table B.2 and B.3) productivity and TFP (Table B.4 and B.5) do not change if we consider as dependent variable the fixed effects from the augmented gravity (Col 3, Table 2).[8]

To sum up, we find the export competitiveness of a country in a given sector, once we control for gravity-type determinants of export flows, is stronger not only when its average productivity is higher but also when, for given average, there is higher heterogeneity across firms with a larger mass of highly productivity ones. Though being based on correlations, these results confirms the validity of our working hypothesis.

5 Macroeconomic shocks

The previous section provides evidence that country-sectors with an asymmetric (right skewed) productivity distribution export more than country-sectors with a more symmetric distribution. Not only the average efficiency is an important component of countries competitiveness, but also the underlying composition of the population of firms, the higher moments of the productivity distribution. How far does heterogeneous productivity also influence the impact of exogenous macro shocks? In other words, we need to explore whether and to what extent the impact of macro shocks on exports is affected by the degree of skewness of productivity distributions. Some studies have already addressed this issue, even though with a different perspective and with different types of data. The theoretical model by Auer and Chaney (2009) provides a theoretical framework showing that the response of aggregate exports to external shocks is larger when we allow for heterogeneity in firm productivity. Their result is replicated in a general equilibrium model calibrated with the Compnet data base that looks at the effect of exchange rate fluctuations (Di Mauro and Pappadà, 2014).

The most accurate and theoretically grounded analysis and the closest to our approach is the one by Berman et al. (2012) which looks at the impact of exchange rate changes. Their analysis of French

[8]The same conclusions apply if we include the fixed effects from the gravity model without Euro countries as destination markets.

firm-level exports, within a standard gravity framework, shows that allowing for heterogeneity does influence the export elasticity to exchange rate fluctuations. At the individual level the elasticity of export volumes declines with productivity. They also carry out a sector level analysis (by aggregating firm-level data) and show, consistently with their firm-level results, that under Pareto distributions, the elasticity of exports (in value here) is lower in industries with a higher productivity dispersion (the inverse of parameter k) or concentration as measured by a Herfindal index. Both measures capture the rightward skewness of the productivity distribution.

The key underlying mechanism in the results of Berman et al. (2012) is the heterogeneous pricing-to-market behaviour of firms and the fact that this strategy is more extensively implemented by high productivity ones. Pricing-to-market means that firms do not fully pass-through a given exchange rate fluctuation to the prices of their exported products in foreign currency but also change those price when measure in domestic currency (thus counterbalancing the change in foreign currency prices). In the aftermath of a devaluation, this translates into larger profit margins rather than larger sales. Exports in value will increase to a large extent because of the rise in the domestic currency unit value of the exported products, but only to a limited extent because of a rise in volumes. This effect is especially large when the elasticity of substitution between domestic and foreign goods is relatively low, as by definition sales are not particularly price-sensitive. Berman et al. (2012), discuss several theoretical models that generate an endogenous heterogeneous pricing to market strategy. First, linear demand systems *la* Melitz (2008) where the price elasticity of demand increases with the consumer price. As high productivity firms are low cost/low price firms, they will also face a more rigid demand. Second, models with Cournot competition and nested CES demand over several sectors (Atkeson and Burstein, 2008). This works under the assumption that the elasticity of substitution between sectors is lower than within sectors. Firms with higher performance also have a larger market share. With large market shares, they face limited competition within their industry and only competition from other industries; therefore they perceive a smaller price elasticity than smaller firms (which mostly face strong competition in their industry). Third, models with distribution costs (Corsetti and Dedola, 2005) and heterogeneous quality (Baldwin and Harrigan, 2011). In these models, the higher the distribution costs and the higher the quality (most likely the high productivity firms), the lower the share of the consumer price of imported products which is influenced by exchange rate fluctuations.

On top of pricing-to-market strategy, when productivity distributions are especially skewed, a devaluation has also a limited effect on the extensive margins. In principle a devaluation lowers the threshold productivity to profitably export and therefore it favours the entry of firms previously fully focused on the domestic market. Yet, with especially asymmetric distributions, these firms would be small and not very productive. Their exports would not contribute much to aggregate export. This second effect is instead more relevant dominant in Pareto distributions, according to Auer and Chaney (2009) if the elasticity of substitution between domestic and foreign goods is high.

These arguments provide a micro grounded explanation of the macro evidence that the elasticity of aggregate export volumes to exchange rate fluctuations is relatively low (Hooper et al., 1998). This is because the largest and most productive firms account for the dominant share of exports and are also the least responsive firms to changes in relative prices.

Our analysis of the interaction between productivity heterogeneity and exogenous macro shocks is an extension of the estimations carried out in the previous section. In that we focus on exchange rates, it can be seen as a generalization of Berman et al. (2012) to a cross-country comparison of sectoral trade performances. Given that we are looking at total export by industry s from country i we construct an industry specific nominal exchange rate index as follows:

$$ER_{ist} = \sum_{n=1}^{N} NominalER_{int} \frac{export_{ins2002}}{export_{is2002}} \tag{13}$$

where the first term is the bilateral exchange rate between exporting country i (from CompNet) and destination market n, at time t. The nominal exchange rate is defined in term of units of domestic currency for a unit of foreign currency. Therefore, an increase in the exchange rate indicates a devaluation of the domestic currency. The second term of Eq. 13 is a weight: the share of destination country n in country Is total exports of in sector s. The weight captures the relative importance of a foreign market n for sector s in for each CompNet country i. The weight is time- invariant, constructed on export data in as of 2002 (the median year in our series), so as to clean ER_{ist} from changes in export shares.

We use nominal instead of real exchange rate to clean it from changes in pricing policies. Consequently, we estimate the following equation:

$$Comp.Ind_{ist} = a_0 + a_1 Asim_{ist-1} + a_2 Disp_{ist-1} a_3 Mean_{ist-1} + a_4 Asim_{ist-1} * ER_{ist-1} \quad (14)$$

$$+a_5 Disp_{ist-1} * ER_{ist-1} + a_6 ER_{ist-1} + D_n + D_s + D_t + e_{ist} \quad (15)$$

where S is the exchange rate in log-levels. We interact the shock exchange rate variable with the measures of dispersion or asymmetry, and we test the empirical model using both labour productivity and TFP indicators. The country's degree of competitiveness ($Comp.Ind.$) is measured with both fixed effect from full gravity and restricted gravity (without Euro countries). Finally, we include country, sector, and year fixed effects so that we can somehow read the coefficient of ER_{ist} as the effect of an exchange rate shock. We report the beta coefficients.

Table 9 shows the results for the baseline model (both $LProd$ and TFP) where we interact the macroeconomic shocks with asymmetry. There exists a positive and statistically significant correlation between the exchange rate and the dependent variables, that is to say that a depreciation is, as expected, associated to an improvement in export volumes. Most interestingly, the elasticity of $Comp.Ind$ to ER ($ER * Asim$) is decreasing with the asymmetry. Consistently with Berman et al. (2012), the elasticity of exports to exchange rates is lower in countries and industries with highly symmetric productivity distributions. When we interact ER with the indicator of dispersion ($Disp_{p90/p10}$), we find again that depreciation are less effective in raising export volumes where firm-level productivities are more dispersed productivity.

To test the robustness of the results, we replicate columns 1 and 2 in Table 9 considering the asymmetry of TFP distribution (on the same estimation sample). The estimated coefficients are reported in columns 3 and 4. The average TFP has a positive effect on the competitiveness index. Again, we find a statistically significant and positive effect of an exchange rate macro-shocks which, though, decreases the more the TFP distribution is right-skewed.

As a final robustness check, we include $country * year$ fixed effects, and $sector * year fixed$ effects to control for time-varying shocks across countries and sectors. We report uniquely the results for ER interacted with the asymmetry index (Table 10). The inclusion of additional fixed effects does not modify previous findings. A depreciation has a positive effect on the competitiveness, but such effect is less relevant when the firm-level productivity distribution is more asymmetric to the right.

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Tables

Table 1: Log of Export by destination, sector, year Averages‡

	Belgium	Czech Republic	Estonia	France	Germany	Hungary	Italy	Romania	Slovakia	Slovenia	Spain	Total
Mean	13.095	9.535	4.443	14.616	15.049	7.892	14.578	6.914	6.674	6.878	12.614	10.565
St.Dev	5.088	6.59	6.031	4.335	4.225	6.909	4.442	6.748	6.832	6.765	5.627	6.856
Iqr	4.905	14.748	10.243	4.642	5.157	14.056	4.866	13.187	13.098	13.266	5.285	15.842
Obs.	52065	42352	42352	52065	52065	42352	52065	42352	42352	42352	52065	514437

‡ Source: our calculation from Eurostat/ComExt. Iqr: inter quantile range.

Table 2: Gravity Model ‡

	(1) Baseline	(2) No Euro	(3) Augmented
Log(Distance)	-.444***	-.6846***	-.444***
	(-0.011)	(-0.010)	(-0.011)
Common Border	1.418***	2.445***	1.418***
	(-0.037)	(-0.049)	(-0.037)
Common Language	.5401***	.8019***	.5401***
	(-0.021)	(-0.024)	(-0.021)
Former Colony	2.196***	1.766***	2.196***
	(-0.023)	(-0.026)	(-0.023)
Log (Tot.Import)	1.319***	1.326***	1.319***
	(-0.002)	(-0.002)	(-0.002)
Obs.	514437	476817	514437
R^2	0.71	0.73	0.71

‡ Notes: OLS estimation. Robust standard errors in parenthesis. Column 2 reports gravity model without Euro country destinations. Column 3 includes sectorXyear fixed effects. Significance level: *0.10>p-value, ** 0.05>p-value, *** 0.01>p-value

Table 3: Gravity ‡

	Mean			Standard Deviation			Interquantile range		
	Col.1	Col. 2	Col. 3	Col. 1	Col. 2	Col. 3	Col. 1	Col. 2	Col. 3
Belgium	-6.89	-4.79	-5.71	1.16	1.23	1.88	1.15	1.22	0.72
Czech Republic	-10.48	-8.64	-9.14	1.29	1.32	2.25	2.14	2.2	2.04
Estonia	-15.5	-13.69	-14.16	1.61	1.57	2.66	1.69	1.65	2.16
France	-5.71	-3.49	-4.53	0.58	0.6	2.02	0.67	0.72	1.35
Germany	-4.92	-2.73	-3.74	0.52	0.56	1.95	0.53	0.55	1.5
Hungary	-12.15	-10.45	-10.81	1.53	1.59	2.08	1.66	1.73	2.01
Italy	-5.29	-3.14	-4.12	0.89	0.92	2.29	1.33	1.37	2.01
Romania	-13.09	-11.38	-11.75	1.52	1.53	2.52	2.14	2.07	2.75
Slovakia	-13.35	-11.66	-12.01	1.43	1.42	2.33	2.21	2.21	2.29
Slovenia	-13.15	-11.38	-11.81	1.32	1.33	2.21	1.65	1.66	2.32
Spain	-7.48	-5.38	-6.3	0.85	0.9	2.08	0.95	1.05	1.15

‡ Notes: our calculations from gravity model (see Table 2. The estimated fixed effects are reported in logarithmic terms.

Table 4: Averages from CompNet database (Labour Productivity)‡

	Firms per cell	Worker per firm	LProd	$\frac{LProd}{St.Dev}$	Disp.$_{p90/p10}$	Disp.$_{p75/p25}$	Asim.	Skew	St.Dev.
Belgium	666.91	74.71	65.59	1.62	3.55	1.84	0.25	2.83	41.71
Czech Republic	455.28	143.65	17.36	1.52	4.32	2.06	0.27	2.5	12.12
Estonia	166.36	37.98	14.83	1.35	6.82	2.64	0.26	1.83	11.52
France	3503.63	76.91	47.32	2.07	3.07	1.76	0.23	1.84	23.31
Germany	797.92	343.05	94.1	1.62	3.41	1.83	0.22	3.69	62.82
Hungary	427.89	110.33	16.25	1.22	5.54	2.36	0.29	3.02	13.54
Italy	1429.3	41.27	47.92	2.24	2.79	1.69	0.22	1.74	21.49
Romania	2235.9	61.02	9.69	0.87	10.37	3.16	0.29	4.23	10.88
Slovakia	96.37	228.08	15.32	1.64	4.64	2.07	0.25	2.06	10.41
Slovenia	213.46	68.92	23.59	1.72	3.85	1.91	0.23	2.07	13.78
Spain	2714.85	46.27	38.84	1.75	3.61	1.9	0.23	2.31	22.44
Total	1149.28	115.12	39.02	1.63	4.43	2.05	0.24	2.51	24.34

‡ Source: our calculation from CompNet. Unit of calculation is defined by the triple country, sector, and year. Firms per cell: numbers of firms used to calculate CompNet statistics by country, region, and year.

Table 5: Baseline model - Labor productivity distribution and competitiveness index ‡

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Mean(LProd)$_{t-1}$	.1204***	.1167***	.1248***	-0.02	.1155***	.1384***	.1163***	.1234***	0.0591
	(-0.1022)	(-0.1071)	(-0.1073)	(-0.1759)	(-0.1021)	(-0.1023)	(-0.1069)	(-0.1064)	(-0.2116)
Disp.$_{p90/p10}$ (LProd)$_{t-1}$		0.0085					-0.002		
		(-0.1245)					(-0.1264)		
Disp.$_{p75/p25}$ (LProd)$_{t-1}$			-0.0095					-0.0175	
			(-0.2464)					(-0.2434)	
St.Dev. (LProd)$_{t-1}$				.1235***					.0649**
				(-0.1343)					(-0.1607)
Asim(LProd)$_{t-1}$					.0263***		.0266***	.0284***	
					(-0.5011)		(-0.5123)	(-0.5072)	
Skew(LProd)$_{t-1}$						.0399***			.0276***
						(-0.0777)			(-0.0943)
Obs.	2379	2379	2379	2379	2379	2379	2379	2379	2379
R^2	0.94	0.94	0.94	0.941	0.94	0.941	0.94	0.94	0.941

‡ Notes: OLS estimate of Eq. 11. Dependent variable: competitiveness index from Eq. 10. All the variables are in logarithmic terms. Beta coefficients reported. Robust standard errors are included in parentheses. Significance level: *0.10>p-value, ** 0.05>p-value, *** 0.01>p-value. Country, Sector, and Year dummies included.

Table 6: Robustness analysis - Labor productivity distribution and competitiveness index ‡

	(1)	(2)	(3)	(4)	(5)	(6)
Mean(LProd)$_{t-1}$	.0506*	.09***	.0674**	.0993***	-.1269**	0.0141
	(-0.1446)	(-0.109)	(-0.1405)	(-0.1086)	(-0.2774)	(-0.2163)
Disp.$_{p90/p10}$ (LProd)$_{t-1}$	0.018	0.0074				
	(-0.1437)	(-0.126)				
Disp.$_{p75/p25}$ (LProd)$_{t-1}$			-0.0052	-0.0126		
			(-0.2607)	(-0.2453)		
Asim(LProd)$_{t-1}$	.0253***	.0291***	.0287***	.0318***		
	(-0.4848)	(-0.5385)	(-0.4772)	(-0.5328)		
Skew(LProd)$_{t-1}$					0.0053	.0259***
					(-0.0988)	(-0.0997)
St.Dev.(LProd)$_{t-1}$					.1642***	.0855***
					(-0.1814)	(0.1656)
Obs.	2379	2379	2379	2379	2379	2379
Fixed Effect 1	Country x Year	Sector x Year	Country x Year	Sector x Year	Country x Year	Sector x Year
Fixed Effect 2	Sector	Country	Sector	Country	Sector	Country
R^2	0.942	0.946	0.942	0.946	0.942	0.946

‡ Notes: OLS estimate of Eq. 11. Dependent variable: competitiveness index from Eq. 10. All the variables are in logarithmic terms. Beta coefficients reported. Robust standard errors are included in parentheses. Significance level: *0.10>p-value, ** 0.05>p-value, *** 0.01>p-value. Country*Year, and sector dummies included in columns (1), (3), and (5). Sector*year, and country dummies included in columns (2), (4), and (6).

Table 7: Baseline model - TFP distribution and competitiveness index ‡

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Mean(TFP)$_{t-1}$	.2144***	.2096***	.2105***	-0.0084	.2102***	.2594***	.2073***	.2081***	.4091***
	(-0.0486)	(-0.0487)	(-0.0488)	(-0.1116)	(-0.0484)	(-0.0497)	(-0.0486)	(-0.0487)	(-0.1375)
Disp.$_{p90/p10}$ (TFP)$_{t-1}$		0.011					0.0069		
		(-0.099)					(-0.1003)		
Disp.$_{p75/p25}$ (TFP)$_{t-1}$			0.0107					0.006	
			(-0.1991)					(-0.2009)	
St.Dev. (TFP)$_{t-1}$				.219***					-.1426*
				(-0.1113)					(-0.1321)
Asim(TFP)$_{t-1}$					.0243***		.0235***	.0235***	
					(-0.3901)		(-0.3902)	(-0.3896)	
Skew(TFP)$_{t-1}$						.051***			.0609***
						(-0.0527)			(-0.0653)
Obs.	2379	2379	2379	2376	2379	2375	2379	2379	2375
R2	0.939	0.939	0.939	0.939	0.939	0.94	0.939	0.939	0.94

‡ Notes: OLS estimate of Eq. 11. Dependent variable: competitiveness index from Eq. 10. All the variables are in logarithmic terms. Beta coefficients reported. Robust standard errors are included in parentheses. Significance level: *0.10>p-value, ** 0.05>p-value, *** 0.01>p-value. Country, Sector, and Year dummies included.

Table 8: Robustness analysis - TFP distribution and competitiveness index ‡

	(1)	(2)	(3)	(4)	(5)	(6)
Mean(TFP)_{t-1}	.1823***	.186***	.1842***	.1865***	.3023***	.3605***
	(-0.0492)	(-0.0484)	(-0.0496)	(-0.0486)	(-0.145)	(-0.1352)
$\text{Disp.}_{p90/p10}\ \text{(TFP)}_{t-1}$	.0145*	0.0054				
	(-0.1053)	(-0.0971)				
$\text{Disp.}_{p75/p25}\ \text{(TFP)}_{t-1}$			0.0122	0.005		
			(-0.2041)	(-0.2035)		
Asim.(TFP)_{t-1}	.0244***	.0276***	.0243***	.0275***		
	(-0.3846)	(-0.414)	(-0.3846)	(-0.4144)		
Skew(TFP)_{t-1}					.059***	.0607***
					(-0.0669)	(-0.0666)
$\text{St.Dev.(TFP)}_{t-1}$					-0.0567	-0.1109
					(-0.1403)	(-0.1318)
Obs.	2379	2379	2379	2379	2375	2375
Fixed Effect 1	Country x Year	Sector x Year	Country x Year	Sector x Year	Country x Year	Sector x Year
Fixed Effect 2	Sector	Country	Sector	Country	Sector	Country
R^2	0.941	0.944	0.941	0.944	0.942	0.945

‡ Notes: OLS estimate of Eq. 11. Dependent variable: competitiveness index from Eq. 10. All the variables are in logarithmic terms. Beta coefficients reported. Robust standard errors are included in parentheses. Significance level: *0.10>p-value, ** 0.05>p-value, *** 0.01>p-value. Country*Year, and sector dummies included in columns (1), (3), and (5). Sector*year, and country dummies included in columns (2), (4), and (6).

Table 9: Labour productivity & TFP - Macroeconomic shocks ‡

	(1)	(2)	(3)	(4)
	LProd		TFP	
	Comp.Ind.	Comp.Ind.	Comp.Ind.	Comp.Ind.
	All	No Euro	All	No Euro
Mean_{t-1}	.1206***	.1145***	.1902***	.1799***
	(-0.1007)	(-0.104)	(-0.0505)	(-0.0525)
$\text{Disp.}_{p90/p10t-1}$	0.0112	0.0102	-9.70E-04	-0.0017
	(-0.1327)	(-0.1342)	(-0.107)	(-0.1091)
Asim_{t-1}	.0252***	.023***	.0344***	.0329***
	(-0.4594)	(-0.4688)	(-0.3813)	(-0.3931)
ER*Asim_{t-1}	-.0865**	-.0869**	-.0276*	-.0262*
	(-0.3223)	(-0.3328)	(-0.155)	(-0.1608)
ER_{t-1}	.5283***	.4466***	.3987***	.3203***
	(-0.1528)	(-0.1579)	(-0.1361)	(-0.1409)
Obs	2376	2376	2376	2376
R^2	0.942	0.944	0.94	0.943

‡ Notes: OLS estimate of Eq. 11. Dependent variable: competitiveness index from Eq. 10 (Col1 & Col.3), and competitiveness index from Eq. 10 without Euro countries (Col2. & Col.4). All the variables are in logarithmic terms. Beta coefficients reported. Robust standard errors are included in parentheses. Significance level: *0.10>p-value, ** 0.05>p-value, *** 0.01>p-value. Country, Sector, and Year dummies included.

Table 10: Robustness - Labour productivity and macroeconomic shocks ‡

	(1) Comp.Ind. All	(2) Comp.Ind. All	(3) Comp.Ind. No Euro	(4) Comp.Ind. No Euro
Mean(LProd)$_{t-1}$	.0626**	.0951***	.0575**	.0889***
	(-0.1403)	(-0.1029)	(-0.1444)	(-0.106)
Asim (LProd)$_{t-1}$	.0239***	.0277***	.022***	.0254***
	(-0.442)	(-0.5002)	(-0.4545)	(-0.5129)
Disp.$_{p90/p10}$(LProd)$_{t-1}$	.0309**	0.0177	.0287**	0.0164
	(-0.1488)	(-0.1304)	(-0.1506)	(-0.1323)
ER$_{t-1}$	.5362***	.4484***	.45***	.3666***
	(-0.161)	(-0.1595)	(-0.1675)	(-0.1646)
ER*Asim$_{t-1}$	-.088**	-.069*	-.089**	-.0695*
	(-0.3415)	(-0.3404)	(-0.3528)	(-0.3507)
Obs.	2376	2376	2376	2376
Fixed Effect 1	Country*Year	Sector*Year	Country*Year	Sector*Year
Fixed Effect 2	Sector	Country	Sector	Country
R2	0.942	0.945	0.945	0.947

‡ Notes: OLS estimate of Eq. 11. Dependent variable: Col.1 and 2 fixed effect from gravity model; Col.3 and 4 fixed effect from gravity model with small sample (no Euro countries). All the variables are in logarithmic terms. Beta coefficients reported. Robust standard errors are included in parentheses. Significance level: *0.10>p-value, ** 0.05>p-value, *** 0.01>p-value. Country, Sector, and Year dummies included.