The Exchange rate, asymmetric shocks and asymmetric distributions

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Abstract

The elasticity of exports to exchange rate fluctuations has been the subject of a large literature without a clear consensus emerging. Using a novel sector-level dataset based on firm level information, we show that exchange rate elasticities double in size when the country and sector specific firm productivity distribution is taken into account in empirical estimates. In addition, exports appear to be sensitive to appreciation episodes, but rather unaffected by depreciations. Finally, only rather large changes in the exchange rate appear to matter.

JEL codes: F14, F41, F31

Keywords: exchange rate elasticity, bilateral trade, productivity dispersion, TFP

Non-technical Summary

The link between exchange rates and international trade has been the subject of a broad body of literature without a clear consensus on the size of the effect emerging. Overall, there is a disconnect between estimates using aggregate data and the ones using firm level information: macro estimates tend to be insignificant or very close to zero while micro based research tends to find significant and economically meaningful results. This paper attempts to bridge the gap between these two strands of the literature by using sector level productivity statistics derived from firm level data as additional explanatory variables for exports performance.

The main value added of the paper is empirical and derives from the use of a novel data set of productivity statistics for 22 sectors in 10 European Union (EU) countries over 11 years, constructed from firm level data, as part of the CompNet project at the ECB (Lopez-Garcia, di Mauro et al. 2015).

Four main results emerge from our estimations:

1. The inclusion of the productivity distribution in the export equation drastically affects the average elasticity estimate by reducing unobserved bias. In our benchmark specification, it more than doubles the estimated elasticity from 34% to 77%. Having derived sector specific elasticities allows us also to compute country and EU-wide sector specific elasticities that are reliably identified.
2. In line with previous literature, the exchange rate elasticity of exports is lower in sectors where the dispersion of firm productivity is higher.
3. Exports appear to react mostly to appreciations rather than depreciations. More specifically, in our preferred specification, the exchange rate elasticity is about 80% in the case of appreciation and statistically not significant in the case of depreciation. Moreover, the size of the coefficient in case of appreciation is much larger than the baseline estimate, indicating that most of the empirically estimated elasticity results from firms' response to appreciation. The negative relationship between a sector's productivity dispersion and export elasticity still holds, but it is significant only in the case of appreciation.
4. Exchange rate movements matters more when they are relatively sizeable. To show this, we split the sample in relation to the size of the exchange rate change – i.e. outer 20% and 10- 90% range of the distribution, respectively. Results show that in the case of small movements – which in our sample are those between 9% depreciation and 12% appreciation – the exchange rate elasticity is smaller than for extreme movements.

1. Introduction

The link between exchange rate movements and international trade has been the subject of a large volume of literature. While theoretical models predict that exchange rate depreciations would boost exports and an appreciation would inhibit them, the empirical literature has yet to find a consensus on the size and relevance of such effects. A long line of research using aggregated time series data (Kenen and Rodrik (1986), Hooper et al. (1998), Bahmani-Oskooee and Ratha (2008), among others) has found that the elasticity of exports to exchange rates is rather small, if significant at all. Most studies found values ranging from zero to around two, with most plausible values well below unity.

However, a recent strand of literature, has found that the impact of exchange rate movements on exports is rather substantial when firm level data are utilised (Tybout and Roberts (1997), Goldberg and Tracy (1999) or Verhoogen (2008)). This difference between macroeconomic empirical estimates and microeconomic ones has been dubbed in the literature as the "exchange rate disconnect", one of the 6 puzzles in international macroeconomics identified by Obstfeld and Rogoff (2000).

In this paper, we re-examine empirically the issue, also by taking a more disaggregated view. More specifically, we estimate how the exchange rate elasticity of exports varies for a broad set of European countries when the productivity distribution at the sector level is taken into account. To do so, we build on Dekle et al. (2009) and Berman et al (2012).

Our contribution to the literature is mainly empirical and consists in two main additions. First, unlike previous research based on single countries firm level data (e.g. Berman et al.,2013, for France) we use a new and expanded dataset of sector level productivity statistics for 22 manufacturing sectors in 10 EU countries over 12 years, based on firm level balance sheet data. Very importantly, the data set is constructed in such a fashion to ensure cross-country comparability (Lopez-Garcia, di Mauro et al. (2015)). By using a disaggregated dataset, we also partly correct for the downward bias in the elasticity estimates, originating from the aggregation of firm level data (as underlined by Dekle et al. (2009)).

Second, we use a more general approach in characterizing the sectors' productivity distribution: whereas previous literature (e.g. Berman et al. (2012)) use a Herfindahl concentration index and an estimated Pareto parameter for the productivity distribution, implicitly assuming a specific type of distribution[1], we use the second and third moments of the underlying firm-level productivity data.

Empirically, our left hand side variable is the total value of bilateral exports – by sectors- to all possible trading partners. Our regressors include the bilateral real exchange rate, alone as well as interacted with

[1] The true productivity distribution is unlikely to be Pareto, as argued among many others by Rossi-Hansberg & Wright (2007), Bee et al. (2014), Head et al. (2014). Assuming Pareto leads to fatter tails, potentially biasing the results upward.

two productivity distribution statistics, namely the standard deviation and skewness. The standard deviation controls for the dispersion and overall level of productivity, as there is a strong link between the average TFP and the sector's standard deviation, while the skewness, unit less and typically positive in our data, controls for the degree of asymmetry in the distribution.

Four main results emerge from our estimations:

1) The inclusion of the productivity distribution in the export equation drastically affects the average elasticity estimate by reducing unobserved bias. In our benchmark specification, it more than doubles the estimated elasticity from 34% to 77%. Having derived sector specific elasticities allows us also to compute country and EU-wide sector specific elasticities that are reliably identified.
2) In line with previous literature, the exchange rate elasticity of exports is lower in sectors where the dispersion of firm productivity is higher.
3) Exports appear to react mostly to appreciations rather than depreciations. More specifically, in our preferred specification, the exchange rate elasticity is about 80% in the case of appreciation and statistically not significant in the case of depreciation. Moreover, the size of the coefficient in case of appreciation is much larger than the baseline estimate, indicating that most of the empirically estimated elasticity results from firms' response to appreciation. The negative relationship between a sector's productivity dispersion and export elasticity still holds, but it is significant only in the case of appreciation.
4) Exchange rate movements matters more when they are relatively sizeable. To show this, we split the sample in relation to the size of the exchange rate change – i.e. outer 20% and 10- 90% range of the distribution, respectively. Results show that in the case of small movements – which in our sample are those between 9% depreciation and 12% appreciation – the exchange rate elasticity is smaller than for extreme movements.

Following a brief account on the conceptual underpinnings (section 2) and related literature (section 3), sections 4 and 5 report on the data used in the empirical estimation and the results, respectively. Section 6 concludes.

2. Conceptual underpinning

That firms are heterogeneous in terms of productivity is a well-established fact of the firm-level literature, starting with the seminal works of Bernard and Jensen (1995, 1999a, 1999b). While only a subset of firms exports, even among exporters, there is huge variation in the productivity characteristics of firms, both within sectors and countries, as well as across them. Consequently, a sector's productivity distribution will vary with its sectorial composition and this will influence its response to exchange rate movements.

Sectors that are more heterogeneous in terms of productivity will have lower exchange rate elasticity: as productivity has a lower zero bound, more heterogeneity implies a concentration of highly productive firms. These top firms have lower exchange rate elasticity than less productive ones. Several theoretical models can account for this negative relation between productivity and elasticity: imperfect Cournot competition (Atkeson and Burstein, 2008), linear demand (Melitz and Ottaviano, 2008) or distribution costs priced in local currency (Corsetti and Dedola, 2005, Berman et al, 2012). Dekle et al. (2014) argues that in response to a negative exchange rate shock, firms will pull out from export markets first products with lower productivity. Since these low productivity products are numerous but have low share in aggregate exports, firm level exports will exhibit a large elasticity while aggregate level export will be less elastic.

Additional arguments can be made that large firms may have other objectives beside immediate profits, such as acquiring and maintaining market shares or having a presence in as many markets as possible. Moreover, since the largest exporters are also the largest importers an unfavourable exchange rate movement in their export market can be offset by a favourable movement in the supply market. Since the aim of this paper is empirical, we do not take a particular stance on which channel is the dominant one.

Besides looking at the impact of exchange rate movements on export values, we also investigate whether exchange rate elasticities differ between episodes of appreciation and depreciation. A key assumption of most theoretical models and empirical papers in this area is that the elasticity of exports to exchange rate fluctuations is linear (or log-linear) and symmetric between positive and negative changes. We hypothesize that depreciation will have an opposite effect than an appreciation but that the elasticity coefficients don't need to have the same magnitude.

The key determinants of asymmetry are likely to be two rigidities, i.e. prices are rigid downwards and quantities upwards. In the case of depreciation, exporters could earn extra profits in the domestic currency for each unit sold. Alternatively, they may choose to lower their prices in hopes of selling more and gaining a larger market share, but since setting up a distribution network takes time and is expensive, they may be unable to increase the quantity sold. On the other hand, a currency appreciation makes exporters less competitive, affecting their export capacity. They can choose to lower their prices in order to maintain their market share, but there are obvious constraints on how much they can lower their prices before incurring negative profits. Faced with this downward rigidity, the rational choice for exporters is to decrease the quantity they sell abroad. As a result of these two rigidities (upward quantity rigidity and downward price rigidity), we expect that depreciations will have smaller effects than appreciations, as most of the exchange rate adjustment tends to happen on the quantity side (Bernard and Jensen, 2004a and 2004b, Bugamelli and Infante, 2003).

We further test whether large exchange rate movements have a more pronounced effect than small ones. As we are looking at the impact of exchange rate at the one-year interval, we expect that both nominal and real rigidities will play a significant part in hampering immediate price or quantity adjustments. While we cannot test which rigidities are present and significant, we expect menu costs, adjustments costs, setting a distribution network, quantities and prices negotiated in advance to all play some part. A change in the exchange rate is likely to make some of the agreed upon prices and quantities less than optimal. If the exchange rate variation is small, so will be the change in profits; due to adjustments costs, it may actually be loss inducing to optimally respond to the new exchange rate. However, to the extent that change in the exchange rate is large, firms will have no choice but to respond, even taking into account adjustment costs as in Baldwin and Krugman (1989).

3. Related literature

The link between exchange rates and international trade has been extensively covered in the literature, using a wide range of tools and methods. Some papers use real effective exchange rates (REER) and some use bilateral ones, some papers focus on the nominal exchange rate, as the tool of policy makers, while others focus on the real exchange rate (RER), as the driver of export competitiveness[2]. In this literature review, we will not attempt to cover all papers on this topic but rather focus on the ones addressing productivity and asymmetry issues.

While many papers deal with the impact of exchange rates on trade aggregates[3], the literature on the asymmetric impact of exchange rate movements is much sparser. Raham and Serletis (2009) use a structural VAR with multivariate GARCH-in-Mean errors model to look at the asymmetric impact of exchange rate shocks using monthly aggregate US data. They find that the impact of an appreciation on exports is not the mirror image of that of a depreciation and that the response to a depreciation is very imprecisely estimated. Employing a similar methodology, Grier and Smallwood (2013) look at the impact of bilateral RER fluctuations for 27 developed and developing countries. They find that there are significant differences between developed and developing countries in their response to exchange rate shocks. While the authors find that in the case of exchange rate appreciations, export values decline across the board, the results for depreciations are mixed: only for a handful of countries do the elasticities have the expected sign, and even then, the estimates are insignificant. Fang et al. (2009) look into the effect of exchange rate risk on exports from eight Asian countries to the US. They find that in both periods of appreciations and depreciation, risk affects exports, but for five of the eight countries covered the results are asymmetric. Edwards and Yeyati (2004) investigate the asymmetric effects that terms of trade shocks have on countries' output and they find that the output response is larger for negative than for positive shocks.

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[2] The link between nominal and real exchange rates is fairly well established, especially in the short and medium run. See Vaubel (1976), Edwards (1989), Connolly and Taylor (1976), Bahmani-Oskooee and Miteza (2002) or Cheung and Sengupta (2013) for research in this regard.

[3] For instance Bun and Klassen (2014), Berthou(2008)

Cheung and Sengupta (2013), using a firm level panel dataset of Indian firms, investigate how REER movements affect the share of exports in firms' total sales. They find that a REER appreciation is associated with a decrease in export share, as the textbook case would predict. However, when separately investigating appreciation and depreciation episodes they find that appreciation is associated with a stronger export share change while the effect of depreciation is negligible. In addition, they find that the impact of exchange rates fluctuations is stronger for firms with small export shares, which are likely to be the least productive.

Other papers fully incorporate productivity in their regressions. Berman et al. (2012) use detailed French firm level data to investigate how firm level export volumes and prices react to exchange rate fluctuations, while controlling for firm level productivity. They find a very low response of prices to exchange rates (an implicit elasticity of around 8%) and larger elasticity of quantities, but still far below unity (around 40%). They find that firms that are more productive are more likely to adjust their prices upwards and quantities downwards in response to exchange rate depreciations. Aggregating their data into 114 sectors, they find that the elasticity of exports is lower in sectors with a higher degree of exporter concentration.

Using EUKLEMS sector level TFP data, Dekle and Fukao (2009) investigate how the Plaza Accords in the 80s influenced bilateral trade between the US and Japan. They find that the yen appreciation had a significant negative effect on Japanese competitiveness but the effect was very heterogeneous across sectors. By 2004, the impact of the appreciation had been neutralized in highly productive growth sectors, whereas in laggard sectors the competitiveness gap had remained significant.

Dekle et al. (2007) examine the difference between macroeconomic and microeconomic estimates. They show that the traditional equations and method used to estimate export elasticities lead to inconsistent estimates due to omitted variable bias. They test these predictions on Japanese data and show that when using aggregate data, the estimates are not significant while when firm level data are used, estimates are statistically significant with substantially larger values. Their exchange rate elasticity estimates range from 41% to 71%, depending on the specification. They further show that when micro-data is not readily available, including productivity statistics in the aggregate regression helps to reduce the bias, albeit not completely, as it is impossible to control for the full joint distribution of exports and productivity.

Dekle et al. (2013) build a dynamic model in which they find that REER depreciations are associated with increased exports if shocks to TFP and foreign assets liquidity demand are important. Working with a product level model, they argue that if firm's productivity for certain products is close to the export threshold, export elasticity measured at the firm level will be large since the firms will be likely to stop exporting them in response to a shock. However, the exchange rate elasticity will tend to be smaller for products that are nearly always exported. As these productive products have a considerable market share, the overall exchange rate elasticity will be small. Moreover, these high productivity products are likely to be preponderantly produced by high productivity firms, therefore generating variety in firms' responses to exchange rate movements.

Within the broader literature, our paper is also connected to Imbs and Mejan (2009, 2010) and Feenstra, Russ, and Obstfeld (2014) who estimate various trade elasticities and argue that macro level equations are downward will be biased due to the aggregation. Finally, as we investigate asymmetries, our paper is related to the exchange rate pass-through literature, where a number of papers have looked into this. Pollard and Coughlin (2004) investigate how pass-through prices are affected by the size and direction of the exchange rate movement in the US. They find that the response to appreciations and depreciations is asymmetric and importers are more likely respond only to large changes in the exchange rate. Bussiere (2006) performs a similar exercise with G7 data and looks at both export and import prices at the sector level. He also finds strong evidence in favour of both asymmetry and non-linear response to exchange rate movements. Similar results are found by Delatte and Lopez-Villavicencio (2012) for both the short and long run. Auer and Schoenle (2013) examine how the exchange rate pass-through varies across sectors. They find that the pass-through differ depending upon on which side – i.e. from the importers or exporters - the exchange rate adjustment happens; also the pass-through is higher the larger the trade partner's import share. Auer and Schoenle (2014) further look at how market structure affects the response of importers to exchange rate movements. They find that there is substantial pricing-to-market and the price response of domestic firms to exchange rate movements is limited in nature as imported goods differ from domestically produced ones.

4. Data and Empirical Specification

4.1. Data

Our main data source is the dataset produced by CompNet, the Competitiveness Research Network of the European Central Bank. In this section we will only offer a brief overview of the data while we redirect the reader to consult López-García, di Mauro et al. (2015) for a general description of the dataset and how it was constructed and Berthou et al. (2015) for a detailed description of the trade variables within the dataset.

The data is collected as part of a distributed code approach using balance sheet data from 21 European countries. As firm-level data are confidential and their usage is typically restricted to one country analysis, in order to be able to pool countries and observe cross-country effects one has to work with a higher level of aggregation. CompNet aggregates the firm level information for each country to two digit NACE 2 levels[4]. At this level of aggregation, we have a plethora of statistics in each sector. While the list of available statistics and indicators is staggering, for the purposes of this paper we will only be using productivity distribution statistics for the subset of exporting firms. However, not all countries involved in the project have external trade data so we limit ourselves to 10 countries, listed in column (1) of Table 1. One key feature of the database is that sector level estimates of productivity are obtained directly from firm level data. The sample of exporters is restricted to manufacturing firms, i.e. those classified as having the main productive activity within sectors 10-32 of the NACE classification[5].

As we are particularly interested in heterogeneity across sectors, we will be focusing on higher order statistics of productivity: namely dispersion and skewness. We define productivity as Total Factor productivity (TFP), estimated at the firm level using a methodology based on Wooldridge (2009). For details on the exact estimation procedure, check Box 3 of López-García, di Mauro et al. (2015). In the appendix to this paper we report on robustness checks on estimates, in redoing all the exercises replacing TFP with apparent labour productivity as the variable of interest.

In order to characterize the productivity distribution we consider two measures: the skewness and the dispersion. For skewness we use the standard definition, derived from the distribution's third moment while for dispersion we choose to use the standard deviation[6]. As we care about variations in TFP's dispersion and skewness, we will be focusing on the characteristics of these two moments of the TFP distribution and not on those of the TFP itself. Table 1 presents some key statistics on these higher moments: The standard deviation measure follows roughly the country's level of development: more developed countries will have a larger mean TFP, and implicitly also a larger standard deviation. Skewness is somewhat bound and does not follow a clear pattern depending on the countries' level of development. What is interesting, is that skewness is not always positive, indicating that in some sectors there are more high productivity firms than low productivity ones.

[4] Special care was devoted to harmonizing definitions of variables, the outlier treatment and the use of deflators

[5] We exclude sector 12 (Manufacturing of Tobacco) as it is present in only a few countries and there are only a handful of producers, too few to draw meaningful inferences. See appendix II for a complete list of sectors.

[6] We consider one alternative for each higher moment: we use the interquartile range as a measure for dispersion and the mean/median ratio as an asymmetry measure. All results with either statistic are virtually identical and we do not present them here.

Table 1: summary statistics on the standard deviation and skewness of TFP

Country	TFP Standard deviation				TFP Skewness			
	Mean	Median	Minimum	Maximum	Mean	Median	Minimum	Maximum
Belgium	41.44	38.41	11.41	114.11	1.48	1.60	-0.85	4.05
Croatia	10.15	7.85	1.90	44.08	1.33	1.21	0.17	3.71
Estonia	5.75	4.88	1.57	15.04	1.04	0.91	0.02	3.71
Finland	30.47	24.11	8.93	107.64	0.97	1.05	-1.08	2.33
Italy	16.96	15.69	5.74	44.14	1.16	1.21	-0.32	2.43
Lithuania	5.88	5.27	1.22	20.06	1.27	1.12	0.04	3.31
Portugal	12.86	14.32	2.58	30.15	1.35	1.33	-0.11	3.33
Romania	3.61	2.74	0.66	23.60	1.71	1.63	0.10	4.83
Slovenia	6.75	5.48	1.80	22.20	1.00	0.92	-0.65	3.32
Spain	16.87	16.06	4.52	36.76	0.86	0.85	-0.57	2.67

Note: Results are pooled over years and sectors

Our productivity data is complemented with data on bilateral trade between each country in the CompNet dataset and every possible partner in the world. The data was downloaded from the UN Comtrade repository through the WITS interface. Trade data were first downloaded in 4-digit ISIC 3 format, to be subsequently converted and aggregated into NACE 2, 2 digit industries to match the productivity data. Finally, as trade data is in nominal terms, it was converted to constant 2005 units, using a set of sector specific deflators prepared for the CompNet project.[7] Table 2 below provides some basic characteristics of export flows by country. The left hand side panel provides information on years covered, number of exporters and number of trading partners for each country, pooling all sectors together. On the right, the table shows some key statistic related to the bilateral exports by country.

[7] Cheung and Sengupta (2013) analyse how the effect of exchange rates on real exports varies when using several different deflators. Their results are virtually unchanged regardless of the price adjustments they perform.

Table 2: Summary statistics on exports

Country	Years	Average number of exporters	Average number of trading partners	Bilateral exports (millions of Euros)[8]				
				Mean	Median	S.D.	Min	Max
Belgium	2001-2011	3749	166	56	1	344	0	8794
Croatia	2002-2011	2398	91	3	0	13	0	298
Estonia	2001-2012	1046	86	3	0	14	0	397
Finland	2001-2012	2389	141	15	0	73	0	2051
Italy	2001-2012	44626	174	71	2	297	0	6912
Lithuania	2000-2011	1088	97	3	0	13	0	374
Portugal	2006-2012	8750	143	9	0	53	0	1400
Romania	2003-2012	4374	113	8	0	38	0	1017
Slovenia	2001-2012	1939	109	6	0	27	0	782
Spain	2001-2012	9443	164	35	1	225	0	10600

Note: Left panel shows the number of exporting firms and average trading partners per country averaged across years. The right panel shows the export value statistics across trading partners averaged across time and sectors. Zeros values are not true zeros but are due to rounding error. We only keep positive trade flows. Our results do not change if we exclude very small trade flows.

GDP and other country characteristics and bilateral real exchange rates, were obtained from Catini et al. (2010). As the real exchange rates were vis-a-vis the US dollar, we converted them into national currency ones for the European countries assuming that no arbitrage was possible.

In order for an export destination to feature in our dataset, we must have both exchange rate data and trade data for a given year. Naturally, we do not have a balanced panel as for some partners it was impossible to obtain real exchange rates and, more frequently, some country pairs simply do not trade. While the problem of zero trade has received a lot of attention (e.g. Chaney, 2008; Santo-Silva and Tenreyro, 2004) and several methods have been proposed to deal with missing values, in our present exercise we do not consider these issues relevant. Specifically, we are interested in how exchange rate fluctuations affect existing and on-going trade relationships. We do not consider exchange rate movements that induce countries to start or stop trading.

Table 3 below shows some basic statistics on the yearly movements of bilateral exchange rates by country, that is the delta log of the exchange rates. Overall, the exchange rate movements experienced by the countries in our sample were quite similar. As we are looking exclusively at European countries this comes

[8] Note that the zeros values are not true zeros but are due to rounding error. We only keep positive trade flows. Our results don't change if we exclude very small trade flows.

as little surprise, as they are likely to be exposed to common shocks vis-a-vis third parties. What stands out in Table 3 is the difference between old and new EU countries. While for Belgium and Finland the average change in the exchange rate has been below 1%, for countries such as Romania, Estonia and Lithuania, it has been over 3 %. Also of interest is that in our sample, with the exception of Portugal, all countries had a negative average change in the exchange rate, indicating increasing in price competitiveness. For mature EU countries, this is likely due to the initial devaluation of the Euro in the first part of the 2000s. For Central and Eastern European (CEE) countries, it is likely due to EU accession. Mature EU countries had a roughly equal share of appreciation and depreciation episodes while for CEE countries, only about a third of bilateral relationships were appreciation, going as low as about 26 % in the case of Romania. Nonetheless, for all countries the standard deviation was between 8 and 10%, indicating a rather stable exchange rate.

Table 3: Statistics on the movements of the exchange rate

	Delta Exchange rate			Share of	
	Mean	Median	S.D.	Appreciation	depreciation
Belgium	-0.63%	0.01%	9.37%	50.19%	49.81%
Croatia	-1.75%	-1.07%	8.02%	41.97%	58.03%
Estonia	-3.41%	-2.82%	8.11%	27.26%	72.74%
Finland	-0.35%	0.37%	9.18%	53.58%	46.42%
Italy	-0.94%	-0.26%	9.61%	47.16%	52.84%
Lithuania	-3.60%	-2.30%	8.11%	30.32%	69.68%
Portugal	2.01%	1.01%	8.10%	57.10%	42.90%
Romania	-5.20%	-6.14%	8.96%	26.44%	73.56%
Slovenia	-2.07%	-0.81%	8.69%	40.90%	59.10%
Spain	-1.38%	-1.04%	9.75%	40.53%	59.47%

Note: The table for each country shows the statistics on bilateral exchange rates pooled overall trade partners and years in the sample

4.2. Empirical specification

In order to estimate the elasticity of exports on the exchange rate we start from a standard gravity equation where we have exports on the left hand side, countries' GDPs and bilateral controls on the right hand side, along with our variables of interest: the real exchange rate and productivity statistics terms interacted with the exchange rate.

$$(1)\ \ln\left(X^j_{ni,t}\right) =$$
$$\alpha + \beta ln\left(RER_{ni,t}\right) + \gamma ln\left(RER_{ni,t}\right) \times \ln Prod\ D^j_{n,t} + \sigma ln\left(RER_{ni,t}\right) \times \ln Prod\ S^j_{n,t} +$$
$$\varsigma_1 \ln Prod\ S^j_{n,t} + \varsigma_2 \ln Prod\ D^j_{n,t} + \delta_1 D^j_{ni,t} + \delta_2 GDP_{n,t} + \delta_3 GDP_{i,t} + controls^j_{ni} + \varepsilon^j_{ni,t}$$

Where n denotes the exporting country, i the importing one, j the sector and t is the year. On the left hand side of the equation, we have the log change in bilateral exports; on the right hand side, RER denotes the bilateral real exchange rate between the two countries, D is a pair and sector specific demand shifter, whose construction is detailed below. *Prod S* and *Prod D* are productivity distribution higher order statistics we will be looking at. The regression contains both importer and exporter GDP to control for the relative size of the economies.

Since our interest also lies in the non-linear response of exports to exchange rate fluctuations, we estimate our model in first differences. This estimation strategy is a popular approach in the literature (see Bahmani-Oskooee and Ratha (2008) for an overview, likely due to the time-series focus that this research has traditionally adopted. However, there are panel-setting approaches, which also run the models in first differences, such as Cheung and Sengupta (2013).

Note that by taking the first difference of the equation above, the standard gravity controls, such as distance or common border, drop out. The same is true for whatever sector and country fixed effects we may also wish to include. Finally, other typical gravity controls such as population vary too little from year to year and we do not include them[9]. The first difference specification we will run is equation (2), where our variables of interest are β, γ_1 and σ_1[10]. Our benchmark specification is very similar to the sector level regression in Berman et al. (2012) and to the first difference one in Cheung and Sengupta (2013).

$$
\begin{aligned}
(2)\quad \Delta\ln\left(X_{ni,t}^{j}\right) = {} & \alpha + \beta\Delta ln\left(RER_{ni,t}\right) + \gamma_1\Delta ln\left(RER_{ni,t}\right) \times \ln Prod\ D_{n,t}^{j} + \gamma_1\Delta ln\left(RER_{ni,t}\right) \times \\
& \ln Prod\ D_{n,t}^{j} + \sigma_1\Delta\ln\left(RER_{ni,t}\right) \times \ln Prod\ S_{n,t}^{j} + \\
& \gamma_2 ln\left(RER_{ni,t}\right) \times \Delta\ln Prod\ D_{n,t}^{j} + \gamma_3\Delta\ln\left(RER_{ni,t}\right) \times \Delta\ln Prod\ D_{n,t}^{j} + \sigma_2 ln\left(RER_{ni,t}\right) \\
& \times \Delta\ln Prod\ S_{n,t}^{j} + \sigma_3\Delta ln\left(RER_{ni,t}\right) \times \Delta\ln Prod\ S_{n,t}^{j} + \\
& \delta_1\Delta D_{ni,t}^{j} + \delta_2\Delta GDP_{n,t} + \delta_3\Delta GDP_{i,t} + \Delta\varepsilon_{ni,t}^{j}
\end{aligned}
$$

In order to control for foreign demand, we construct a trade weighted measure of foreign income similar to the one used in the literature to construct industry specific real effective exchange rates (Goldberg, 2004). For country pair *in* at time *t* we generate the following weights in sector *j*:

[9] We have run versions of our equations that include exporter, importer and/or sector dummies and their interactions as controls. Results are change little when we include country, time or sector fixed effect in the regression, bar for a slightly higher R^2 statistic.

[10] We freely admit that the specification appears to be cumbersome but the first difference specification must take into account changes in all pairs of interacted variables. We tried running a simpler version of equation (2), without the cross-product terms and the results don't change in any meaningful way. However, as the estimates are numerically different we decided to keep the full specification.

(3) $$D_{ni,t}^{j} = GDP_{i}^{t} \frac{X_{ni,t}^{j} + X_{ni,t-1}^{j}}{X_{n,t}^{j} + X_{n,t-1}^{j}}$$

Where $X_{ni,t}^{j}$ are bilateral exports at time t and $X_{n,t}^{j}$ are total exports at time *t*. We average over two consecutive years in order to smooth out any transitory shocks.

Ideally, we would like to control for both dispersion and skewness but it is instructive to see how the results change when one or both statistics are not included. Therefore, we have four specifications: a basic one where we don't control for any sectorial characteristics (that is, the γ and σ terms are absent), one which controls for the skewness of TFP, one which controls for the dispersion of TFP and one which controls for both these effects. Our preferred specification is the latter as it controls for both higher order characteristics of the productivity distribution.

In terms of data clean up, we remove observations pairs, when the exchange rate moves by more than 50% in one direction or another in a given year. This has a minimal effect since it causes the drop of only around 2000 observations. We further drop from the analysis sectors with fewer than 20 firms, as these sectors are unlikely to have robust skewness and dispersion statistics. Also, in order to have results comparable across specifications, we drop observations than have all variables present, regardless if the variables are required in that particular specification.

Results

5.1 Benchmark results

In this section, we present the results of our specifications without taking into account any of the non-linear effects discussed in the introduction. The main variables of interest are presented in the first three rows of Table 4. Column (1) shows the results without taking into account any of the higher moment of the productivity distribution. The results indicate that a 10% depreciation of the exchange rate would boost exports by about 3%. Column (2) shows the results, when taking into account the dispersion of productivity. Two aspects stand out: the coefficient of the interaction term is positive and statistically significant, indicating lower elasticity in sectors where firms are most productive. Second, when including sector specific productivity dispersion statistics, the baseline elasticity changes, more than doubling. We also find there is substantial variation in the response of sectors depending on their productivity distribution: standard deviation of TFP significantly associated with lower exchange rate elasticity. In the context of our data, a higher TFP standard deviation implies a fatter right tail for the productivity distribution and a distribution shifted more to the right, i.e. a more performing sector. Table 5 presents the country and sector specific exchange rate elasticity estimates, showing substantial variation both within and across countries. The distribution across countries is highly reminiscent of the one in Table 3 in that elasticities tend to be higher in Southern and Eastern European countries. This is expected, though, as the estimated elasticities are a log-linear function of productivity dispersion.

Table 4: Regression of delta log exchange rates on exchange rates without taking into account non-linear characteristics

	(1)	(2)	(3)	(4)
Δln(XR)	-0.356***	-0.774***	-0.355***	-0.773***
	(0.0355)	(0.129)	(0.0357)	(0.129)
Δln(XR) × ln(TFP) dispersion		0.157***		0.157***
		(0.0434)		(0.0435)
Δln(XR) × ln(TFP) skewness			-0.0121	-0.0173
			(0.0456)	(0.0461)
Δln(TFP) dispersion × Δln(XR)		-0.528		-0.548
		(0.292)		(0.315)
Δln(TFP) dispersion × ln(XR)		0.0227***		0.0323***
		(0.00700)		(0.00749)
Δln(TFP) skewness × Δln(XR)			-0.0180	0.0327
			(0.0921)	(0.0985)
Δln(TFP) skewness × ln(XR)			-0.00410**	-0.00815***
			(0.00208)	(0.00223)
ΔForeign Demand	0.00258***	0.00257***	0.00258***	0.00257***
	(0.000179)	(0.000179)	(0.000179)	(0.000178)
Δln(GDP_n)	1.404***	1.379***	1.402***	1.371***
	(0.0860)	(0.0863)	(0.0860)	(0.0863)
Δln(GDP_i)	1.444***	1.423***	1.444***	1.413***
	(0.109)	(0.110)	(0.109)	(0.110)
Observations	172,501	172,501	172,501	172,501
R-squared	0.008	0.008	0.008	0.008

*** p<0.01, ** p<0.05

Robust standard errors in parentheses. Allowing for various patterns of error clustering (by exporter/importer/sector or various combinations) does not affect the significance of results in any meaningful way, albeit for higher p-values.

Column (3) shows the results controlling for TFP skewness. The estimated exchange rate elasticity is not very different from the one in column (1) and the coefficient on skewness interaction is not significant. Finally, column (4) which is our preferred specification controls for both skewness and dispersion. These results are almost identical to those of column (2).

One puzzling result of our estimation is that skewness (line 3 in the table) has virtually zero impact on export elasticity. This result consistently appears in all our specifications. In appendix I, we discuss why the skewness may not be a good indicator of export performance and provide several stylized examples in this regard. From a more technical point of view, since the shape of the distributions is similar across sectors and countries, we may simply do not observe enough variation in order to identify the coefficient. Nonetheless, we choose to retain skewness in the list of covariates as its inclusion adds extra information, albeit in a non-straightforward fashion, on the sectors' underlying productivity distributions and its inclusion affects the magnitude of the other variables, alleviating potential bias. The variables in the middle of Table 3 are only included because they result from the mathematical derivation of the first difference. As mentioned previously, including or excluding them has a negligible effect on the sign and magnitude of the other covariates. They are, however, difficult to interpret and will not be commented upon.

The last three variables in Table 4 measure changes in foreign and domestic demand and have the expected signs. The coefficients related to GDP are significant and equal to about 1.4 across the various specifications, a value, which is in line with previous estimations of gravity models[11].

[11] See Anderson and van Wincoop (2004) for a thorough survey of the gravity literature.

Table 5: country and sector specific elasticity estimates

Sector	BE	EE	ES	FI	FR	HR	IT	LT	PT	RO	SI
Manufacture of food products	-63.5%	-34.1%	-24.2%	-38.3%	-44.4%	-41.5%	-49.4%	-41.4%	-71.7%	-52.0%	-63.5%
Manufacture of beverages		-42.3%		-42.8%	-46.7%	-37.9%	-48.0%	-37.6%	-64.8%		
Manufacture of textiles	-51.7%	-30.9%	-16.9%	-18.8%	-41.1%	-30.2%	-42.4%	-50.2%	-59.2%	-42.7%	-51.7%
Manufacture of wearing apparel	-57.5%	-31.7%	-16.6%	-17.4%	-47.1%	-29.8%	-59.6%	-57.1%	-59.6%	-53.8%	-57.5%
Manufacture of leather and related products	-53.1%	-31.5%	-28.6%	-27.5%	-41.1%	-29.7%		-51.4%	-59.3%	-50.6%	-53.1%
Manufacture of wood and of products of wood and cork, except furniture	-56.0%	-51.2%	-31.1%	-50.4%	-48.5%	-39.9%	-51.6%	-53.1%	-65.9%	-57.8%	-56.0%
Manufacture of paper and paper products		-22.6%	-18.4%	-33.1%	-39.8%	-19.2%	-36.2%	-33.5%	-62.6%	-38.7%	
Printing and reproduction of recorded media	-39.2%	-31.3%	-33.8%	-24.5%	-38.9%	-25.2%	-48.9%	-39.6%	-51.5%	-43.7%	-39.2%
Manufacture of chemicals and chemical products	-42.9%	-41.9%	-28.3%	-26.4%	-47.9%	-33.4%	-47.4%	-32.2%	-60.5%	-52.3%	-42.9%
Manufacture of basic pharmaceutical products and pharmaceutical preparations		-29.4%		-12.3%		-24.3%		-25.3%	-46.3%		
Manufacture of rubber and plastic products	-60.6%	-41.7%	-27.8%	-53.2%	-54.6%	-48.9%	-63.9%	-62.1%	-79.8%	-61.4%	-60.6%
Manufacture of other non-metallic mineral products	-63.8%	-42.2%	-28.7%	-35.9%	-61.9%	-44.8%	-67.2%	-55.4%	-77.3%	-63.7%	-63.8%
Manufacture of basic metals		-32.1%	-27.6%	-30.0%	-53.5%	-37.7%		-40.3%	-60.1%	-45.3%	
Manufacture of fabricated metal products, except machinery and equipment	-62.7%	-36.3%	-28.6%	-34.2%	-56.4%	-45.1%	-57.1%	-56.5%	-68.2%	-63.2%	-62.7%
Manufacture of computer, electronic and optical products	-41.7%	-33.8%	-13.0%	-21.4%	-31.9%	-31.7%	-40.7%	-26.8%	-50.1%	-36.3%	-41.7%
Manufacture of electrical equipment	-42.9%	-27.7%	-15.8%	-25.3%	-29.2%	-28.9%	-49.1%	-29.2%	-47.6%	-34.8%	-42.9%
Manufacture of machinery and equipment	-43.9%	-26.3%	-23.6%	-27.3%	-37.2%	-32.0%	-48.7%	-33.3%	-59.9%	-45.3%	-43.9%
Manufacture of motor vehicles, trailers and semitrailers		-25.1%	-30.9%	-39.3%	-38.5%	-32.2%		-31.0%	-60.4%	-48.2%	
Manufacture of other transport equipment		-28.3%	-12.8%	-16.6%	-25.8%	-39.8%		-35.8%	-35.3%		
Manufacture of furniture	-60.2%	-40.4%	-39.6%	-26.9%	-54.1%	-36.2%	-62.3%	-33.4%	-71.0%	-62.9%	-60.2%
Other manufacturing	-45.3%	-37.0%	-40.4%	-26.2%	-48.8%	-34.2%	-57.9%	-31.7%	-69.4%	-54.3%	-45.3%
Repair and installation of machinery and equipment	-49.9%	-38.3%	-32.6%	-21.8%	-44.9%	-37.1%	-59.5%	-31.8%	-62.7%	-51.6%	-49.9%

Note: Estimates are obtained by adding the base elasticity and multiplying the log of each sector's TFP standard deviation by the interaction coefficient obtained in Table 4. The results are averaged over time. This does not mean, though, that the elasticities are constant over time. Splitting the sample in two, we find substantially higher elasticities in the first half of the 2000 than afterwards, an effect already documented in Di Mauro et al (2008). We do not pursue this further in the paper.

Our baseline elasticity of exports increases to 77%, a figure in line with the broad literature (see Table 6 for some comparable estimates). Our results also confirm the findings in Dekle et al. (2009), in that accounting for productivity statistics alleviates the bias towards zero in macroeconomic regressions and our results are numerically close to theirs and to those in Berthou (2008). Our results are qualitatively similar to Berman et al. (2012), who run a similar regression, albeit in levels, interacting real exchange rate movements with sector level productivity dispersion. They find an elasticity of almost 90% and that more heterogeneous sectors are less sensitive to exchange rate movements. The heterogeneity estimates have the same sign, but they cannot be directly compared as they proxy productivity dispersion by a Herfindahl index of concentration and an estimated Pareto parameter fitted to the underlying sector distribution. This difference in approaches could possibly explain their higher elasticity parameters as the fatter tails of the Pareto distribution may bias the results upwards.

Table 6: Sample of exchange rate elasticity estimates in the literature

Source	Bilateral elasticity estimate
Berthou (2008)	68%
Berman et al. (2013)	40-91%
Bun and Klassen (2014)	56%
Dekle et al. (2009)	41-71%

Note: The table includes only the estimates that were derived in a manner comparable to the one in this paper.

A key result is how much the elasticity estimates change when properly accounting for heterogeneity. However, not controlling in any way for variations across countries and sectors is not a fair benchmark. Assuming no other information is available besides trade and exchange rate data, the easiest way to account for variability is to include sector and country dummies and let them interact with the exchange rate elasticity estimates. This approach has two drawbacks, though. First, sectors and countries vary by more than just productivity and the dummies capture all these distinct characteristics, obfuscating the effect of productivity variation. Second, by including dummies, we restrict the observed variability we observe, forcing us to rely more on the time dimension for identification, which in our case involves a rather short panel. We run nevertheless several versions of these dummy augmented regressions and summarize them in Table 7. The last column shows our preferred estimates for comparison.

Several results emerge. First, the R^2 does not change between models. Second, while including dummies has the advantage of producing sector and country specific estimates, these estimates lack reliability: for most counties the sector/country specific estimates are statistically indistinguishable from the average effect[12]. Third, and somewhat surprising, while including sectors dummies reduces the zero bias in the elasticity estimates, including exporter dummies actually brings the coefficient closer to zero and including both effects has no effect on the baseline elasticity estimates.

Table 7: Exchange rate base estimates under various controls

VARIABLES	(1)	(2)	(3)	(4)	(5)
Δln(XR)	-0.356***	-0.463***	-0.208***	-0.357**	-0.773***
	(0.0338)	(0.143)	(0.0730)	(0.154)	(0.129)
Δln(XR) interacted with	No controls	sector dummies	exporter dummies	sector and exporter dummies	Productivity moments
Observations	172,501	172,501	172,501	172,501	172,501
R-squared	0.008	0.008	0.008	0.009	0.008

Note: All other covariates are included in the estimation. Robust standard errors in parentheses;
*** p<0.01, ** p<0.05

4.3. Asymmetry

While we expect a depreciation to boost exports and an appreciation to inhibit them, the two effects need not be the mirror image of each other. In order to more easily compare our results between the two cases, we specify our regression such that the elasticity coefficients associated with depreciations to have the same sign as the one associated to appreciation. However, as mentioned in section 2, we expect them to have different magnitudes. In order to test this hypothesis, we let the interact the RER coefficients in equation (2), β, γ_1 and σ_1, with dummies indicating the sign of the exchange rate movement.

As in the benchmark, we run four specifications, in turn including TFP dispersion and skewness as asymmetry measures. Our preferred specification is the one including both of them. The results are summarized in Table 8 where the first three rows show the estimates for the variables of interest during appreciation episodes and the next three rows show them during depreciation episodes. We will only focus on columns (1) and (4) as including skewness by itself has no impact on the estimates and column (4) is virtually identical to column (2). Column (1) shows the results without taking into account any productivity distribution statistics. In the case of appreciation the coefficient is significant and with the right sign. For depreciations instead, as in Dekle et al. (2009) the baseline elasticity estimate has the wrong sign and is highly significant. Our result further stresses the need to include productivity statistics in order to obtain accurate estimates. Including dispersion statistics helps the elasticity identification. For appreciations, the elasticity tends to be higher than zero. For depreciations, the estimates tend to be close to zero and with

[12] These full list of estimates are not shown here but are available on request.

the correct sign. In our preferred specification, column (4) which includes both productivity distribution statistics, we find that the impact in the case of appreciation is both statistically significant and substantially meaningful. That is, a 10% RER increase will decrease the value of exports by 10%. Meanwhile, currency depreciation will not have a noticeable effect on exports. We also find that in countries and sectors with higher TFP dispersion the RER fluctuations are less pronounced. These results are in line with our expectation and the theoretical motives described in the introduction.

Table 8: Regression of delta exports on exchange rates taking into account the sign of the shock

	(1)	(2)	(3)	(4)
Appreciation				
Δln(XR)	-0.761***	-1.011***	-0.759***	-1.006***
	(0.0515)	(0.150)	(0.0519)	(0.150)
Δln(XR) × ln(TFP) dispersion		0.0995**		0.0995**
		(0.0503)		(0.0504)
Δln(XR) × ln(TFP) skewness			-0.0158	-0.0263
			(0.0559)	(0.0563)
Depreciation				
Δln(XR)	0.217***	-0.208	0.215***	-0.212
	(0.0746)	(0.261)	(0.0747)	(0.263)
Δln(XR) × ln(TFP) dispersion		0.148		0.148
		(0.0840)		(0.0851)
Δln(XR) × ln(TFP) skewness			0.0190	0.0244
			(0.0790)	(0.0806)
Δln(TFP) dispersion × Δln(XR)		-0.420		-0.445
		(0.292)		(0.315)
Δln(TFP) dispersion × ln(XR)		0.0228***		0.0323***
		(0.00702)		(0.00753)
Δln(TFP) skewness × Δln(XR)			-0.0157	0.0277
			(0.0921)	(0.0985)
Δln(TFP) skewness × ln(XR)			-0.00388	-0.00789***
			(0.00208)	(0.00223)
ΔForeign Demand	0.00258***	0.00258***	0.00258***	0.00257***
	(0.000179)	(0.000179)	(0.000179)	(0.000179)
$\Delta\ln(GDP_n)$	1.426***	1.407***	1.425***	1.399***
	(0.0858)	(0.0864)	(0.0858)	(0.0865)
$\Delta\ln(GDP_i)$	1.278***	1.257***	1.280***	1.251***
	(0.112)	(0.113)	(0.112)	(0.113)
Observations	172,501	172,501	172,501	172,501
R-squared	0.008	0.008	0.008	0.009

*** p<0.01, ** p<0.05

Robust standard errors in parentheses. Allowing for various patterns of error clustering (by exporter/importer/sector or various combinations) does not affect the significance of results in any meaningful way, albeit for higher p-values. In some combinations the interaction term between dispersion and appreciation becomes insignificant.

Note: In line with the literature, we expect depreciation to boost exports and appreciation to inhibit them. Despite these opposite effects, in our specification, the elasticity coefficients in the two cases should have the same sign if we are to believe this hypothesis. In other words, for appreciation, we look at the difference in effect between a 2% and 3% appreciation and for depreciation we look at the difference in effect between a -3% and -2% depreciation.

4.4. Large changes

In this section, we investigate the hypothesis that exporters are more likely to react to large changes in the exchange rate than to small ones. As we are looking at the effects of exchange rate over the relatively short run, we expect there to be differences in the response of firms depending on the size of the shock due to adjustment rigidities. As contracts are negotiated in advance and setting a distribution network is costly, prices and quantities are sticky in the short term and a firm may choose not to optimally adjust immediately following an exchange rate fluctuation and may allow its mark-up to absorb some of the losses. However, a large change in exchange rate may make it much too unprofitable to stick to this course of action and may induce the firm to change its prices or quantities.

We define as small shocks those lying between the 10^{th} and 90^{th} percentile of changes in the exchange rate. This way, half of the exchange rate movements in our sample will be considered large and half of them will be considered small. Numerically, this classifies movements between 9% depreciation and 12% appreciation as small. This is much larger than what is considered in the exchange rate pass through literature: for instance, Bussiere (2006) considers small movements being +/- 3%.

Table 9 shows the estimated elasticities allowing them to differ depending on the classification of the shock. The first block of estimates, under the header "Small" indicate the elasticities in the case of central 80% movements in the exchange rate while those under the header "Large shocks" indicate the estimates in the outer 20% of movements. As usual, the first column shows the estimates without taking into account any productivity characteristics. The elasticities for both small and large shocks are statistically significant, and for small shocks, the elasticity estimate is smaller, as expected. Taking into account the standard deviation of TFP, the results change drastically. The elasticity estimates for both small and large shocks increases, but more for the large ones. In the case of large exchange rate movements, we also observe that the more dispersed sectors have a lower elasticity of exports. Including the productivity skewness has a minimal impact on the estimated coefficients. We tried different thresholds for the definition of large shocks and the more extreme the events the larger the elasticity estimates we obtained. This makes sense as we are now able to capture adjustments on the extensive not just the intensive side: larger shocks will not only generate stronger responses but also will cause marginal firms to adjust their exports, amplifying the observed elasticity (remember we only observe trade variables at the sector level).

Table 9: Regression of delta log exchange rates on exchange rates taking into account the size of the shock

	(1)	(2)	(3)	(4)
Small shocks				
Δln(XR)	-0.294***	-0.512**	-0.289***	-0.511**
	(0.0697)	(0.234)	(0.0705)	(0.234)
Δln(XR) × ln(TFP) dispersion		0.0831		0.0843
		(0.0794)		(0.0797)
Δln(XR) × ln(TFP) skewness			-0.0464	-0.0420
			(0.0949)	(0.0953)
Large shock				
Δln(XR)	-0.375***	-0.866***	-0.374***	-0.865***
	(0.0407)	(0.152)	(0.0409)	(0.152)
Δln(XR) × ln(TFP) dispersion		0.183***		0.183***
		(0.0511)		(0.0513)
Δln(XR) × ln(TFP) skewness			-0.00219	-0.0107
			(0.0524)	(0.0530)
Δln(TFP) dispersion × Δln(XR)		-0.531		-0.556
		(0.293)		(0.316)
Δln(TFP) dispersion × ln(XR)		0.0228***		0.0324***
		(0.00700)		(0.00749)
Δln(TFP) skewness × Δln(XR)			-0.0149	0.0383
			(0.0923)	(0.0988)
Δln(TFP) skewness × ln(XR)			-0.00408	-0.00813***
			(0.00208)	(0.00223)
ΔForeign Demand	0.00258***	0.00258***	0.00258***	0.00257***
	(0.000179)	(0.000179)	(0.000179)	(0.000179)
$\Delta\ln(GDP_n)$	1.404***	1.381***	1.402***	1.372***
	(0.0860)	(0.0863)	(0.0860)	(0.0864)
$\Delta\ln(GDP_i)$	1.443***	1.418***	1.444***	1.409***
	(0.109)	(0.110)	(0.109)	(0.110)
Observations	172,501	172,501	172,501	172,501
R-squared	0.008	0.008	0.008	0.008

*** p<0.01, ** p<0.05

Robust standard errors in parentheses. Allowing for various patterns of error clustering (by exporter/importer/sector or various combinations) does not affect the significance of results in any meaningful way, albeit for higher p-values. In some combinations the elasticity for small changes becomes insignificant.

5. Conclusions

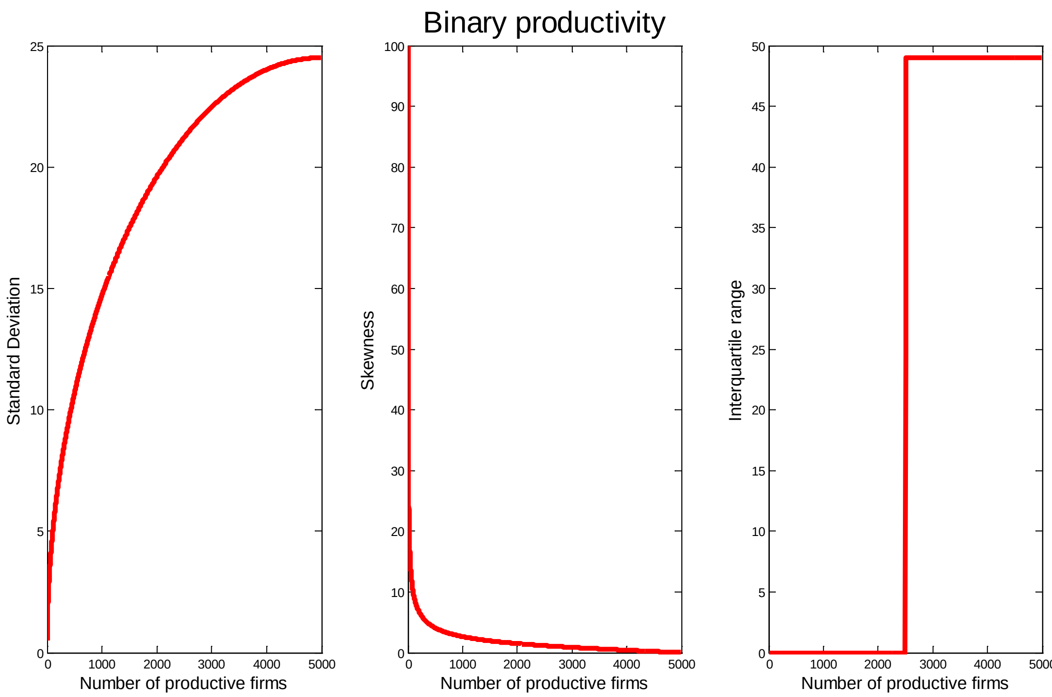
This paper provides new empirical estimates of the elasticity of exports to the exchange rate. The value added of the paper is the use of a novel database of sector productivity for a set of EU countries, derived from firm level information. The main result is that when the underlying firm productivity distribution is taken into consideration the elasticity estimates double in value. In addition, the more heterogeneous is the sector - i.e. the higher is the concentration of highly productive firms - the lower is the sensitivity of exports to exchange rates movements. Finally, reactions to exchange rate movements are not symmetric, since what appears to matter are only appreciations – as opposed to depreciations –, as well as relatively large – rather than small – exchange rate swings.

Appendix

Appendix I – The link between dispersion and skewness

This section provides some numerical examples to help understand the interplay between dispersion and skewness of a right-tailed distribution, such as in the case of productivity. Let us assume two countries of 10000 firms each and all firm are exporters. For the sake of simplicity, let us assume productivity is binary: firms can be either low productivity or high productivity. Without loss of generality, low productive firms have productivity equal to one and high productive firms have productivity equal to 50. In country A, out of the 10000 firms, 2000 are high productivity and 8000 are low productivity while in country B only 10 firms are high productivity. Economically speaking, we expect the impact of exchange rate fluctuations in country A to be much less pronounced, as there are more productive firms than in country B. However, the statistics of the two distributions are radically different. Economy A has a standard deviation of 19.6 and a skewness of 1.5 whereas country B has a standard deviation of 1.6 and a skewness of 30.1. It is clear that, at least in our example, a higher standard deviation implies a larger concentration of productive firms, while a higher skewness implies exactly the opposite.

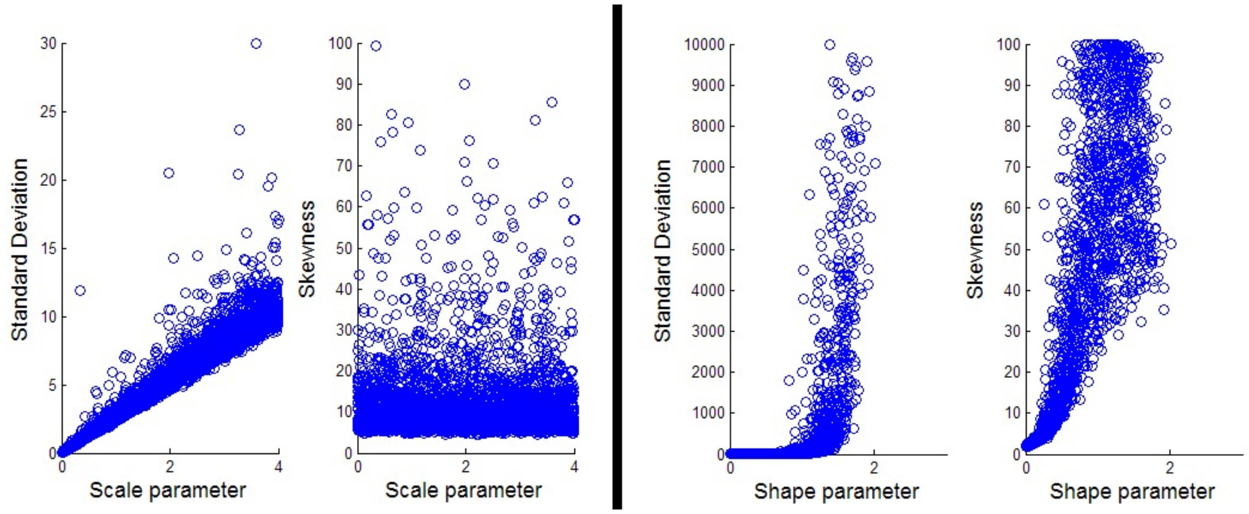
Figure A1: Evolution of higher order statistics in a binary productivity setting



Finally, let us consider two popular distributions in the theoretical firm level literature, the Pareto and the lognormal distribution. Both distributions have two parameters, a location and a shape parameter, and increasing either of them makes the sector more competitive: increasing the location moves the whole distribution more to the right while increasing the shape parameter has a stronger impact on the right tail.

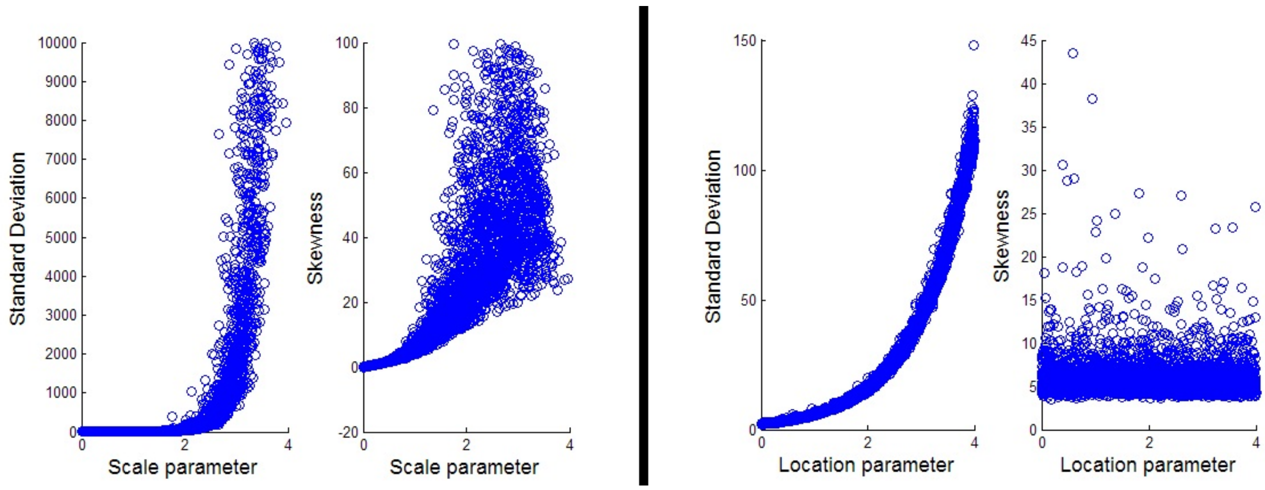
Figure A2 plots the evolution of productivity standard deviation and skewness for a sector with 10000 firms randomly drawn from a Pareto distribution. In Panel 1, we increase the scale parameter from zero to four, whereas in panel B we increase the shape parameter from zero to two. In both cases, we keep the other parameter constant.

Figure A2: Simulation of Pareto distributions under various scale and shape parameters.



In Figure A3, we plot the standard deviation and skewness for the lognormal distribution resulting from simulations allowing the underlying distribution's two parameters to vary. Again, an increase in either parameter of the distribution would make the economy more export prone. The standard deviation increases with an increases in an exponential fashion in both parameters but the skewness increases only when the scale parameter increase.

Figure A3: Simulation of Lognormal distributions under various scale and location parameters.



Appendix II – Robustness check

In order to check the sensitivity of our results to our choice of productivity proxy, we repeat our previous exercises using an alternative productivity measure: apparent labour productivity, defined as real value added per employee. The data is also collected as part of the CompNet dataset defined in real Euros, adjusted for value added PPPs. The same outlier and data clean up treatment as for TFP, detailed in section 3, is applied to labour productivity. Table A1 summarizes the key statistics for the standard deviation and skewness of labour productivity for the countries covered in this paper. The country profiles are similar as in the case of TFP. As labour productivity is directly derived from balance sheet information, it is less likely to be affected by the implicit and explicit assumptions of the TFP estimation procedure. It is likely, though, to be somewhat correlated, or more correlated than TFP, with other characteristics that affect exports.

Table A1: statistics on dispersion and skewness of labour productivity

Country	Standard deviation				Skewness			
	Mean	Median	Minimum	Maximum	Mean	Median	Minimum	Maximum
Belgium	30.79	32.24	5.36	54.02	1.81	1.82	-0.28	5.92
Croatia	11.25	10.49	2.85	22.47	1.79	1.59	0.03	4.99
Estonia	6.65	6.27	2.10	13.85	1.29	1.21	-0.51	3.44
Finland	30.78	27.72	5.81	72.45	2.15	2.09	-0.31	5.78
Italy	16.24	16.69	5.07	26.51	1.17	1.20	-0.09	2.55
Lithuania	5.60	5.62	1.15	10.12	1.32	1.26	0.10	4.26
Portugal	9.57	11.13	1.66	15.35	0.84	0.86	-0.80	2.29
Romania	4.61	4.34	1.60	8.97	1.71	1.59	-0.63	4.40
Slovenia	6.25	5.67	1.66	13.82	1.39	1.39	-0.15	2.92
Spain	16.76	17.59	4.99	25.22	1.09	1.08	0.22	2.13

Note: Results are pooled over years and sectors

Estimation

We repeat all the exercises in section 4 without changing anything but the productivity measure. This approach is likely to produce biased results as export sales are part of the construction of the value added variable. Moreover, value added, as it is an accounting concept, is more likely that TFP to be influenced by other unobserved factors.

The estimates in column (1) of Table A2 are identical to the ones in Tables 7, as they are the simplest form of regression without including any of our productivity statistics. The following two columns include, in turn, productivity dispersion and skewness statistics and column (4) includes both measures. When taking into account these additional covariates, the elasticity estimates change drastically, and the heterogeneous effect due to dispersion across sectors is about as pronounced as in the case of TFP regression. Puzzlingly, the skewness results are negative and statistically significant, indicating the sectors with a long productivity right tail are more sensitive to exchange rate movements.

In the case of asymmetric shocks, Table A3, our labour productivity results are again similar to the TFP ones: including sector characteristics drastically changes the estimated elasticity, although the estimated elasticities are lower than for TFP. Interestingly, for depreciation, an increase in productivity dispersion lowers the elasticity by 20% although the baseline elasticity estimate is not statistically significant. We suspect that the elasticity point estimate is different from zero but we do not have enough variation in our sample to pinpoint the exact value. What is more puzzling is that the skewness coefficients is significant in the case of appreciation but again has the opposite signs than expected.

Finally, in Table A4 we once again split the sample into large and small shocks, using the same rules as in the TFP section. For small shocks, neither the baseline elasticity nor the productivity interactions are significant.

Table A2: Regression of delta log exchange rates on exchange rates without taking into account any non-linear response of exchange rates

	(1)	(2)	(3)	(4)
Δln(XR)	-0.331***	-0.821***	-0.286***	-0.765***
	(0.0340)	(0.144)	(0.0409)	(0.146)
Δln(XR) × ln(lprod SD)		0.181***		0.177***
		(0.0485)		(0.0484)
Δln(XR) × ln(lprod skewness)			-0.154**	-0.146**
			(0.0713)	(0.0713)
Δln(lprod SD) × Δln(XR)		-0.509**		-0.534
		(0.251)		(0.279)
Δln(lprod SD) × ln(XR)		0.0301***		0.0411***
		(0.00585)		(0.00653)
Δln(lprod skewness) × Δln(XR)			0.0540	0.110
			(0.123)	(0.135)
Δln(lprod skewness) × ln(XR)			-0.00354	-0.0110***
			(0.00240)	(0.00269)
ΔForeign Demand	0.00209***	0.00208***	0.00209***	0.00208***
	(0.000249)	(0.000248)	(0.000249)	(0.000248)
$\Delta\ln(GDP_n)$	1.427***	1.397***	1.422***	1.381***
	(0.0821)	(0.0823)	(0.0821)	(0.0825)
$\Delta\ln(GDP_i)$	1.515***	1.476***	1.517***	1.472***
	(0.105)	(0.105)	(0.105)	(0.105)
Observations	187,225	187,225	187,225	187,225
R-squared	0.008	0.008	0.008	0.008

*** p<0.01, ** p<0.05

Robust standard errors in parentheses. Allowing for various patterns of error clustering (by exporter/importer/sector or various combinations) does not affect the significance of results in any meaningful way, albeit for higher p-values.

Table A3: Regression of delta log exchange rates on exchange rates taking into account asymmetric effects

	(1)	(2)	(3)	(4)
Appreciation				
Δln(XR)	-0.749***	-0.986***	-0.668***	-0.890***
	(0.0489)	(0.165)	(0.0566)	(0.167)
Δln(XR) × ln(lprod SD)		0.0933*		0.0883
		(0.0557)		(0.0556)
Δln(XR) × ln(lprod skewness)			-0.242***	-0.242***
			(0.0849)	(0.0849)
Depreciation				
Δln(XR)	0.267***	-0.300	0.241***	-0.343
	(0.0721)	(0.299)	(0.0806)	(0.301)
Δln(XR) × ln(lprod SD)		0.195**		0.201**
		(0.0961)		(0.0961)
Δln(XR) × ln(lprod skewness)			0.101	0.105
			(0.120)	(0.120)
Δln(lprod SD) × Δln(XR)		-0.417		-0.455
		(0.251)		(0.279)
Δln(lprod SD) × ln(XR)		0.0300***		0.0410***
		(0.00587)		(0.00655)
Δln(lprod skewness) × Δln(XR)			0.0495	0.104
			(0.123)	(0.135)
Δln(lprod skewness) × ln(XR)			-0.00278	-0.0102***
			(0.00243)	(0.00272)
ΔForeign Demand	0.00209***	0.00208***	0.00209***	0.00208***
	(0.000248)	(0.000248)	(0.000248)	(0.000248)
$\Delta\ln(GDP_n)$	1.448***	1.426***	1.444***	1.411***
	(0.0818)	(0.0824)	(0.0818)	(0.0825)
$\Delta\ln(GDP_i)$	1.340***	1.298***	1.369***	1.319***
	(0.107)	(0.108)	(0.108)	(0.109)
Observations	187,225	187,225	187,225	187,225
R-squared	0.009	0.009	0.009	0.009

*** p<0.01, ** p<0.05

Robust standard errors in parentheses. Allowing for various patterns of error clustering (by exporter/importer/sector or various combinations) does not affect the significance of results in any meaningful way, albeit for higher p-values.

Table A4: Regression of delta log exchange rates on exchange rates taking into the size of the shock

	(1)	(2)	(3)	(4)
Small shocks				
Δln(XR)	-0.306***	-0.597**	-0.246***	-0.512
	(0.0676)	(0.259)	(0.0765)	(0.263)
Δln(XR) × ln(lprod SD)			-0.215	-0.212
			(0.127)	(0.127)
Δln(XR) × ln(lprod skewness)		0.109		0.101
		(0.0884)		(0.0884)
Large shock				
Δln(XR)	-0.339***	-0.900***	-0.299***	-0.854***
	(0.0388)	(0.170)	(0.0473)	(0.172)
Δln(XR) × ln(lprod SD)		0.206***		0.203***
		(0.0572)		(0.0571)
Δln(XR) × ln(lprod skewness)			-0.133	-0.123
			(0.0835)	(0.0835)
Δln(lprod SD) × Δln(XR)		-0.516**		-0.544
		(0.252)		(0.281)
Δln(lprod SD) × ln(XR)		0.0301***		0.0412***
		(0.00585)		(0.00653)
Δln(lprod skewness) × Δln(XR)			0.0557	0.113
			(0.123)	(0.136)
Δln(lprod skewness) × ln(XR)			-0.00353	-0.0110***
			(0.00240)	(0.00269)
Demand	0.00209***	0.00209***	0.00209***	0.00208***
	(0.000249)	(0.000248)	(0.000249)	(0.000249)
$\Delta\ln(GDP_n)$	1.427***	1.399***	1.422***	1.383***
	(0.0821)	(0.0823)	(0.0821)	(0.0825)
$\Delta\ln(GDP_i)$	1.514***	1.471***	1.518***	1.468***
	(0.105)	(0.105)	(0.105)	(0.105)
Observations	187,225	187,225	187,225	187,225
R-squared	0.008	0.008	0.008	0.008

*** p<0.01, ** p<0.05

Robust standard errors in parentheses. Allowing for various patterns of error clustering (by exporter/importer/sector or various combinations) does not affect the significance of results in any meaningful way, albeit for higher p-values.

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Competitiveness Research Network
This paper presents research conducted within the Competitiveness Research Network (CompNet). The network is composed of economists from the European System of Central Banks (ESCB) - i.e. the 29 national central banks of the European Union (EU) and the European Central Bank – a number of international organisations (World Bank, OECD, EU Commission) universities and think-tanks, as well as a number of non-European Central Banks (Argentina and Peru) and organisations (US International Trade Commission).

The objective of CompNet is to develop a more consistent analytical framework for assessing competitiveness, one which allows for a better correspondence between determinants and outcomes.

The research is carried out in three workstreams: 1) Aggregate Measures of Competitiveness; 2) Firm Level; 3) Global Value Chains CompNet is chaired by Filippo di Mauro (ECB). Workstream 1 is headed by Pavlos Karadeloglou (ECB) and Konstantins Benkovskis (Bank of Latvia); workstream 2 by Antoine Berthou (Banque de France) and Paloma Lopez-Garcia (ECB); workstream 3 by João Amador (Banco de Portugal) and Frauke Skudelny (ECB). Monika Herb (ECB) is responsible for the CompNet Secretariat.

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The paper is released in order to make the research of CompNet generally available, in preliminary form, to encourage comments and suggestions prior to final publication. The views expressed in the paper are the ones of the author(s) and do not necessarily reflect those of the ECB, the ESCB, and of other organisations associated with the Network.

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