Export Decision under Risk∗

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Preliminary version

Abstract

In firm-based trade theory, consumer expenditure in foreign markets is typically assumed to be known with certainty. Firms’ surveys suggest however that expenditure uncertainty is a top business driver and little is known about how firms deal with this uncertainty in foreign markets. A simple heterogeneous-firms trade model with risk-averse managers shows that on average firm-level exports decrease with uncertainty. However, uncertainty also impacts endogenously the number of exporters and the industry supply in a destination. As a consequence, firm’s responses to uncertainty are heterogeneous: on average, the most productive firms sell more than the least productive ones, but this difference shrinks with uncertainty. These predictions are put to the test by using French firm-level exports across destinations and sectors with different levels of expenditure volatility. Results are consistent with our theoretical predictions and confirm that expenditure volatility acts as an equalizer between firms.

JEL classification: D81, F12, L25
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1 Introduction

Firm-based trade theory assumes typically that consumer expenditure in foreign markets is known with certainty. Firms know the exact demand function and only the first central

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moment of the expenditure distribution, i.e., market size, plays a role in export decisions and export sales. Yet, according to the recent Capgemini surveys of leading companies, market/expenditure volatility is their top business driver.\textsuperscript{1} Macroeconomic volatility, as a source of uncertainty, potentially influences trade decisions.\textsuperscript{2} This view agrees with empirical evidence showing that macroeconomic volatility plays a key role in a wide variety of economic outcomes such as investment, production and pricing decisions (see Bloom, 2014 for a survey). Though the impact of trade on volatility has received much attention (Giovanni and Levchenko, 2009; Koren and Tenreyro, 2007), relatively little attention has been given to the reverse question. This paper aims to study the impact of aggregate expenditure volatility on both the extensive and intensive margins of trade, i.e., on both export entry/exit and sales.

Our theory is motivated by reduced-form evidence on the relationship between sector-specific volatility of expenditure in a destination and individual export sales of French manufacturing firms. Combining firm-level exports over the period 2000-2009 with measures of expenditure volatility, as proxied by the variance of apparent consumption, we show in Section 2 two regularities at the intensive margin: (i) individual firm exports are negatively affected by the sector-specific variance of expenditure in destination countries, but positively affected by its mean and skewness; (ii) the response of firms to volatility is heterogeneous and striking: volatility reduces the export difference between the least and the most productive firms. In other words, the market share of the most productive firms decreases with expenditure volatility. We also show that the extensive margin of trade reacts to the moments of the expenditure distribution. The firm’s probability to enter in a given export market is negatively and significantly affected by the expenditure volatility, but positively and significantly influenced by its mean and skewness. Opposite influence of volatility and skewness are observed for the probability of exit.

We next develop a simple firm-based trade model in Section 3 that accounts for these empirical facts. The model features two key ingredients: (1) managers are averse to both

\textsuperscript{1}Capgemini surveys on supply chain agenda can be publicly accessed in 2011, 2012, and 2013.

\textsuperscript{2}Due to the practical difficulties of separating risky events from uncertain events, we follow Bloom (2014) and refer to a single concept of uncertainty, which is a stand-in for a mixture of risk and uncertainty. Risk and uncertainty terms are thus used interchangeably.
risk and downside losses and (2) they make entry/exit and production/pricing decisions before the uncertainty on aggregate expenditure is known. Firms are heterogeneous in productivity, but do not face some initial uncertainty concerning their future productivity. Thus, firms’ decisions to enter an export market hinges on the level of their given productivity. However, once they enter, exporters face a delay between the time strategic variables (price or quantity) are chosen and the time the output reaches the market. During this delay, the foreign expenditure or the market price can change due to random shocks such as changes in climatic conditions, consumer tastes, opinion leaders’ attitudes, or popularity of competing products.

As firms can only partially diversify out of the risks that they face, they act in a risk-averse manner. There is one reason why the managers of the exporting firm and the firm’s shareholders might be risk averse: if the uncertainty is common to all firms, risk is non-diversifiable (Grossman and Hart, 1981). There are also various reasons why the manager might be risk-averse even if the firm is risk-neutral: (i) bankruptcy costs can be potentially high (Greenwald and Stiglitz, 1993), (ii) exchange rate risk is not hedged well (Wei, 1999), (iii) open-account terms are common in trade finance and allow an importer to delay payment until a certain time following receipt of the goods (Antràs and Foley, 2015), (iv) manager’s human and financial capital (through their equity shares) are disproportionately tied up in the firm they manage (Bloom, 2014). Thus, in making all of their economic decisions (investment, production, and pricing), managers take into account their risk exposure.\(^3\)

To consider that decision-makers have to manage their risk exposure, we follow the expected utility theory (a mean-variance-skewness analysis), where the risk-aversion behavior is intrinsically equivalent to a preference for diversification (Eeckhoudt et al., 2005). As shown in the literature on production decision under risk and imperfect competition, an increase in risk (as measured by a higher variance of the random variable) has a negative effect on output size when the decision-maker is risk-averse (Klemperer and Meyer, 1986). Nevertheless, the second central moment of a distribution does not distinguish

\(^3\)Recent research shows that risk aversion is an important feature in decision of managers under uncertainty (see Panousi and Papanikolaou, 2012).
between upside versus downside risk, which can be captured by the third central moment (or skewness) (Menezes et al., 1980). A basic intuition is that, for a given mean and variance, a decrease in the skewness of expenditure distribution involves a higher probability of low returns. In our case, we show empirically that a higher variance and a lower skewness of the expenditure distribution in a destination country have a negative effect on French exports. This result suggests exporting firms’ managers are willing to pay a “risk premium” to avoid uncertainty in this destination market.

Our model leads to simple theoretical predictions, which rationalize our reduced-form estimations. As expected, the probability of exporting decreases with expenditure volatility but increases with its mean and skewness. In other words, the trade extensive margin depends on the first three central moments of the expenditure distribution. We also show that the equilibrium certainty-equivalent quantities, which incorporates the risk-premium, are negatively correlated with the volatility of expenditure, but positively affected by its mean and skewness.

Further, even if firms face the same industry-wide demand uncertainty, risk-averse managers react differently to an increase in volatility according to their productivity, leading to a reallocation of market share. Expenditure volatility may force some producers to not enter the export market or to cease exporting and, in turn, the expenditure for the incumbent exporting firms may rise. Additionally, changes in uncertainty may modify the relative prices among varieties supplied leading to a reallocation of market shares across the incumbent exporters. Hence, the effects of the industry-specific uncertain expenditure on firms’ export performance are not a priori clear. We show that, even though higher foreign expenditure volatility reduces the volume of industry export sales, its effect on the level of export sales (intensive margin) at the firm level is ambiguous. Indeed, a rise in expenditure volatility induces a reallocation of market shares from the most to the least productive firms. Under this configuration, the export sales of medium-sized firms (or the smallest exporters) may grow. However, this effect is weakened when the skewness of demand distribution increases. In addition, it appears that higher variance of industry demand in a foreign market raises the unit prices set by firms in this market through a
change in their markup. The magnitude of this effect increases with the productivity of firms but decreases with trade costs.

Related literature

The expected utility theory has been used to analyze international trade under risk by Helpman and Razin (1978) and Turnovsky (1974). However, they consider perfect competition. Even if uncertainty has been introduced in Melitz-type trade models, the uncertain parameter (firm’s productivity) is revealed before the firm supplies any destination. In the very last years, the trade literature has witnessed a revival of interest for studying uncertainty (Feng et al., 2016, Handley, 2014; Handley and Limao, 2013; Lewis, 2014; Nguyen, 2012; Novy and Taylor, 2014; Ramondo et al., 2013). These studies focus their attention on trade policy uncertainty or the trade-off between trade and foreign investment and assume for simplicity that price and quantity to be exported are determined under certainty. In other words, they consider that the uncertainty is resolved before firms set their price (or quantity) for each destination. In this paper, we show theoretically and empirically that higher moments of the demand distribution affect the entry decisions and also production and pricing decisions leading to a reallocation of market shares. This finding also shows that the second- and third-moment shocks also need to be considered for understanding trade patterns.

This paper also contributes to the literature on international trade which emphasizes the role of demand and expenditure in export performance (Di Comite et al., 2014; Fajgelbaum et al., 2011). Although firm heterogeneity in productivity is an important factor in explaining firms’ entry into export markets, it has been shown that demand factors plays a key role too in explaining the variability in firm-level prices and sales across a range of export destinations (Armenter and Koren, 2015; Eaton et al., 2011). We view our paper as a complement to their approach. By relaxing the certain demand assumption, it appears that demand fluctuation affects the extensive and intensive margins. In addition, the literature studying the determinants of trade focuses on the impact of first-moment (levels) shocks.
2 Reduced-form Evidence on Trade and Uncertainty

In this section, we present reduced-form evidence that individual exporting firms react to uncertainty and in particular to the volatility of consumption expenditure. We also show that other moments of the expenditure distribution matter such as the skewness. This reduced-form evidence motivates the theory presented in Section 3.

2.1 Data and descriptive statistics

2.1.1 Data

We employ two types of data.\textsuperscript{4} We first use a very rich firm-level export data from the French customs over the period 2000-2009. For each firm located on the French metropolitan territory, we observe volume (in tons) and value (in thousand euros) of exports for each product-destination-year triplet. Unit values are computed as the ratio of export value to export volume. Using the official firm identifier, we merge custom data with the BRN (Bénéfices réels normaux) dataset from the French Statistical Institute, which provides the firm’s balance-sheet data, i.e., value added, total sales, employment, etc. The BRN dataset allows us to compute the firm’s productivity, defined as the value added over employment. Our sample contains on average 43,589 firms per year. Firms export to a total of 90 different destination countries.

Then, in addition to firm-level data, we use destination-country information, such as distance from France and manufacturing sector-level production, imports and exports. Distance from France is computed as the population-weighted geodesic distance between the main cities in France and in each destination-country, collected from the CEPII. The ISIC 4-digit level manufacturing production, exports and imports data come from COMTRADE and UNIDO, and cover the period 1995 to 2009. Sector-level data allow us to define a consumption expenditure variable $R$, also known as apparent consumption or absorption, and defined as domestic production minus net exports:

$$R_{jt}^k = \text{Production}_{jt}^k + \text{Imports}_{jt}^k - \text{Exports}_{jt}^k,$$

\textsuperscript{4}Further details about the data sources are provided in Appendix A.
where Production, Imports and Exports are defined, respectively, as total production, total imports, and total exports for each triplet destination \(j\), year \(t\), and 4-digit \(k\). The intention here is to infer the sector consumption expenditure that is used in destination for any purpose.\(^5\) Our sample covers 119 manufacturing 4-digit sectors \(k\) (see Table 4 in Appendix A).

Based on the expenditure series, we compute the three central moments of its distribution: the expected value \(E(R^K_{jt})\), the variance \(V(R^K_{jt})\), and the skewness \(S(R^K_{jt})\). These moments are calculated for each destination \(j\) and year \(t\) at the upper 3-digit \(K\) sector-level to use more information and get more reliable estimates:

- The expected value \(E(R^K_{jt})\) is computed in year \(t\) as the mean of 5 previous years in expenditure \(R\).

- The volatility is measured by the variance of expenditure \(V(R^K_{jt})\), which is computed in year \(t\) as the standard deviation of the yearly growth rates of \(R\) over a 6-year period and the 4-digit sub-sectors \(k\). As an example, consider the manufacture of beverages (\(K=155\)) in the United Kingdom (UK) in 2000. This sector is disaggregated into 4 sub-sectors (\(k=1551, 1552, 1553, 1554\)).\(^6\) First, we compute, for each sub-sector \(k\), the 5 yearly growth rates of apparent consumption over 1995 to 2000. Then, we calculate \(V(R^{155\text{UK,2000}})\) as the standard deviation of the 20 computed growth rates for the 4 sub-sectors.

- The unbiased skewness of expenditure \(S(R^K_{jt})\) is computed using the same strategy than the volatility, i.e., as the skewness of the yearly growth rates of \(R\) over a 6-year period and the sub-sectors \(k\).

We now present some descriptive statistics on expenditure moments and their variation (1) across destination markets, (2) across sectors, and (3) over time. We show in particular that these moments match some facts put forth by the literature on uncertainty.

\(^5\)Eaton et al., 2011 use the absorption measure to capture market size.
\(^6\)The 4 sub-sectors of \(K=155\) are: 1551 - Distilling, rectifying and blending of spirits; ethyl alcohol production from fermented materials; 1552 - Manufacture of wines; 1553 - Manufacture of malt liquors and malt; 1554 - Manufacture of soft drinks; production of mineral waters.
2.1.2 Descriptive statistics on expenditure moments

**Observed central moments of expenditure.** Figure 1 reports the volatility of expenditure in 53 destinations, in 2005, in beverages. This 3-digit industry represents one of the top 10 French manufactured sector exports. For a same level of mean expenditure, we observe different levels of volatility (1a) and skewness (1b) across countries. Similar trends are observed for other industries.\(^7\)

![Figure 1: Mean, volatility and skewness of expenditure in a given sector](image)

(a) Volatility  
(b) Skewness

**Expenditure volatility and skewness across destination markets.** Figure 2 provides the distribution of expenditure volatility (in logs) and expenditure skewness across the 10 main and minor destination markets of French exports over the 2000-2009 period.\(^8\) We observe that the main destinations (2a) have lower median volatility than minor destinations (2b). There is however a composition effect because main partners are most often developed countries. They have both higher average expenditure and lower volatile expenditure than developing countries (see Table 12 in Appendix B). It is reassuring that our volatility measure confirms that on average developed countries are less volatile than developing ones as documented in Bloom (2014) and the World Development Report 2014 on risk and opportunity (World Bank, 2013). For the skewness, the difference between the main and minor French trading partners is less visible, with low and high level of

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\(^7\)Figures on other industries are available upon request.

\(^8\)The distribution is computed for each destination using all 3-digit sectors and years for which we are able to compute the apparent consumption (at most we have 10 years * 57 three-digit sectors = 570 observations). We keep only countries for which we have at least 10% of the 570 potential observations.
skewness in both groups. Moreover, the difference between developed and developing countries in terms of skewness appears also less pronounced than for volatility (see Table 13 in Appendix B).

Figure 2: Distribution of volatility and skewness, by group of countries

Expenditure volatility and skewness across sectors. Figure 3 depicts the distribution of expenditure volatility (in logs) and skewness across 2-digit industries. The ranking of industries is not similar for both moments. For example, “food and beverages” is among the most volatile industries, while its skewness is rather low. By contrast, the industry “medical and optical instruments” has a relatively low volatility but a high skewness. Only two industries (Tobacco; Office, accounting) have a negative median skewness.

Figure 3: Distribution of volatility and skewness, by industry
Expenditure volatility and skewness over time. The literature documents fluctuations in uncertainty over time (Bloom, 2014), and we find a similar pattern in our data. In particular, Figure 4 shows that mean volatility of food and beverages expenditure in the United States increased between 2000 and 2008 (plain line). It is again reassuring that our volatility measure confirms a trend that has been documented in the literature in the US food industry (Gorbachev, 2011). We also observe fluctuations in the skewness distribution that we use as a source of identification (dotted line).

Figure 4: Volatility and skewness of U.S. expenditure in food and beverages, 2000-2008


2.2 Stylized facts on trade and expenditure volatility

We provide here four stylized facts showing second-moment expenditure effects on French exports at the 4-digit level. These facts are presented using both volumes and prices instead of export values. The reason is that we expect opposite effects of volatility on quantities and prices, as theoretically shown in Section 3. Export values average out the effects.

Fact 1: Negative correlation between export volumes and expenditure volatility. Figure 5 shows prima facie evidence of a negative correlation between 4-digit sector expenditure volatility and French export volumes in destination markets. A destination market is defined as a destination-year-sector triplet. Each triplet is placed into a bin.
based on the quartile of its volatility, with bins from Q1 to Q4 where Q1 is the lowest quartile of volatility and Q4 the highest one. Then, we sum the French firm-level exports in each bin. While the volume exported by French firms attains 0.345 billions of tons for the destination-year-sector with the lowest volatility (Q1), it reaches 48 millions of tons in the last quartile (Q4).

Figure 5: French Export Volumes and Expenditure Volatility
(Volatility in destination-year-sector markets – 2000-2009)

Firm export volumes and expenditure volatility

Note: Q1 represents the lowest 25% volatile markets in terms of expenditure. A destination market is a destination-year-sector (4-digit) triplet.

Fact 2: Positive correlation between export unit values and expenditure volatility. Our measure of price is unit value (value divided by quantity) for a given exporter-destination-year-sector (4 digit) observation. Then, unit values are averaged across firms in each bin of volatility (as defined above). Despite being a rough measure of prices (see Harrigan et al., 2015), unit values are informative. Figure 6 shows that unit values are positively correlated with expenditure volatility. This result is intuitive and formalized in the theoretical section: in response to volatility, firms reduce quantities, which reduce competition and enable incumbent firms to raise prices.
Fact 3: Volatility reduces the export volume difference between the least and the most productive firms. Firms are heterogeneous and may respond differently to volatility. Figure 7 compares most-to-least productive exporters in terms of export volumes and expenditure volatility in destination markets between 2000 and 2009. As previously, each destination-sector-year is placed into a bin based on the quartile of its expenditure volatility (x-axis). The y-axis displays the interquartile ratio that compares the highest 25% of productive firms to the lowest 25% in terms of weighted average export volumes for each quartile of expenditure volatility. The weighted average export volumes are computed at the 4-digit sector-destination-year level. The weights are the lagged mean absorption of the sector-destination-year triplets. They are designed to account for the possible self-selection of firms into destinations with different levels of expenditure. The figure depicts an interesting and striking result: expenditure volatility reduces the export difference between the least and the most productive firms. The 25% most productive firms export on average 3.9 times more than the lowest 25% in stable markets (Q1), while this difference shrinks to a factor of 2.3 in the most volatile markets (Q4).
Figure 7: Export difference between least and most productive firms  
(Volatility in destination-year-sector markets – 2000-2009)

Comparing most-to-least productive exporters by export volume and quartile of expenditure volatility

Fact 4: Volatility does not affect the export unit value difference between the least and the most productive firms. Figure 8 compares most-to-least productive exporters in terms of export unit values and expenditure volatility in destination markets between 2000 and 2009. The x-axis displays the same quartiles of expenditure volatility in 3-digit sector-destination-year triplets. The y-axis reports now the interquartile ratio that compares the highest 25% of productive firms to the lowest 25% in terms of average export unit values for each quartile of expenditure volatility. Interestingly, volatility does not seem to affect the export unit value difference between the least and the most productive firms.

2.3 Identification strategy

We seek to estimate the effects of the moments of the expenditure distribution on the firm-level intensive and extensive margins. In particular, how do exporters react to expenditure volatility? Our stylized facts highlight a negative correlation between the intensive margin of trade and volatility expenditure, which may differ across firms. These facts may be plagued by a potential reverse causality running from trade to volatility, however. To ad-
Figure 8: Export difference between least and most productive firms
(Volatility in destination-year-sector markets – 2000-2009)

Comparing most-to-least productive exporters
by export unit values and quartile of expenditure volatility

The figure compares most-to-least productive exporters in terms of export unit values and expenditure volatility in destination markets between 2000 and 2009. The x-axis displays the quartiles of expenditure volatility in 3-digit sector-destination-year triplets. The y-axis displays the interquartile ratio that compares the highest 25% productive firms to the lowest 25% in terms of average export unit values for each quartile of expenditure volatility. The average export unit values are computed at the 4-digit sector-destination-year level.

To address this concern, we use a simple identification strategy: for a given year and destination, we regress French firm-level exports at the 4-digit sector $k$ on expenditure volatility (and other moments) aggregated at the upper 3-digit level $K$. We expect different moments of aggregated expenditure to affect disaggregated trade patterns but not necessarily the reverse. The identifying assumption is that a 4-digit export flow of an individual firm in a destination does not affect the 3-digit sector expenditure distribution in that destination. This assumption is supported by two key features of the data. First, the 3-digit sector is composed of various 4-digit sub-sectors. Thus, it is reasonable to assume that an individual export shipment of soft drinks ($k=1554$) in the UK only marginally affect volatility of UK’s beverages ($K=155$). However, an issue is that some 3-digit sectors are composed with only one 4-digit sub-sector (see Table 4 in Appendix A). Despite this concern, the second feature of data supports our assumption: there exists substantial evidence of large border effects in trade patterns (see de Sousa et al., 2012). Consumer spending is thus domestically oriented and net exports account for a small share of domestic expenditure, reinforcing the idea that an individual export shipment only affects marginally expenditure moments. Nevertheless, to address the concern that an individual French firm export may affect expenditure shifters in destination, we remove French export and import flows...
from the destination’s expenditure computation.

Our strategy of identification is based on the following specification:

\[ y_{kj}^f = \beta_1 \mathbb{E}(R_{kj}^K) + \beta_2 \mathbb{V}(R_{kj}^K) + \beta_3 S(R_{kj}^K) + FE + \varepsilon_{kj}. \] (1)

At the intensive margin of trade, our dependent variable, \( y_{kj}^f \), is defined as the French firm \( f \) export volumes to destination \( j \) at the 4-digit manufacturing level \( k \) (ISIC classification) in a given year \( t \). Trade is related to the first-three moments of expenditure in destination: expected value \( \mathbb{E}(R_{kj}^K) \), volatility \( \mathbb{V}(R_{kj}^K) \), and skewness \( S(R_{kj}^K) \). These moments, and the volatility in particular, are time-varying. Using various combinations of fixed effects (FE), to wipe out time-invariant unobservable characteristics, we aim here to exploit the fluctuations in uncertainty over time.\(^{10}\) We examine whether fluctuations in volatility affect export decisions. It is important to control for the temporal variation in market size, i.e., the first moment of the expenditure distribution \( \mathbb{E}(R_{kj}^K) \). The fact that firms mechanically export more to a large sector-country than to a small one may indeed vary over time. Moreover, we control for the skewness of the market, \( S(R_{kj}^K) \). The basic intuition of this control is that if exporters prefer high expected returns (high \( \mathbb{E}(R_{kj}^K) \)) and low risk (low \( \mathbb{V}(R_{kj}^K) \)), they also prefer \textit{ceteris paribus} a high probability of an extreme positive event over a high probability of an extreme negative event. In other words, the marginal willingness of accepting a risk increases when the distribution of the risk becomes more skewed to the right, i.e., a higher positive \( S(R_{kj}^K) \). \( \varepsilon_{kj}^f \) represents the error term.

At the extensive margin of trade, we follow the same strategy of identification with a disaggregated left hand-side variable regressed on aggregated right hand-side expenditure moments. We distinguish between entry of new firms on the international market and exit of incumbents from that market. Regarding entry, our dependent variable in equation 2, \( y_{kj}^f \), is the probability that firm \( f \) starts exporting to destination \( j \) in 4-digit sector \( k \)

\(^{10}\)Another possibility would have been to compute time-invariant moments to capture cross-country and -sector specific differences in uncertainty. Ramondo et al. (2013), for instance, compute the volatility of country GDP on a 35-year time-window and study the effects of cross-country specific differences in uncertainty on the firm’s choice between serving a foreign market through exports or through foreign affiliate sales.
and year $t$. Our counterfactual is firms that do not enter in the same triplet $jkt$. This choice model can be written in the latent variable representation, with $y_{fjt}^k$ the latent variable that determines whether a strictly positive export flow is observed for firm $f$ in a destination-sector-year triplet. Our estimated equation is therefore as follows

$$Pr(y_{fjt}^k | y_{fjt-1}^k = 0) = \begin{cases} 1 & \text{if } y_{fjt}^k > 0, \\ 0 & \text{if } y_{fjt}^k \leq 0, \end{cases}$$

with

$$y_{fjt}^k = \ln E(R_{jt}^K) + \rho V(R_{jt}^K) + \eta S(R_{jt}^K) + FE + \epsilon_{fjt}^k.$$  

As previously described, $E(R_{jt}^K)$, $V(R_{jt}^K)$ and $S(R_{jt}^K)$ are the first three central moments of expenditure, and $\epsilon_{fjt}^k$ the error term. $FE$ represents various combinations of fixed effects. This equation is estimated using a linear probability model. The inclusion of fixed effects into a probit model would give rise to the incidental parameter problem. The linear probability model avoids this issue. In all regressions, we account for the correlation of errors by clustering at the country-4-digit sector level.

In addition to the probability of entry, one can also study the exit transition. Higher volatility or lower upside gains may indeed increase exit of firms from the export market. In that case, our dependent variable is the probability that firm $f$ in destination $j$ and sector $k$ in year $t - 1$ stops exporting to this destination that product $k$ in year $t$. Our counterfactual is now firms that continue to serve the same triplet $jkt$. Explanatory variables are the same as for the entry estimations.

### 2.4 Empirical results

We now present our empirical results on the intensive and extensive margins of trade.

#### 2.4.1 Intensive margin of trade

The intensive margin estimations are based on equation 1 and export volumes.\footnote{We report estimations on export unit values in Appendix C.} The sample covers the period 2000 to 2009. Standard errors are clustered by destination $j$ and sector $k$.
4-digit sector level \( k \). We use fairly demanding specifications with a vector \( \mathbf{FE} \) of different combinations of fixed effects. In every specification reported in Table 1, all coefficients are statistically significant (at the 1 and 5 percent confidence level), and of the expected signs. The results clearly show that expenditure volatility is negatively correlated with firm export volumes. This confirms the pattern shown in the stylized facts. Moreover, as expected, the average size of the expenditure, its skewness, and the firm productivity are positively correlated with export volumes.

Table 1: Intensive margin: export volumes

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Firm export volumes: ( \ln q_{fjkt} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Ln Expenditure Volatility(_{fjt}^k)</td>
<td>-0.028\textsuperscript{a} ( \pm 0.010 )</td>
</tr>
<tr>
<td>Expenditure Skewness(_{fjt}^k)</td>
<td>0.012\textsuperscript{a} ( \pm 0.004 )</td>
</tr>
<tr>
<td>Ln Mean 5-year Expenditure(_{fjt}^k)</td>
<td>0.068\textsuperscript{a} ( \pm 0.020 )</td>
</tr>
<tr>
<td>Ln Productivity(_{ft})</td>
<td>-</td>
</tr>
</tbody>
</table>

Observations: 4,697,926, 4,697,926, 4,697,926

\( R^2 \): 0.753, 0.695, 0.885

Sets of Fixed Effects:

Firm.(4-digit-)Sector.Time\(_{fkt}\) Yes - -
Destination\(_j\) Yes - -
Firm.Destination.Time\(_{fjt}\) - Yes -
4-digit-Sector\(_k\) - Yes -
Firm.destination.(4-digit-)Sector\(_{fjk}\) - - Yes
Time\(_t\) - - Yes

Notes: dependent variable is firm-level export volumes in logs aggregated at the 4-digit \( k \) level. All specifications include the overall sample of exporters. Number of years: 10; Number of destinations: 90; Number of 4-digit sectors: 119; Number of firms: 105,777. Expenditure is defined as apparent consumption (production minus net exports) at the 3-digit \( K \) level. See the paper for computational details about expenditure moments. Robust standard errors are in parentheses, clustered by destination and 4-digit sector level, with \( \textsuperscript{a}, \textsuperscript{b} \) denoting significance at the 1% and 5% level respectively.

Results are reported according to the fluctuations in uncertainty across destination markets (col. 1), across sectors (col. 2), and over time (col. 3). The differences between columns are informative on the effects of uncertainty on firm-level exports.

In column 1, we introduce a separate destination country fixed effect \( \alpha_j \), which controls for country-specific factors, and add firm-by-sector-by-year fixed effects \( \alpha_{fkt} \), which capture all time-varying firm-specific determinants such as productivity. Our coefficients of interest on volatility and skewness are identified in the destination dimension. Despite
the fact that firms may change destination to avoid uncertainty, we find a negative effect of expenditure volatility on firm-level exports. This implies that multi-destination firms only partly diversify their exports in different destinations.\(^{12}\)

In column 2, we introduce a separate 4-digit sector fixed effect (\(\alpha_k\)) and firm-by-destination-by-year fixed effects (\(\alpha_{fjt}\)). Our coefficients of interest are now identified in the sector dimension. With this specification, we still absorb productivity differences across firms, but we also control for any time-varying firm- and destination-specific factors. Thus, when shutting down the possibility for firms to diversify across destinations, the magnitude of the volatility estimate increases (from 0.028 in col. 1 to 0.040 in col. 2). At the margin, firms are more impacted because it is intuitively more difficult to change the sector of activity when uncertainty increases. The magnitude of the skewness effect is also a bit larger.

In column 3, we use firm-by-destination-by-sector fixed effects \(\alpha_{fjk}\) and add a separate year fixed effect \(\alpha_t\). We capture any differences that are maintained across our observation period at the firm-destination-sector level. However, this set does not control for time-varying firm characteristics such as productivity, which is introduced as an additional control. The estimates of column 3 have a very natural interpretation with a set of fixed effects corresponding to a within panel estimator. The identification lies in the variation of expenditure moments over time. The within estimates suggest that, for a given firm-destination-sector, an increase in volatility over time reduces firm’s export volumes, while an increase in skewness raises exports.

How economically meaningful are the estimates of volatility and skewness?

Based on the last column estimates, we aggregate firm-level results at the country level. Other things being equal, we find that in 2005 a one standard deviation increase in the average volatility of Belgium, one of the main export destinations, would reduce aggregate French exports to Belgium by 1.35%. A one standard deviation increase in the average volatility of China would reduce aggregate French exports to China by 1.45%.

Moreover, if the United States expenditure was as volatile as Mexico, French exports

\(^{12}\)Note that focusing on the multi-destination and sector exporters only affects marginally the estimates. Results are available from the authors upon request.
to the US would decrease by 2.7%. In contrast, other things being constant, if the US expenditure was as skewed as Mexico, French exports to the US would increase by 1.1%. This implies that both absolute and downside risk matter for exporters.

As a final counterfactual, we ask what French exports would have been if there had been virtually no volatility in destination markets. Total French exports would increase by 4.5% if volatility in all destinations in 2005 would be as low as in the UK’s textile sector (1711). In contrast, total French exports would decrease by .5% if markets with positive skewness would be reduced to zero.

**Heterogeneous responses of firms to expenditure volatility**

Our second stylized fact documents that volatility reduces the export difference between the least and the most productive firms. This is depicted in the non-parametric Figure 7. In Figure 9, we construct a parametric version of this stylized fact.

**Figure 9: Volatility, productivity and export volumes**

We use a simple strategy to construct the parametric figure of the heterogeneous responses of firms to volatility. We run the same specification as in column 3 of Table 1 but we interact productivity with volatility. More precisely, we split the log of productivity into quartiles and the expenditure volatility into deciles. Then, we interact the productivity quartiles with deciles of volatility and run the regression by conditioning the firms’ responses on the firm-by-destination-by-sector (4-digit) fixed effects plus year fixed effects.

13 4-digit sector 1711 is Preparation and spinning of textile fibres; weaving of textiles. UK’s volatility in this sector in 2005 is equal to 0.024.
effects. Finally, based on the estimated parameters, we compute the predicted mean of export volumes (in logs) for each decile of volatility and quartile of productivity. The different predictions of trade are plotted in Figure 9. This plot shows three interesting results: (1) as expected the most productive firms export more than the others for any level of volatility; (2) the larger the expenditure volatility, the lower the export volumes for all levels of productivity, except for the least productive firms; and (3) the marginal decrease in exports is larger for the most productive firms as the volatility increases. These results imply that the export difference between the least and the most productive firms decreases with volatility.

2.4.2 Extensive trade margin

We now investigate the impact of uncertainty on the extensive margin of trade. Do consumer expenditure moments affect firm presence in a given destination $j$, 4-digit sector $k$ and year $t$? To answer this question, we estimate equation 2 using a linear probability model, which avoids the incidental parameter problem of running a probit with the inclusion of multiple fixed effects (FE). Estimations cover the entry and exit of French firms from a destination-sector-year triplet over the 2000-2009 period.

Our counterfactual is defined as firms that do not enter (or do not exit) in the same destination-sector-year triplet. This dramatically increases the number of observations. In order to reduce the size of our sample, to avoid creating false zeros, and to address our computational problems, we apply the following strategy. We first compute the number of firms per destination-sector (4-digit) and keep destination-sector pairs for which the number of firms is above the median. Then, we drop a firm in a destination or a firm in a sector when one of the following criteria is met:

1. the number of years of presence of the firm in a destination is below the median number years of presence of all firms in a destination between 2000 and 2009;

2. the number of years of presence of the firm in a sector is below the median number years of presence of all firms in a sector between 2000 and 2009.
Applying these criteria does not mean that we necessarily remove the firm from our sample but mean that we only drop its erratic entry and exist over time in a given sector or in a given destination. This limits the interest of investigating the (within) effect of volatility on the probability of exit and entry in the export markets over time. We investigate instead the effects across sectors or destinations in Table 2. The first two columns deal with the probability of firms’ entry in the international market, while the last two columns focus on the probability of exit. We use two different sets of fixed effects: firm-by-destination-by-year plus sector in columns 1 and 3, and firm-by-destination-by-sector plus year in columns 2 and 4. Note that the sector level is at 4-digit. In all regressions, we account for correlation of errors by clustering at destination-4-digit sector level.

Table 2 shows quite intuitive results. The probability for a firm to enter the export market is positively and significantly influenced by the expenditure level (col. 1 and 2). On the other hand, expenditure level significantly reduces the probability of exit the export market (col. 3 and 4). As expected for the two dimensions ‘within firm-sector-time’ (col. 1) and ‘within firm-destination-time’ (col. 2), the expenditure volatility significantly decreases the probability of entry, suggesting some reallocation effects across destinations and sectors in terms of export decisions. The opposite effect is observed on the exit probability (col. 3 and 4). However, skewness has no significant impact on the entry probability, nor on the exit one.

2.4.3 Heterogeneity among firms in response to expenditure volatility

Firms are heterogeneous in terms of number of destinations and sectors. Our sample indeed includes four types of firms: firms exporting only to one sector and one destination (mono-sector and mono-destination firms); firms exporting to one sector and to multiple markets (mono-sector and multi-destination firms); firms exporting to more than one sector but to one market only (multi-sector and mono-destination firms); finally, firms exporting to multiple sectors and serving more than one market (multi-sector and multi-destination firms).
Firms exporting to various sectors and destinations may reduce their exposition to risk by exporting to less volatile markets (sector or destination). If this is the case, only the firms exporting to one destination and/or one sector would be affected by volatility. To account for this possibility, we check whether our previous results at the intensive and extensive margins still hold when firm heterogeneity, in terms of number of destinations and sectors, is controlled for. To do so, we interact our measure of expenditure volatility with four dummies. The two first dummy variables distinguish mono- vs. multi-sector firms, while the two others divide our sample between mono- vs. multi-destination firms. Results are reported in Table 3.

The intensive margin results (col. 1 and 4) somewhat confirm the heterogeneity of firm’s responses to expenditure volatility. In column 1, the effects of uncertainty are identified across destinations and highlight a negative effect only for the multi-sector firms which appear also to be the most productive ones. In column 4, when shutting down the possibility for firms to diversify across destinations, the magnitude of the volatility estimate stay constant for multi-destination firms but become negative and larger for the mono-destination firms.

At the extensive margin of trade, estimations highlight three main results. First,
Table 3: Diversification across destinations and sectors

<table>
<thead>
<tr>
<th>Dependent variable:</th>
<th>Diversification across destinations</th>
<th>Diversification across sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Export Volumes</td>
<td>Proba. of Entry</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
</tbody>
</table>
| Ln Expenditure Vol. | 0.027          | 0.003          | 0.012  
| $K_{jt}$ x Mono-sector firms | (0.026)        | (0.0007)       | (0.005)       | 0.032          | -0.002        | 0.004  
| $K_{jt}$ x Multi-sector firms | (0.010)        | (0.0003)       | (0.001)       | -0.103         | 0.0005        | -0.001  
| Ln Expenditure Vol. | -0.038         | -0.006        | 0.003  
| $K_{jt}$ x Mono-dest. firms | (0.014)        | (0.0002)       | (0.001)       | 0.011          | 0.0002        | -0.0004 
| $K_{jt}$ x Multi-dest. firms | (0.04)         | (0.0001)       | (0.0005)      | 0.015          | 0.0001        | -0.0004 
| Expenditure Skewness | 0.068          | 0.003         | -0.013 
| $K_{jt}$ | (0.02)         | (0.0004)       | (0.002)       | 0.079          | 0.001         | -0.007  
| Ln Mean 5-year Expenditure | -              | -              | -              | 4.697,926      | 33,690,403  | 3,819,122 |
| $K_{jt}$ | 0.753          | 0.111          | 0.444          | 0.695          | 0.485          | 0.643         |
| $R^2$ | 0.753          | 0.111          | 0.444          | 0.695          | 0.485          | 0.643         |

Sets of Fixed Effects:
- Firm 4-digit Sector.Time $f_{kt}$: Yes
- Destination $j$: Yes
- Firm Destination.Time $f_{jt}$: Yes
- 4-digit Sector $k$: Yes

Notes: dependent variable is firm-level export volumes in logs aggregated at the 4-digit $k$ level (col. 1 and 4), probability for a firm to enter the export market (col. 2 and 5) and probability for a firm to exit the export market (col. 3 and 6). Intensive margin sample: 10 years, 90 destinations, 119 4-digit sectors, and 105,777 firms. Entry sample: 9 years, 77 destinations, 116 4-digit sectors, and 63,895 firms. Exit sample: 9 years, 77 destinations, 116 4-digit sectors, and 64,268 firms. Expenditure is defined as apparent consumption (production minus net exports) at the 3-digit $K$ level. See the paper for computational details about expenditure moments. Robust standard errors are in parentheses, clustered by destination and 4-digit sector level, with ‘a’, ‘b’ denoting significance at the 1% and 5% level respectively.
expenditure volatility decreases the probability of entry of multi-sector and -destination firms (col. 2 and 4), while it decreases the probability of entry of mono-sector and -destination firms. This is in line with the previous results on the intensive margin. Second, volatility increases the probability of exit of mono- and multi-sector firms, and this effect is stronger for mono-sector firms (col. 3). Third, volatility only impacts the exit probability of multi-destination firms (col. 6). Overall, these results confirm that the responses to volatility therefore differ across firms.

3 Theory

Our objective here is to present a simple trade model that rationalizes our empirical results on the role of expenditure uncertainty on trade.

3.1 The role of expenditure uncertainty

We develop a monopolistically competitive model of trade with heterogeneous firms but where the role of uncertainty differs from Melitz (2003). Firms do not face some initial uncertainty concerning their future productivity. We assume for simplification that firm heterogeneity is given. Risk-averse producers face instead an industry-wide uncertainty over expenditure and make decisions before the resolution of uncertainty. We thus consider that firms do not know with certainty the expenditure allocated to an industry in a destination country at the time strategic variables (entry/exit, quantity or price) are chosen.

The uncertainty comes from the fact that industry-level expenditure in destination country \( j \), \( R_j \), is subject to random shocks. Among the numerous factors beyond the producer’s control that influence the demand realization are weather, changes in consumer tastes, opinion leaders’ attitudes, popularity of competing products, or industrial policy. We assume that \( R_j \) is independently distributed with a mean, a variance, and a skewness given by \( \mathbb{E}(R_j) \), \( \mathbb{V}(R_j) \), and \( \mathbb{S}(R_j) \) respectively.\(^{14} \) The economic interpretation of these

\(^{14}\)Note that \( \mathbb{E}(R_j) \) and \( \mathbb{V}(R_j) \) are always positive, while \( \mathbb{S}(R_j) \) can be positive or negative.
central moments is discussed below. We also consider that shocks are not correlated across countries, \( \text{Cov}(R_l, R_j) = 0 \) for all \( l \neq j \), for the sake of simplicity.

Under imperfect competition, the choice of the action variables (quantity or price) merits a discussion. We know from Leland (1972), Weitzman (1974), and Klemperer and Meyer (1986) that, if the choice of behavioral mode by a monopolistic firm is unimportant under certainty, this is no longer the case under uncertainty. The firm has two options: (i) set quantity before demand is known and thereafter the actual demand curve yields the market clearing price or (ii) set price before demand is known and thereafter the actual demand curve yields the market clearing quantity. Ideally, we would determine endogenously if firms choose either a quantity to produce or a price to charge, as in Klemperer and Meyer (1986). To keep things simple, we consider that firms set quantity \textit{ex ante}, before demand is known. In Appendix D, we develop the case where price is the strategic variable. We show that this configuration yields the same predictions than the case where firms set quantity even if the level of prices and quantities differ according to the behavioral mode.

3.2 Preferences and demand

Consider a multi-country economy with one sector supplying a continuum of differentiated varieties indexed by \( v \).\(^{15}\) Labor is the sole factor of production. Consumers in each county share the same preferences and the utility resulting from the consumption of the differentiated good is given by a general additively separable utility:

\[
U_{c_j} = \int_{v \in \Omega_j} u_j(v) dv,
\]

where the measure of the set \( \Omega \) represents the mass of available varieties and \( q(v) \) is the individual quantity of varieties consumed. Hence, as in Dixit and Stiglitz (1977), Krugman (1979), and Zhelobodko et al. (2012), we assume that preferences over the differentiated product are additively separable across varieties and \( u_j(.) \) is thrice continuously differentiable.

\(^{15}\)Note that we could easily consider a multi-sector economy. However, doing this increases the complexity of the formal developments without adding any new insights.
tiable, strictly increasing, and strictly concave on \((0, \infty)\). Formally, we have \(u_j(0) = 0\), 
\[ u_j' \equiv \frac{\partial u(v)}{\partial q(v)} > 0 \text{ and } u_j'' \equiv \frac{\partial^2 u(v)}{\partial q(v)^2} < 0. \]  
As \(u_j' > 0\) and \(u_j'' < 0\), consumers exhibit a love for variety.

The budget constraint faced by a consumer in destination \(j\) is given by

\[
\int_{\Omega_j} p_{\ell j}(v)q_{\ell j}(v)dv = R_j, \tag{4}
\]

where \(R_j\) denotes aggregate expenditure, and \(p_{\ell j}(v)\) is the price of variety \(v\) produced in country \(\ell = i, j, \ldots, L\). Using the first-order conditions for utility maximization, the inverse demand curve for each differentiated variety is:

\[
p_{ij}(v) = \frac{u_j'(v)}{\lambda}, \tag{5}
\]

where \(\lambda\) is the Lagrange multiplier (corresponding to the marginal utility of income).

Plugging (5) into (4) implies \(\lambda = \Psi_j/R_j\) with

\[
\Psi_j \equiv \int_{\Omega_j} u_j'(v)q_{ij}(v)dv, \tag{6}
\]

where \(\Psi_j\) can be interpreted as a measure of industry supply. As a consequence, the inverse demand for each variety is now

\[
p_{ij}(v) = R_j u_j'(v)\Psi_j^{-1}. \tag{7}
\]

As expected, the price of each variety increases with expenditure \((R_j)\) and decreases with both its own quantity \((\partial p_{ij}/\partial q_{ij} < 0 \text{ as } u_j'' < 0)\), and the quantity and quality of varieties supplied by rival firms \((\Psi_j)\). Exporting firms face a downward sloping demand curve in destination \(j\), which under uncertainty is characterized by a random shift parameter \(R_j\) (common to all firms).
3.3 Market structure, technology, and firm behavior

Varieties are provided by heterogeneous monopolistically competitive firms. Each variety is produced by a single firm and each firm supplies a single variety. This means that producers are negligible to the market, behave as monopolists on their market, and their decisions do not account for the impact of their choice on aggregate statistics.

Labor is the only production factor and is assumed to be supplied inelastically. Production of $q_{ij}(v)$ units of variety $v$ to be exported in country $j$ requires a quantity of labor equals to $\tau_{ij}q_{ij}(v)/\varphi$, where $\varphi$ is labor productivity and $\tau_{ij}$ is an iceberg variable costs of trade, such that $\tau_{ij} > 1$ units of a variety must be exported from country $i$ to country $j$ in order for one unit to arrive. We assume that labor productivity is given but differs among firms. Thus, the marginal requirement in labor is specific to each firm and to each destination, but does not vary with production.

Without loss of generality, we assume that firms determine quantity to serve destination market $j$, $q_{ij}$, before knowing the exact value of expenditure $R_j$. This ex ante quantity is based on firm’s characteristics and features of origin $i$ and destination $j$ markets, such as moments of the distribution of expenditure $R_j$. Equilibrium prices $p_{ij}$ are determined ex post in accord with realized demand. We assume that firms cannot adjust quantity ex post with respect to the expenditure shock. The decision to produce for exports has been taken ex ante and thus ex post quantity adjustments are not feasible. Both parties cannot refuse the deal ex post once the price is realized. This implies that products cannot be sent back. They are sold once exported.

As the shocks to expenditure are unobservable, the impact of quantity on price is uncertain. The expected export profit in a given destination market $j$ is

$$\mathbb{E}[\pi_{ij}(v)] = \mathbb{E}[p_{ij}(v)]q_{ij}(v) - c_{ij}(v)q_{ij}(v),$$

(8)

with $c_{ij}(v) = w_i\tau_{ij}/\varphi$ where $w_i$ is the wage rate prevailing in the exporting country $i$.

The uncertain terminal profit $\pi_i$ of a firm producing variety $v$ and located in country

---

\(^{16}\text{Recall that Appendix D develops the case where price is determined first.}\)
i can be decomposed into two parts: the profit of domestic sales \( \pi_{ii} \), which is assumed to be certain for simplicity, and the uncertain profit of total exporting sales \( \Sigma_j \pi_{ij} \), such that

\[
\pi_i = \pi_{ii} + \Sigma_j \pi_{ij}.
\]  

(9)

3.4 Uncertainty and firm behavior

We consider a risk-averse manager with a concave utility function \( U_m(\pi_i) \) representing her risk preferences. Being risk-averse means that the manager dislikes every destination market with an expected payoff of zero. She is thus willing to pay a “risk premium” to avoid risk in some destination markets. We follow the expected utility theory, where the risk-aversion behavior is intrinsically equivalent to a preference for diversification (see Eeckhoudt et al., 2005). Assume that \( U_m(\pi_i) \) is continuously differentiable up to order 3, with \( U_m'(.) > 0, U_m''(.) < 0, \) and \( U_m'''(.) > 0 \). Following the methodology developed in Eeckhoudt et al. (2005), a third-order Taylor expansion of \( U_m(\pi_i) \) evaluated at \( E(\pi_i) \) gives

\[
U_m(\pi_i) \approx U_m[E(\pi_i)] + U_m'[\pi_i - E(\pi_i)] + \frac{1}{2} U_m''[\pi_i - E(\pi_i)]^2 + \frac{1}{6} U_m'''[\pi_i - E(\pi_i)]^3.
\]

Taking the expectation and assuming that the first three moments of \( R_j \) exist lead to

\[
EU_m(\pi_i) \approx U_m[E(\pi_i)] + \frac{1}{2} U_m''V(\pi_i) + \frac{1}{6} U_m'''S(\pi_i),
\]

(10)

where \( V(\pi_i) = E[\pi_i - E(\pi_i)]^2 \) is the variance of profit and \( S(\pi_i) = E[\pi_i - E(\pi_i)]^3 \) its skewness. According to the expected utility theory, one way to measure the degree of risk aversion of a decision maker is to ask her how much she is ready to pay to get rid of the zero-mean risk. The answer to this question will be referred to as the risk premium \( \Gamma \) associated with that risk.\(^{17}\) In our context, the risk premium \( \Gamma \) is defined as the sure amount of money a manager would be willing to receive to become indifferent between the risky return \( \pi_i \) (Eq. 9) and the non-random amount or certainty equivalent of the

---

\(^{17}\)As an illustration, for a random lottery \( x \), the risk premium must satisfy the certainty equivalent condition that \( EU_m(x) = U_m(E(x) - \Gamma) \). In other words, the decision maker ends up with the same welfare either by accepting the risk or by paying the risk premium \( \Gamma \).
expected utility, i.e.

\[ \mathbb{E}U_m(\pi_i) = U_m(\mathbb{E}(\pi_i) - \Gamma) \approx U_m(\mathbb{E}(\pi_i)) - \Gamma U'_m, \]  

where \( \mathbb{E}U_m(\pi_i) \) is approximated by a first-order Taylor expansion. Using this approximation in (10) yields

\[ \Gamma \approx \rho_v V(\pi_i) - \eta_v S(\pi_i), \]  

where \( \rho_v = -U''_m/2U'_m > 0 \) and \( \eta_v = -U'''_m/6U'_m < 0 \) are the marginal contributions of variance and skewness of \( \pi_i \) to the risk premium \( \Gamma \), respectively.

Several remarks are in order. First, \( \rho_v \) is the so-called Arrow–Pratt absolute risk aversion coefficient. Being positive, it implies that managers are risk averse. However, their risk aversion is assumed to be decreasing because \( \eta_v < 0 \). This means that manager’s risk preferences are DARA, which stands for Decreasing Absolute Risk Aversion.\(^{18}\) DARA requires the necessary condition that \( U'''_m \) be positive, or that marginal utility be convex. A drawback of DARA preferences is that the index of absolute risk aversion is not unit free, as it is measured per dollar (Eeckhoudt et al., 2005). Thus, absolute risk aversion measures the rate at which marginal utility decreases when wealth is increased by one dollar. However, a unit-free measurement of sensitivity is not without its own set of drawbacks. Constant Relative Risk Aversion (CRRA) would measure the rate at which marginal utility decreases when wealth is increased by one percent. But, this implies to redefine the risk premium as \( \Gamma \) times the product of the manager’s wealth. Yet, the manager’s wealth should not be considered as given but endogenous to risk and economic conditions. An advantage of DARA preferences is to capture a sense of relativeness without taking a stand on the manager initial wealth. The fact that the marginal utility is convex (or \( U'''_m > 0 \)), which is a very intuitive condition, implies that an increase in initial wealth tends to reduce the manager’s willingness to insure (as measured by the risk premium \( \Gamma \)). In this case, private wealth accumulation and insurance motives are substitutes.

\(^{18}\)In contrast, \( \eta_v = 0 \) would imply Constant Absolute Risk Aversion (CARA) preferences.
Next, note also that given $U''''_m > 0$, the term $\eta_v = -U''''_m/6U'_m < 0$ captures a preference for positive skewness. It implies a low probability of obtaining a large negative return. This entails that the absolute risk aversion of the exporter decreases with its level of domestic sales. Last, $U''''_m > 0$ corresponds to a situation of “downside risk aversion”, implying that a decrease in $S(\pi_i)$ would tend to increase the willingness to pay to avoid risk (Menezes et al., 1980). Thus, for given $E(\pi_i)$ and $V(\pi_i)$, downside risk averse exporters will favor destination markets with positive skewness of profits.

Finally, we know from the expected utility theory that maximizing $E U_m(\pi_i)$ is equivalent to maximizing the certainty equivalent payoff $\Pi_v(\pi_i) = E(\pi_i) - \Gamma$. Since expression (12) provides a local approximation to the risk premium $\Gamma$, it follows that the objective function of a decision-maker can always be approximated by

$$\Pi_v(\pi_i) \approx E(\pi_i) - \Gamma = E(\pi_i) - \rho_v V(\pi_i) + \eta_v S(\pi_i).$$

(13)

This equation provides an intuitive interpretation of the risk premium ($\Gamma$) that measures the shadow cost of private risk bearing. It is a cost since it appears as a reduction in expected gain, $E(\pi_i)$. This general formulation of the objective function does not require a full specification of the utility function $U_m(\pi_i)$ and it allows us going beyond a simple mean-variance analysis in the investigation of export decision under expenditure uncertainty. This may be particularly useful in the analysis of “downside risk” exposure. However, the reader should keep in mind that expression $U_m(\pi_i)$ is valid only in the neighborhood of the point $E(\pi_i)$. In other words, we only consider small risk. Given that the share of export sales of a destination in total sales of firms is usually low, this assumption is not too restrictive.

### 3.5 Risk premium and firm size

Remember that $R_j$ is not known for certain at the time the contracts with the importers are signed. The expected price prevailing for each firm in the foreign market is therefore
given by
\[ E[p_{ij}(v)] = E(R_j)u'_j(v)\Psi^{-1}. \] (14)

whereas the expected market share for each firm in country \( j \) is
\[ s_{ij}(v) = \frac{E(p_{ij})q_{ij}(v)}{E(R_j)} = u'_j(v)q_{ij}(v)\Psi^{-1}. \] (15)

As expected, the expected market share increases with output size. Indeed, we have
\[ \frac{\partial s_{ij}(v)}{\partial q_{ij}(v)} = \Psi^{-1} \Lambda_{ij}(v) > 0 \]
with
\[ \Lambda_{ij}(v) \equiv u'_j(v) + u''_j(v)q_{ij}(v) > 0 \]
which guarantees that the marginal revenue of firms is always positive. This condition is checked for a large class of utility functions, including the case where the elasticity of substitution is constant like in numerous trade models. For example, if \( u_j(q_{ij}) = \theta v q_{ij}^\gamma \) with \( 0 < \gamma < 1 \) so that the elasticity of substitution between any pair of varieties is constant, given by \( 1/(1-\gamma) \), and
\[ \Lambda_{ij}(v) = \theta v^2 q_{ij}^{\gamma-1} > 0. \]

The risk premium for each firm is \( \Gamma_v = \sum_j \Gamma_{ij} \) with:
\[ \Gamma_{ij} \equiv \rho_v V(\pi_{ij}) - \eta_v S(\pi_{ij}), \]
(16)
as \( \text{Cov}(R_l, R_j) = 0 \) for all \( l \neq j \). \( \Gamma_{ij} \) can be interpreted as the risk premium associated with a destination country. It is straightforward to check that the variance and the skewness of the profit distribution are given by
\[ V(\pi_{ij}) = V(R_j)s_{ij}^2 \quad \text{and} \quad S(\pi_{ij}) = S(R_j)s_{ij}^3, \] (17)
respectively. The variance of firm’s profit increases with its output size (through a higher expected market share). The skewness of the profit distribution rises when the firm’s output size increases as long as \( S(R_j) > 0 \). Hence, the impact of output size on risk premium is ambiguous when \( S(R_j) > 0 \) as risk premium depends negatively on the skewness of expenditure distribution. The following Lemma summarizes our main results.

**Lemma 1.** The variance of profit increases with output size whereas the relationship between risk premium and output size is ambiguous when \( S(R_j) > 0 \).
It is worth stressing that the variance and the skewness of profits decreases with the industry’s output size. Hence, the mass of rivals serving the same market has an ambiguous effect on the export performance at the firm level. Indeed, a rise in $\Psi_j$ decreases the marginal revenue of the firm but reduces the variance of profits.

### 3.6 Intensive margin

The payoff of each firm $\Pi_v(\pi_i) = \sum_j s_{ij}E(R_{ij}) - c_{ij}q_{ij} - \sum_j \Gamma_{ij}$. Hence, the marginal revenue is uncertain while the marginal cost is known with certainty. The expected export sales $E[p_{ij}(v)]q_{ij}(v)$ increases with $q_{ij}$ but decreases with the industry’s output size (captured through $\Psi_j$).

The first order conditions for payoff maximization $\partial \Pi_v/\partial q_{ij} = 0$ implies

$$
\frac{\partial s_{ij}}{\partial q_{ij}}E(R_j) \left[1 - \frac{\partial \Gamma_{ij}}{\partial s_{ij}(v)} \frac{1}{E(R_j)} \right] - c_{ij} = 0.
$$

whereas the second order condition requires $\partial^2 s_{ij}/\partial q^2_{ij} < 0$ and $\partial^2 \Gamma_{ij}/\partial q^2_{ij} > 0$ to check that $\partial^2 \Pi_v/\partial q^2_{ij} < 0$. Using (16), (18), and the implicit function theorem, it is readily to check that

$$
\partial q_{ij}/\partial V(R_j) = -[\partial^2 \Pi_v/\partial q_{ij} \partial V(R_j)]/[\partial^2 \Pi_v/\partial q^2_{ij}] < 0.
$$

As a result, in accordance with the standard literature related to producer theory under uncertainty, the risk averse firms produce less than it would under certainty, for a given mass of exporters. The reason is that the certainty equivalent export quantity $q_{ij}$ incorporates the risk premium composed of $\rho_vV(R_j) > 0$. However, we have also to take into account the fact that the marginal willingness of exporters to accept a risk increases when the distribution of the risk becomes more skewed to the right. Indeed, we have

$$
\partial q_{ij}/\partial S(R_j) = -[\partial^2 \Pi_v/\partial q_{ij} \partial S(R_j)]/[\partial^2 \Pi_v/\partial q^2_{ij}] > 0.
$$

Regardless of the sign of $S(R_j)$, each exporter has an incentive to increase its level of output for a given $V(R_j)$ when the income distribution becomes more skewed to the right.
right. The degree of skewness modifies the desirability of risk.

Further, we can readily check that quantities are concave in productivity ($\partial q_{ij}/\partial \varphi > 0$ and $\partial^2 q_{ij}/\partial \varphi^2 < 0$). Thus, the most productive firms are the largest in terms of labor and quantity produced. In addition, the relationship between quantities trade costs are negative and convex ($\partial q_{ij}/\partial \tau_{ij} < 0$ and $\partial^2 q_{ij}/\partial \tau_{ij}^2 > 0$). More interesting, it is straightforward to check that

$$\frac{\partial^2 q_{ij}}{\partial \varphi \partial \mathcal{V}(R_j)} < 0 < \frac{\partial^2 q_{ij}}{\partial \tau \partial \mathcal{V}(R_j)},$$

when $\rho_v > 0$. For a given $\rho_v$, the negative effect of expenditure volatility is strengthened when firm productivity is high and trade costs are low. Remember that the variance of profits in a given foreign market increases with the variance of foreign expenditure and the output size dedicated to that foreign country (see equation 17). As $\partial q_{ij}/\partial \varphi > 0$ and $\partial q_{ij}/\partial \tau_{ij} < 0$, the variance of profits of a firm increases with its productivity and decreases with trade costs for a given mass of firms.

However, standard calculations show also that

$$\frac{\partial^2 q_{ij}}{\partial \varphi \partial S(R_j)} > 0 > \frac{\partial^2 q_{ij}}{\partial \tau \partial S(R_j)},$$

as $\partial q_{ij}/\partial \varphi > 0$ and $\partial q_{ij}/\partial \tau > 0$. The magnitude of the positive impact of a higher $S(R_j)$ on production is stronger for firms exhibiting a higher productivity and for destinations implying lower trade costs. To summarize,

**Proposition 1** For a given industry supply ($\Psi$), the negative effect of expenditure volatility on export quantities is strengthened when firm productivity increases and trade costs decrease provided that the skewness of expenditure distribution is unchanged.

More generally, the market shares of large firms are more impacted by a rise in expenditure volatility than the small firms when the skewness is unchanged as $\partial^2 s_{ij}/\partial \varphi \partial \mathcal{V}(R_j) < 0$, leading to a reallocation of market share from the high productivity firms to the less productivity firms.
Equilibrium prices

The first order condition (18) can be rewritten as follows:

\[
\mathbb{E}[p_{ij}(v)] = c_{ij}(v) \left[ 1 - \frac{-u''_j(v)q_j}{u'_j(v)} \right]^{-1} \left[ 1 - \frac{\partial \Gamma_{ij}(v)}{\partial s_{ij}(v)} \frac{1}{\mathbb{E}(R_j)} \right]^{-1},
\]

(19)

where

\[
\frac{\partial^2 \Gamma_{ij}}{\partial s_{ij} \partial V(R_j)} > 0 > \frac{\partial^2 \Gamma_{ij}}{\partial s_{ij} \partial S(R_j)} \quad \text{and} \quad \frac{\partial^2 \Gamma_{ij}}{\partial s_{ij} \partial c_{ij}} = \frac{\partial^2 \Gamma_{ij}}{\partial s_{ij}^2} \frac{\partial q_{ij}}{\partial c_{ij}} < 0,
\]

as \(\frac{\partial q_{ij}}{\partial s_{ij}} < 0\) and \(\frac{\partial^2 \Gamma_{ij}}{\partial s_{ij} \partial c_{ij}} > 0\) according the first and the second order conditions, respectively.

This implies that, at the equilibrium supply, expected price is equal to the marginal cost \(c_{ij} = w_i \tau_{ij}/\varphi\) times a markup including the marginal risk premium. The markup increases with a higher variance of expenditure distribution when the skewness is unchanged.

Under demand certainty, the markup is equal to \(1 + u''_j(v)q_j/u'_j(v)\) (which is equal to \(1/\gamma\) when the substitution elasticity is constant). With uncertain demand and risk-averse firms, the markup is higher on average than the markup prevailing under certain demand due to the expenditure fluctuations. Hence, uncertain demand curve increases the prices through a higher markup.

It is worth stressing that, unlike models of monopolistic competition with perfect information, the markup is not a constant. Firms charge variable markups even under CES preferences. In other words, expenditure uncertainty and risk-averse firms allow for variable markups even though demand curve is iso-elastic. Markup depends on the expenditure volatility, firm’s productivity and features of origin and destination countries. The markup increases with the firm’s productivity (\(\varphi\)) and decreases with trade costs (\(\tau_{ij}\)) and the mass of rivals (captured by \(\Psi_j\)). Those findings are in accordance with industrial organization theory. However, the mechanisms at work are different. Our results are related to the existence of demand fluctuations and risk aversion. The variance of profits being high for the most productive firms, they charge greater markups. Similarly, low market size induces low variance of profits so that the markup is lower for destinations with a low potential market. Hence, even though preferences exhibit an iso-elastic demand,
markups vary according to destinations and firms. The next proposition sums up our results on prices in destination markets:

**Proposition 2** The markups increase with a higher industry-level foreign expenditure uncertainty for large firms and for markets with low trade costs.

Two comments are in order. First, data provide information on the *ex post* prices. In our framework, the *ex post* equilibrium prices are given by \( p_{ij}(v) = R_j u_j'(v) \Psi_j^{-1} \) evaluated at the equilibrium price leading to \( p_{ij}(v) = \frac{R_j}{E_j} \mathbb{E}[p_{ij}(v)] \). Second, Propositions 1 and 2 are related to the intensive margin of trade, i.e., variation in trade of existing trade relationships. However, departing from equilibrium, an exogenous increase in volatility may lead to an adjustment in the industry supply (\( \Psi_j \)), through an adjustment in the quantities produced by the competitors. This adjustment reinforces proposition 2 on export prices but renders proposition 1 on exported quantities more ambiguous. Before presenting the effect of an increase in volatility in Section 3.8, we study the role of uncertainty on the extensive margin of trade, i.e., on the existence of trade relationships (non-zero trade flows).

### 3.7 Export decision

The mass of firms serving country \( j \) is treated as endogenous. There is a large supply of potential entrants in the international market. However, entry in destination market \( j \) is subject to a fixed cost \( f_{ij} \), which is the cost to maintain a presence in foreign markets, i.e., maintaining a distribution and service network, minimum freight and insurance charges, costs of monitoring foreign customs procedures and product standards, etc. The decision to serve a foreign market is taken on the basis of the expected payoff. A firm exports to destination \( j \) if and only if the variable payoff (not including fixed cost) is positive, i.e., \( \Pi_{ij} = \mathbb{E}(\pi_{ij}) - \Gamma_{ij} > w_i f_{ij} \). It is straightforward to check in our general framework that (i) there exists a productivity cutoff above which a firm can profitably serve country \( j \) as \( \Pi_{ij} = 0 \) when \( \varphi = 0 \) and \( \partial \Pi_{ij} / \partial \varphi > 0 \) evaluated at the equilibrium output and (ii) a firm is more likely to serve a country with a low variance and a high skewness of its expenditure...
distribution as \( \partial \Pi_{ij} / \partial \mathcal{V}(R_j) < 0 < \partial \Pi_{ij} / \partial \mathcal{S}(R_j) \) evaluated at the equilibrium output. To summarize,

**Proposition 3** A higher industry-level foreign expenditure volatility reduces the share of exporting firms when the skewness of expenditure distribution is unchanged.

### 3.8 Ex-post adjustments in intensive and extensive margins

Having established the equilibrium, we look at the effect on the extensive and intensive margins of increasing expenditure volatility. We have to take into account the direct and indirect effects of expenditure volatility on prices and quantities. The indirect effects on export quantities and prices come from a change in \( \Psi_j \) when \( \mathcal{V}(R_j) \) changes.

To keep things simple and tractable, we consider that \( u_j(q_{ij}) = \theta_v q_{ij}^{1/2} \) in Eq. (3) where \( \theta_v > 0 \) can be interpreted as a measure of product quality and \( \eta_v = 0 \). Under this configuration, the equilibrium certainty-equivalent quantities are given by

\[
q_{ij}(v) = \frac{\mathbb{E}(R_j) \theta_v \varphi}{2 w_i \tau_{ij}} \Psi_j^{-1} \left[ 1 + \rho_v \mathcal{V}(R_j) \Psi_j^{-2} \frac{\theta_v^2 \varphi}{w_i \tau_{ij}} \right]^{-1} \tag{20}
\]

It is then straightforward to check that \( \Pi_v(\pi_{ij}) = r_{ij}(\varphi)/2 \) where \( r_{ij}(\varphi) \equiv \mathbb{E}(p_{ij})q_{ij} \) is firm revenue with

\[
s_{ij}(\varphi) = \frac{\mathbb{E}(R_j)^2}{2} \left[ \frac{w_i \tau_{ij}}{\theta_v^2 \varphi} \Psi_j^2 + \rho_v \mathcal{V}(R_j) \right]^{-1}. \tag{21}
\]

As a result, \( \Pi_v(\pi_{ij}) = 0 \) when \( \varphi = 0 \) and \( \partial \Pi_v / \partial \varphi > 0 \). Hence, there exists a quality-adjusted productivity cutoff \( \theta_v^2 \varphi \) above which a firm serves country \( j \). Let \( \xi \equiv 1/(\theta_v^2 \varphi) \geq 0 \) be an inverse measure of quality-adjusted productivity and \( \mu(\xi) \) is the distribution of \( \xi \). The cutoff for exporting \( \hat{\xi}_{ij} \) is such that \( \Pi_v(\hat{\xi}_{ij}) = w_i f_{ij} \) or, equivalently,

\[
\hat{\xi}_{ij} = \frac{\mathbb{E}(R_j)^2}{4 w_i f_{ij}} - \rho_v \mathcal{V}(R_j) \Psi_j^{-2} w_i \tau_{ij}. \tag{22}
\]

It follows that a firm exports as long as \( \xi < \hat{\xi}_{ij} \). As expected, high productivity firms are more likely to be exporters, while high fixed and variable trade costs reduce the probability

\[^{19}\text{This implies that downside and upside risks are not distinguished, such that the manager has a CARA utility function instead of DARA one. See above for details.}\]
of exporting. However, unlike trade models with heterogeneous firms, the exporting zero-payoff cutoff condition $\xi_{ij}$ can be non-positive. No firm finds a priori profitable to serve country $j$ if the expected income $\mathbb{E}(R_j)$ is not sufficiently high relatively to its variance $\mathbb{V}(R_j)$. Hence, we provide a rationale for the prevalence of zeros in bilateral trade without making an ad hoc assumption on the distribution of productivity across firms. Helpman et al. (2008) allow also for zero bilateral trade volumes as the authors assume that the most productive firms exhibit a level of productivity which is below the exporting threshold.

We are now equipped to determine the relationship between $\Psi_j$ and $\mathbb{V}(R_j)$ and the total effect of $\mathbb{V}(R_j)$. We show in Appendix E that

$$
\epsilon_{\Psi_j} = -\frac{\mathbb{V}(R_j)}{\Psi_j} \frac{\partial \Psi_j}{\partial \mathbb{V}(R_j)} > 0,
$$

or, equivalently, $\partial \Psi_j / \partial \mathbb{V}(R_j) < 0$. As expected, an increase in the variance of income reduces the aggregate supply for destination market $j$ and, in turn, affects the equilibrium prices. Hence, equilibrium prices increase with demand fluctuations through two effects: (i) a direct effect due to risk aversion (through $\rho_v \mathbb{V}(R_j)$ as explained above) and (ii) an indirect effect via the exit of firms relaxing competition among surviving firms. In contrast, the effect of expenditure volatility on the export sales (or profits) is ambiguous when $\Psi_j$ adjusts to a change in $\mathbb{V}(R_j)$. Indeed, we have

$$
\frac{dr_{ij}(\varphi)}{d\mathbb{V}(R_j)} = \frac{\partial r_{ij}(\varphi)}{\partial \mathbb{V}(R_j)} + \frac{\partial r_{ij}(\varphi)}{\partial \Psi_j} \frac{\partial \Psi_j}{\partial \mathbb{V}(R_j)} = \frac{r_{ij}(\varphi) 2w_i \tau_{ij} \xi \epsilon_{\Psi_j} - \rho_v \mathbb{V}(R_j) \Psi_j^{-2}}{\mathbb{V}(R_j)} - \frac{w_i \tau_{ij} \xi + \rho_v \mathbb{V}(R_j) \Psi_j^{-2}}{\mathbb{V}(R_j)}.
$$

where $\partial r_{ij}/\partial \mathbb{V}(R_j) < 0$ while $\partial r_{ij}/\partial \Psi_j < 0$ and $\partial \Psi_j / \partial \mathbb{V}(R_j) < 0$ (see above). It follows that a rise in expenditure volatility induces a reallocation of market shares from larger firms to smaller ones as $dr_{ij}/d\mathbb{V}(R_j)$ increases with $\xi$. Hence, the aggregate productivity of exporters can decrease ceteris paribus with a higher uncertainty, in accordance with empirical facts (see Bloom, 2014). In addition, as the larger firms reduce their export sales in high proportion when demand fluctuations increase, the export sales of smaller exporters may expand at their expense (see Figure 10).
The effect of expenditure volatility on the probability of exporting is also ambiguous. Some standard calculations reveal that

\[
\frac{d\hat{\xi}_{ij}}{d\mathcal{V}(R_j)} = \frac{\partial \hat{\xi}_{ij}}{\partial \mathcal{V}(R_j)} + \frac{\partial \hat{\xi}_{ij}}{\partial \Psi_j} \frac{\partial \Psi_j}{\partial \mathcal{V}(R_j)} = \left[ \frac{\mathcal{E}(R_j)^2}{4w_i f_{ij}} - \rho_v \mathcal{V}(R_j) \left( 1 + \frac{1}{2\epsilon_j} \right) \right] \frac{2\epsilon_j \Psi_j^{-2}}{\mathcal{V}(R_j) w_i \tau_{ij}},
\]

where \( \partial \hat{\xi}_{ij}/\partial \mathcal{V}(R_j) < 0 \) while \( \partial \hat{\xi}_{ij}/\partial \Psi_j < 0 \) and \( \partial \Psi_j/\partial \mathcal{V}(R_j) < 0 \) (see above). Hence, the probability of serving a country decreases with the volatility of its demand provided that fixed trade costs or expenditure volatility are not too high. If fixed trade costs are low enough, more small and medium sized firms can export when demand/expenditure fluctuations rise as the export sales of large firms decrease (see Figure 11).

When we focus on the total effect of demand fluctuation on quantity, it appears

\[
\frac{dq_{ij}(v)}{d\mathcal{V}(R_j)} = q_{ij}(v) \frac{w_i \tau_{ij} \xi - \rho_v \mathcal{V}(R_j) \Psi_j^{-2} (1 + \epsilon_j)}{\mathcal{V}(R_j)} \text{ and } \frac{\partial^2 q_{ij}}{\partial \gamma \partial \mathcal{V}(R_j)} < 0 < \frac{\partial^2 q_{ij}}{\partial \tau \partial \mathcal{V}(R_j)}
\]

so that the effects of \( \mathcal{V}(R_j) \) on \( q_{ij}(v) \) when \( \Psi_j \) reacts to a change in expenditure volatility are qualitatively similar to the effects on export sales. It should also be noted that higher uncertainty can make trade policy (lowering trade costs) or innovation policy (rising productivity) less effective, in accordance with Bloom (2014).
The next proposition sums up our results on the increase in expenditure volatility:

**Proposition 4** A rise in industry-level foreign expenditure uncertainty decreases industry export sales, on average, but with heterogeneous effects across firms

(i) it decreases the export sales of large firms and increases the market share of small sized firms;

(ii) it increases the probability of exporting and the export sales of small-sized firms when trade costs are not too high.

### 4 Preliminary conclusion

A rise in expenditure volatility induces a reallocation of market shares from most productive (and largest) firms to smaller ones. Under this configuration, the export sales of medium-sized firms (or the smallest exporters) may grow when demand volatility increases. However, this effect is weakened when the skewness of foreign income distribution increases. Our different estimations confirm our main predictions.

Our results are robust over different sized panels and to the inclusion of a plethora of fixed effects, and additional controls.
References


KRUGMAN, P. R. (1979): “Increasing returns, monopolistic competition, and international trade,” Journal of international Economics, 9, 469–479.


**Appendices**

**A Data appendix**

**Industry classification:** The International Standard Industrial Classification rev. 3 (ISIC) of manufacturing activities is a United Nations (UN) system for classifying eco-
nomic data into 22 2-digit, 59 3-digit and 125 4-digit industries, as depicted in Table 4. We use this classification to distinguish between 3-digit $K$ sectors and 4-digit $k$ sub-sectors.

Table 4: Industry Classification of Manufacturing (ISIC classification)

<table>
<thead>
<tr>
<th>2-digit sectors</th>
<th>3-digit</th>
<th>4-digit</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 Food products and beverages</td>
<td>151</td>
<td>1511-4, 1520</td>
</tr>
<tr>
<td>17 Tobacco products</td>
<td>171</td>
<td>1721-4, 1723-4, 1730</td>
</tr>
<tr>
<td>18 Textiles</td>
<td>181</td>
<td>1820</td>
</tr>
<tr>
<td>19 Wearing apparel, dressing and dyeing of fur</td>
<td>191</td>
<td>1911-12, 1920</td>
</tr>
<tr>
<td>20 Wood and of products of wood and cork, except furniture</td>
<td>201</td>
<td>2010, 2020-4, 2030</td>
</tr>
<tr>
<td>21 Paper and paper products</td>
<td>210</td>
<td>2102-4, 2109</td>
</tr>
<tr>
<td>22 Coke, refined petroleum products and nuclear fuel</td>
<td>221</td>
<td>2211-4, 2219, 2220-4, 2229</td>
</tr>
<tr>
<td>23 Chemicals and chemical products</td>
<td>231</td>
<td>2310, 2320, 2330</td>
</tr>
<tr>
<td>24 Textile machinery and apparatus n.e.c.</td>
<td>241</td>
<td>2411-4, 2420, 2430</td>
</tr>
<tr>
<td>25 Nonferrous metal products</td>
<td>251</td>
<td>2510, 2520, 2530</td>
</tr>
<tr>
<td>26 Other non-metallic mineral products</td>
<td>261</td>
<td>2612-4, 2620, 2630</td>
</tr>
<tr>
<td>27 Basic metals</td>
<td>271</td>
<td>2710, 2720, 2730-4</td>
</tr>
<tr>
<td>28 Fabricated metal products, except machinery and equipment</td>
<td>281</td>
<td>2811-4, 2820-4, 2830-4, 2899</td>
</tr>
<tr>
<td>29 Machinery and equipment n.e.c.</td>
<td>291</td>
<td>2911-4, 2920-4, 2930-4, 2999</td>
</tr>
<tr>
<td>30 Furniture, manufacturing n.e.c.</td>
<td>301</td>
<td>3010, 3020, 3030, 3099-4, 3109</td>
</tr>
<tr>
<td>31 Electrical machinery and apparatus n.e.c.</td>
<td>311</td>
<td>3110, 3120, 3130, 3140, 3150, 3190</td>
</tr>
<tr>
<td>32 Medical, precision and optical instruments</td>
<td>321</td>
<td>3210, 3220, 3230</td>
</tr>
<tr>
<td>33 Motor vehicles, trailers and semi-trailers</td>
<td>331</td>
<td>3311-4, 3320, 3330</td>
</tr>
<tr>
<td>34 Other transport equipment</td>
<td>341</td>
<td>3410, 3420, 3430</td>
</tr>
<tr>
<td>35 Textile machinery and apparatus n.e.c.</td>
<td>351</td>
<td>3511-4, 3520, 3530, 3599-2, 3599</td>
</tr>
<tr>
<td>36 Furniture, manufacturing n.e.c.</td>
<td>361</td>
<td>3610, 3620, 3630, 3699</td>
</tr>
</tbody>
</table>

Trade: Our empirical analysis focuses on French manufactured exports, which flows reach on average 187.8 billion euros and 71.2 million of tons per year. On average, our sample includes 43,586 firms per year, serving 71 countries and 117 4-digit sectors. The turnover of firms in sectors and destinations is rather high in our sample over the period 2000-2009. On average, a firm is present 2.72 years in one destination-sector (4-digit). Firms serve on average 1.99 sectors per destination-year and 3.19 destinations per sector-
Each year, firms can be classified as (1) ‘mono-destination and -sector firms’ if they export to one 4-digit sector and one destination only; as (2) ‘mono-destination and multi-sector firms’ if they export to various sectors but to one destination only; as (3) ‘multi-destination and mono-sector firms’ if they export to various destinations but to one sector only; and (4) ‘multi-destination and -sector firms’ if they export to multi destinations and sectors. The share of each category in the total of exporting firms is fairly stable over time. The two main categories are multi-destination and -sector firms, 47.2% on average over the period 2000-2009, and mono-destination and -sector firms (27%). The second and third categories represent 7.4% and 18.4% of French exporting firms respectively.

B Additional statistics on volatility and skewness

As in Figure 2, statistics in this appendix are computed using countries for which we have at least 10% of the potential observations.

Which are the most/least volatile countries? We answer this question in Figure 12. Each sub-figure presents 20 countries and reports the median volatility for each of these countries over 2000-2009. The United States has very low volatility, as well as the United Kingdom and Canada. By contrast, the most volatile countries (in the left panel) tend to be developing countries. On average, developed countries are less volatile than developing ones.

Which are the most/least skewed countries? Figure 13 reports the median skewness over 2000-2009 for the 20 most and least skewed countries. We can notice that developed countries are often less skewed. The difference between developing and developed countries in terms of skewness seems however to be less pronounced than for volatility. Two countries in our sample have a negative skewness: Russia and the US.

---

20 One limit of our approach is the number of observations per country: the number of sector-year for which we are able to compute the volatility and the skewness is smaller for developing countries than for developed ones and this restriction may affect the median value that we obtain.
Figure 12: Most and least volatile countries

Figure 13: Most and least skewed countries

C Intensive margin: export unit values
Table 5: Intensive margin: export unit values

<table>
<thead>
<tr>
<th>Dependent variable: Firm export prices: ln $p_{kjt}$</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ln Expenditure Volatility $K_{jt}$</td>
<td>0.004</td>
<td>0.002</td>
<td>0.016 $^{a}$</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.008)</td>
<td>(0.008)</td>
</tr>
<tr>
<td>Expenditure Skewness $K_{jt}$</td>
<td>-0.004</td>
<td>-0.004</td>
<td>-0.006 $^{b}$</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Ln Mean 5-year Expenditure $K_{jt}$</td>
<td>-0.055</td>
<td>-0.001</td>
<td>-0.022</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.014)</td>
<td>(0.018)</td>
</tr>
<tr>
<td>Ln Productivity $f_t$</td>
<td>-</td>
<td>-</td>
<td>0.026 $^{c}$</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Observations</td>
<td>4,697,926</td>
<td>4,697,926</td>
<td>4,697,926</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.871</td>
<td>0.833</td>
<td>0.901</td>
</tr>
</tbody>
</table>

Sets of Fixed Effects:
- Firm: (4-digit-)Sector: Time: $fkt$ Yes - -
- Destination: $j$ Yes - -
- Firm:Destination:Time: $fjt$ - Yes -
- 4-digit-Sector: $k$ - Yes -
- Firm:Destination:(4-digit-)Sector: $fjk$ - - Yes
| Time: $t$ - - Yes |

Notes: dependent variable is firm-level export unit values in logs aggregated at the 4-digit $K$ level. All specifications include the overall sample of exporters. Number of years: 10; Number of destinations: 90; Number of 4-digit sectors: 119; Number of firms: 105,777. Expenditure is defined as apparent consumption (production minus net exports) at the 3-digit $K$ level. See the paper for computational details about expenditure moments. Robust standard errors are in parentheses, clustered by destination and 4-digit sector level, with $^{a,b,c}$ denoting significance at the 1% and 5% level respectively.

D Price setting

The demand for a variety $v$ is

$$q_{ij}(v) = R_j^2 \theta_v^2 \Psi_j^{-2} p_{ij}(v)^{-2}$$

so that

$$\frac{p_{ij} q_{ij}(v)}{R_j} = R_j \theta_v^2 \Psi_j^{-2} p_{ij}(v)^{-1}$$

Summing this expression over each variety consumed in country $j$ yields

$$\Psi_j^{-2} = R_j^{-1} \left[ \int_{\Omega_j} \theta_v^2 p_{ij}(v)^{-1} dv \right]^{-1}$$

implying the demand for a variety can be rewritten as follows

$$q_{ij}(v) = R_j \theta_v^2 \left[ \int_{\Omega_j} \theta_v^2 p_{ij}(v)^{-1} dv \right]^{-1} p_{ij}(v)^{-2} = R_j \theta_v^2 P_j p_{ij}^{-2}$$

with

$$P_j \equiv \left[ \int_{\Omega_j} \theta_v^2 p_{ij}(v)^{-1} dv \right]^{-1}.$$
Hence, the export profit is

$$\pi_{ij} = R_j \theta_v^2 P_j / p_{ij} - c_{ij} R_j \theta_v^2 P_j p_{ij}^2 - w_i \tau_{ij}$$

with $c_{ij} \equiv w_i \tau_{ij} / \varphi$. The payoff of each firm is as follows:

$$\Pi_o(v) = \mathbb{E}(\pi_i) - \rho_v \mathbb{V}(\pi_i),$$

Given the demand of consumers, we have

$$\mathbb{E}(\pi_{ij}) = \mathbb{E}(R_j) \theta_v^2 P_j / p_{ij} - c_{ij} \mathbb{E}(R_j) \theta_v^2 P_j / p_{ij} - w_i \tau_{ij},$$

and

$$\mathbb{V}(\pi_{ij}) = \left( p_{ij}^2 - c_{ij}^2 \right) p_{ij}^{-4} P_j^2 \theta_v^4 \mathbb{V}(R_j)$$

It appears that the expected profit is maximized when the price is equal 2 times the marginal cost $c_{ij}$, while the variance is minimized when the price is equal to the marginal cost.

The first order condition implies that the equilibrium price is implicitly given by $\Phi(p_{ij}) = 0$ with

$$\Phi(p_{ij}) \equiv - (p_{ij} - 2c_{ij}) \mathbb{E}(R_j) + \rho_v \left( p_{ij}^2 - 2c_{ij}^2 \right) 2p_{ij}^{-2} P_j^2 \theta_v^2 \mathbb{V}(R_j)$$

while the second order condition implies

$$\mathbb{E}(R_j) - \rho_v 8 c_{ij}^2 p_{ij}^{-3} P_j ^2 \theta_v^2 \mathbb{V}(R_j) > 0$$

or, evaluated at $\Phi(p_{ij}) = 0$,

$$\left( p_{ij}^2 - 2c_{ij}^2 \right) p_{ij} - 4c_{ij}^2 (p_{ij} - 2c_{ij}) > 0$$

Without uncertainty, the equilibrium price would be $p_{ij} = 2c_{ij}$, which is identical to the
price prevailing when firms determine strategically the level of quantity. However, under uncertainty, \( p_{ij} = 2c_{ij} \) is not an equilibrium as long as \( \rho_v > 0 \). Introducing \( p_{ij} = 2c_{ij} \) into (23) implies \( \Phi(p_{ij}) > 0 \) so that the equilibrium price under uncertainty is higher than \( 2c_{ij} \). Using the envelop theorem:

\[
\frac{\partial p_{ij}}{\partial V(R_j)} = \frac{\mathbb{E}(R_j)}{\mathbb{V}(R_j)} \frac{p_{ij} - 2c_{ij}}{2} - 8\rho_v c_{ij}^2 P^2 \theta^2 \mathbb{V}(R_j) p_{ij}^{-3} > 0
\]

E  Industry supply and income volatility

In this Appendix, we show that \( \partial \Psi_j / \partial V(R_j) < 0 \). According to (6) and (20), we have \( \Lambda[\Psi_j, V(R_j)] = 0 \) with

\[
\Lambda \equiv \Psi_j - \sum_{\ell} M_{\ell} \int_0^{\xi_{\ell j}} \frac{\mathbb{E}(R_j)}{2} \Psi_j^{-1} \left[ w_{\ell} \tau_{\ell j} \xi + \rho_v \mathbb{V}(R_j) \Psi_j^{-2} \right]^{-1} \mu(\xi) d\xi,
\]

where \( \partial \Lambda / \partial V(R_j) > 0 \) because both \( \theta_v q_{\ell j}^{1/2} \) and \( \hat{\xi}_{\ell j} \) decrease with \( V(R_j) \). The envelop theorem implies

\[
\text{sign} \frac{\partial \Psi_j}{\partial V(R_j)} = -\text{sign} \frac{\partial^2 \Lambda}{\partial \Psi_j},
\]

as \( \partial \Lambda / \partial V(R_j) > 0 \). Standard calculations show that

\[
\frac{\partial \Lambda}{\partial \Psi_j} = 1 - \Psi_j^{-1} \sum_{\ell} M_{\ell} \int_0^{\hat{\xi}_{\ell j}} \theta_v \left[ q_{\ell j}(\xi) \right]^{1/2} \frac{\rho_v \mathbb{V}(R_j) \Psi_j^{-2}}{\rho_v \mathbb{V}(R_j) \Psi_j^{-2} + w_{\ell} \tau_{\ell j} \xi} \mu(\xi) d\xi - \frac{\partial \hat{\xi}_{\ell j}}{\partial \Psi_j} \theta_v \left[ q_{\ell j}(\hat{\xi}_{\ell j}) \right]^{1/2},
\]

where \( \partial \Lambda / \partial \Psi_j > 0 \) as the second term on the RHS of (24) is inferior to 1 and \( \partial \hat{\xi}_{\ell j} / \partial \Psi_j < 0 \). As a result,

\[
\epsilon_{\Psi_j} = -\frac{\mathbb{V}(R_j)}{\Psi_j} \frac{\partial \Psi_j}{\partial V(R_j)} > 0.
\]