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José De Sousa
Anne-Célia Disdier
Carl Gaigné

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Abstract

Using firm and industry data, we establish two facts: (i) Uncertainty about demand conditions not only reduces export sales and exporting probabilities but also makes exports less sensitive to trade policy; (ii) the most productive exporters are more affected by higher industry-wide expenditure volatility than the least productive exporters. We rationalize these regularities by developing a new firmbased trade model wherein managers are risk averse. Higher volatility induces the reallocation of export shares from the most to the least productive incumbents. Greater skewness of the demand distribution and/or higher trade cost weaken this effect. Our results hold for a large class of consumer utility functions.

JEL-Codes: D210, D220, F120, F140.

Keywords: firm exports, demand uncertainty, risk aversion, expenditure volatility, skewness.

José De Sousa
Université Paris-Sud
France - 92331 Sceaux, Cedex
jose.de-sousa@u-psud.fr

Anne-Célia Disdier
Paris School of Economics-INRA
France – 75014 Paris
anne-celia.disdier@ens.fr

Carl Gaigné
INRA, UMR1302 SMART
Rennes / France
carl.gaigne@rennes.inra.fr

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1 Introduction

We study the impact of demand uncertainty on export decisions at the firm level. Firm-based trade theory typically assumes that consumer expenditure in foreign markets is known with certainty. Accordingly, firms know their exact demand function, and only market size plays a key role in export performance. However, recent surveys of leading companies note that market/demand volatility is their top business driver.[1] This volatility, being a source of uncertainty, potentially influences trade decisions.[2] This view is consistent with empirical evidence that market 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). Although the impact of trade on volatility has received considerable attention (Giovanni and Levchenko, 2009; Koren and Tenreyro, 2007), relatively little attention has been devoted to the reverse question. Little is known about how firms respond to demand uncertainty in foreign markets. Our aim in this paper is to study the impact of foreign expenditure uncertainty on the intensive and extensive margins of trade at the firm level, i.e., on firm export sales and entry/exit decisions.

Our theory is motivated by reduced-form evidence on the effect of expenditure uncertainty on French manufacturing exports. Using the same dataset as Eaton et al. (2011), we observe the destination countries to which firms export and the products they sell over the 2000-2009 period. We match these firm-level export data with industry-wide measures of expenditure uncertainty in the destination countries, as proxied by the observed central moments of their apparent consumption distributions. The evidence is based on a simple identification assumption conditional on various combinations of fixed effects controlling for firm, industry, destination and year unobservables. Our identifying assumption is that the moments of the industry-wide expenditure distribution in a destination may affect firm-level exports of a product to that destination

[1] See, for instance, the Capgemini surveys of leading companies that can be publicly accessed at 2011, 2012, and 2013.

[2] Due to the practical difficulties of separating risky events from uncertain events, we follow Bloom (2014) in referring to a single concept of uncertainty, which captures a mixture of risk and uncertainty. The terms 'risk' and 'uncertainty' are thus used interchangeably.

but not necessarily the reverse. In Section 2, we document two empirical regularities concerning the role of expenditure uncertainty on the intensive and extensive margins of trade.

First, both foreign market entry/exit decisions and the volume of exports at the firm level are significantly affected by the central moments of the expenditure distribution. The expected value of expenditure (the first moment) positively affects both the probability of entry and the volume of trade while reducing the probability of exit. The volatility, or variance, of expenditure (the second moment) produces the opposite effects by reducing both the volume of exports and the probability of entry while increasing the probability of exit. Moreover, the negative effect of expenditure uncertainty on exports is magnified by lower trade costs. The intuition is that the lower the trade costs, the greater the demand and, therefore, the higher the risk at the margin. In contrast, an increase in skewness (the third moment) positively affects the intensive and extensive margins. The basic intuition is that, for a given mean and variance, an increase in the skewness of the expenditure distribution increases the probability of high returns (a more skewed distribution of expenditures in foreign markets reduces a firm's exposure to downside losses). This reduced-form evidence interestingly shows that uncertainty affects not only the export decision but also the quantity exported. It further suggests that exporting firms' managers are willing to pay a risk premium, which depends on the central moments of the expenditure distribution, to avoid uncertainty in foreign markets.

The second regularity concerns the heterogeneous responses of firms to expenditure uncertainty. As firms differ in size and productivity, they are differently affected by uncertainty. On the one hand, larger and more productive firms may have access to better risk management strategies that can help reduce their risk exposure. On the other hand, according to production theory under uncertainty, the variance in firm profits is proportional to the square of expected output, and hence, the average risk premium increases with firm size. Hence, we do not know *a priori* whether risk exposure grants economic advantages to larger or smaller firms. Our estimations reveal that expenditure volatility reduces the difference in exports between the least and the most productive firms. In other words, the export share of the most productive firms decreases with expenditure volatility.

We next develop a firm-based trade model in Section 3 that accounts for these empirical regularities. The model features three key ingredients: (1) decision makers are averse to both risk and downside losses, (2) firms face the same industry-wide uncertainty over expenditures, and (3) decision makers make entry/exit and production/pricing decisions before uncertainty in market expenditures is revealed. Firms produce under monopolistic competition and are heterogeneous in productivity, which affects the decision of whether to enter an export market. Having entered, exporters face a delay between the time at which strategic variables (price or quantity) are chosen and the time at which output reaches the market. During this delay, foreign expenditures or market prices can change due to random shocks, such as changes in climatic conditions, consumer tastes, opinion leaders' attitudes, or competing products' popularity.

As firms can only partially offset the risks they face through diversification, they act in a risk-averse manner. There is one reason that the managers and shareholders of exporting firms 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 that the manager of an exporting firm might be risk averse even if shareholders are risk neutral: (i) bankruptcy costs might be high (Greenwald and Stiglitz, 1993), (ii) exchange rate risk is not adequately hedged (Wei, 1999), (iii) open-account terms are common in trade finance and allow importers to delay payment for a certain time following the receipt of goods (Antràs and Foley, 2015), and (iv) managers' human and financial capital (through their equity shares) are disproportionately tied up in the firm he or she manages (Bloom, 2014). Thus, in making all of their economic decisions (investment, production, and pricing), managers take into account their risk exposure.[3]

To capture decision makers' willingness to pay a risk premium to avoid uncertainty,

[3]Recent research shows that risk aversion is an important feature of manager decision making under uncertainty (see Panousi and Papanikolaou, 2012).

we draw on expected utility theory (and conduct a mean-variance-skewness analysis). Consequently, risk-averse behavior is intrinsically equivalent to a preference for diversification (Eeckhoudt et al., 2005). As shown in the literature on production decisions under risk and imperfect competition, an increase in risk (as measured by higher variance of the random variable) increases the risk premium and decreases output when the decision maker is risk averse (Klemperer and Meyer, 1986). Nevertheless, the second central moment of a distribution does not distinguish between upside and downside risk. Managers can be more sensitive to downside losses than to upside gains (Menezes et al., 1980). Skewness can be used as a measure of downside risk. Indeed, the sign of the skewness provides information about the asymmetry of the demand distribution and, thus, about downside risk exposure. For a given mean and variance, countries with more right-skewed distributions of expenditure provide better downside protection or less downside risk.[4]

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 extensive margin of trade depends on the first three central moments of the expenditure distribution. We also show that the equilibrium certainty-equivalent quantities, which incorporate the risk premium, are negatively correlated with the volatility of expenditures but positively affected by its mean and skewness.

Further, even if firms face the same industry-wide expenditure uncertainty, risk-averse managers react differently to an increase in volatility depending on their productivity, leading to a reallocation of market shares. Expenditure volatility may impede the export entry of some producers and force others to cease exporting, which may, in turn, increase the market shares of the incumbent exporting firms. Additionally, changes in uncertainty modify the relative prices of the varieties supplied, leading to the reallocation of market shares across incumbent exporters. Hence, the effects of industry-specific expenditure uncertainty on firms' export performance are not *a priori*

[4] A distribution exhibiting more downside risk than another is less skewed to the right. However, the converse is not necessarily true (see Menezes et al., 1980).

clear. We show that, although higher foreign expenditure volatility reduces industry export sales, its effect on an individual exporter's sales is ambiguous. If the most productive firms have larger market shares regardless of expenditure uncertainty, an increase in uncertainty induces a reallocation of market shares from the most to the least productive firms. Under this configuration, the export sales of the least productive *exporters* may grow.[5] However, this reallocation effect is weakened when the expenditure distribution becomes more skewed.

It is worth stressing that our main results hold for a large class of consumer utility functions, including the Constant Elasticity of Substitution (CES) case, as in numerous trade models. Note that unlike trade models of monopolistic competition without uncertainty, the markup is not constant even if demand is isoelastic. In other words, expenditure uncertainty and risk-averse managers allow for variable markups even under CES preferences. We show that markups depend on firm productivity and origin and destination country features, as well as on expenditure uncertainty.

Related literature

This paper complements a recent body of literature on the effects of macroeconomic uncertainty on individual firms. Our theory and empirical evidence reveal a "cautionary effect" that impacts trade outcomes. The same effect can be shown in a very different setting. Bloom et al. (2007) document that greater uncertainty reduces the responsiveness of firms' R&D and investments to changes in productivity. We capture a cautionary or risk-averseness effect of foreign expenditure uncertainty on export behavior. Greater expenditure uncertainty can reduce the positive effects of higher firm productivity or lower trade costs on export sales. Uncertainty not only reduces export sales and exporting probabilities but also makes firms less sensitive to higher productivity and lower trade costs. Thus, we provide a new argument to explain declines in aggregate productivity growth following uncertainty shocks. We show that greater expenditure uncertainty induces the reallocation of market shares from the most to the least productive firms. As the reallocation of resources across heterogeneous firms is a

[5] Note that the least productive exporters are medium-sized firms, as small firms are not productive enough to export.

key factor in explaining aggregate productivity growth (Foster et al., 2008; Melitz and Polanec, 2015), higher expenditure uncertainty can slow productivity growth.

Our paper is also related to the literature on risk and trade. Expected utility theory was used to analyze international trade under risk by Helpman and Razin (1978) and Turnovsky (1974) but with perfect competition. Although uncertainty has been introduced in Melitz-type trade models of imperfect competition, the uncertain parameter (firm productivity) is revealed before the firm supplies any destination. More recently, the trade literature has witnessed a revival of interest in 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 on trade policy uncertainty, the role of inventory holdings, or the trade-off between trade and foreign investment and assume that the price and the quantity of goods to be exported are determined under certainty. In contrast, we theoretically and empirically show that expenditure uncertainty affects not only the decision to enter export markets but also the production and pricing decisions, leading to the reallocation of market shares.

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 heterogeneity in productivity is an important factor justifying firms' entry into export markets, demand factors also play key roles in explaining the variability of 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 expenditure assumption, it appears that expenditure fluctuations affect the extensive and intensive margins of trade. More similar to our paper is Esposito (2016), who focuses on demand complementarities across markets under uncertainty. Our paper, in contrast, explores the reallocation of export shares across firms within a market under uncertainty. Furthermore, we use a more general demand system and theoretically and empirically show that both second- and third-moment shocks need to be considered to understand the patterns of trade at the extensive and intensive margins.

The remainder of this paper proceeds as follows. In Section 2, we present two empirical regularities on the role of expenditure uncertainty at the intensive and extensive margins of trade. We then develop our multi-country model of trade with heterogeneous firms under imperfect competition in Section 3. The final section concludes.

2 Reduced-form Evidence on Trade and Uncertainty

In this section, we present reduced-form evidence that individual exporting firms react to both the volatility and the skewness of consumption expenditure. This reduced-form evidence motivates the theory presented in Section 3.

2.1 Data

We combine two types of data defined at the firm and destination country-industry levels. First, French customs provide export data by firm, product and destination over the 2000-2009 period. For each firm located on French metropolitan territory, we observe the volume (in tons) and value (in thousands of euros) of exports for each destination-product-year triplet. To match these data with other sources, the export data are aggregated at the industry level (4-digit ISIC code)[6] so that we obtain the exports of each firm for each destination-industry-year triplet. Unit values are computed as the ratio of export value to export volume. Using the official firm identifier, we merge the customs data with the BRN (Bénéfices réels normaux) dataset from the French Statistical Institute, which provides firm balance-sheet data, e.g., value added, total sales, and employment.

Our sample contains a total of 105,777 different firms that are located in France, serve 90 destination countries and produce in 119 manufacturing industries (based on the 4-digit codes). In an average year, 43,586 firms export to 71 countries in 117 industries, amounting to 187.8 billion euros and 71.2 million tons. The firm turnover in industries and destinations is rather high over the 2000-2009 period. On average, a

[6] See Table 5 in Appendix A for the detailed classification.

firm is present for 2.72 years in a given destination-industry and serves 1.99 industries per destination-year and 3.19 destinations per industry-year.

In addition to firm-level data, we use annual destination country-industry (ISIC 4-digit codes) information on manufacturing production, exports and imports. These data come from COMTRADE and UNIDO and cover our 119 manufacturing industries over the period from 1995 to 2009. Such destination-industry-year data allow us to define a consumption expenditure variable R, also known as apparent consumption or absorption, defined as domestic production minus net exports:

$$R^k_{jt} = \text{Production}^k_{jt} + \text{Imports}^k_{jt} - \text{Exports}^k_{jt}, \tag{1}$$

where Production, Imports and Exports are defined as total production, total imports, and total exports, respectively, for each triplet destination j, 4-digit k, and year t. The intention here is to infer the industry consumption expenditure that is used in a destination for any purpose.[7]

2.2 Identification Strategy

Our objective is to study the impact of uncertainty on export performance. If firms produce under demand uncertainty, they make their choice by considering different moments of the expenditure distribution. Hence, contrary to the standard trade literature, we assess whether export sales depend not only on (i) the expected value but also on the (ii) variance and (iii) skewness of expenditures. These three central moments are calculated for each destination-industry-year.

One concern is that our estimations may be plagued by a potential reverse causality running from trade to uncertainty. To address this concern, we use the following identification strategy: for a given year t and destination j, the three central moments of the expenditure distribution are calculated at the 3-digit K industry level (rather than at the 4-digit k level). We expect that these moments of aggregated expenditures affect

[7] Eaton et al. (2011) use this absorption measure to capture market size.

disaggregated trade patterns but not necessarily the reverse. The identifying assumption is that the 4-digit export flow of an individual firm to a destination does not affect the 3-digit industry expenditure distribution in that destination. This assumption is supported by two key features of the data. First, the 3-digit industry is composed of various 4-digit sub-industries. Thus, it is reasonable to assume, for example, that an individual export shipment of soft drinks (k=1554) to the United Kingdom (UK) only marginally affects the volatility of the UK's beverages (K=155). However, some 3-digit industries are composed of only one 4-digit sub-industry (see Table 5 in Appendix A). Despite this concern, a second feature of the 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 marginally affects expenditure moments. Nevertheless, to address the concern that an individual French firm's export flow may affect expenditure shifters in a destination, we remove French export and import flows from the destination's expenditure computation.

Different empirical measures of the expected value $\mathbb{E}(R^K_{jt})$, variance $\mathbb{V}(R^K_{jt})$, and skewness $\mathbb{S}(R^K_{jt})$ are suggested in the literature. We could for instance consider that exporters use all information to form expectations about consumers' expenditure. However, to keep matters simple, we assume that agents use a subset of information to make decisions (because of costly information acquisition). Thus, the expected value $\mathbb{E}(R^K_{jt})$ is computed in year t as the mean of expenditure R over the 5 previous years. In this way, we capture the well-known market size effect on trade.

There is also no unique definition of market/demand volatility. Thus, we adopt a widely used empirical measure of volatility based on the standard deviation of the growth rate of a variable (as, for example, in Acemoglu et al., 2003 and Giovanni and Levchenko, 2009). The volatility $\mathbb{V}(R^K_{jt})$ in industry K and year t is computed in two steps. First, we compute yearly growth rates of R (equation 1) over the past 6 years at each 4-digit sub-industry k composing the industry K. Then, volatility is simply the standard deviation of these yearly growth rates. For example, consider the manufacture of beverages (K=155) in the UK in 2000. This industry is disaggregated into 4 sub-industries (k=1551, 1552, 1553, 1554).[8] First, for each sub-industry k, we compute the 5 yearly growth rates of apparent consumption from 1995 to 2000. Then, we calculate $\mathbb{V}(R^{155}_{\text{UK},2000})$ as the standard deviation of the 20 computed growth rates for the 4 sub-industries. Note that we exploit fluctuations in uncertainty over time by computing a time-variant volatility measure.[9]

The third moment of the expenditure distribution corresponds to the unbiased skewness. Instead of the standard parametric skewness index measured as the gap between the mean and the median, the skewness of the expenditure distribution $\mathbb{S}(R^K_{jt})$ is computed using the same strategy as the volatility, i.e., as the skewness of the yearly growth rates of R for 6 years and sub-industries k. This latter index is easily interpreted. When $\mathbb{S}(R^K_{jt})$ is positive (resp., negative), the expenditure distribution is right-skewed (resp., left-skewed).

2.3 Descriptive Statistics

We first present some descriptive statistics on expenditure moments and their variation across (1) destination markets, (2) industries, and (3) time. Specifically, we show that these moments match some facts advanced in the literature on uncertainty. Then, we provide some practical examples comparing French exports to Canada and Mexico to illustrate the usefulness of our approach.

Variation across markets, industries and time

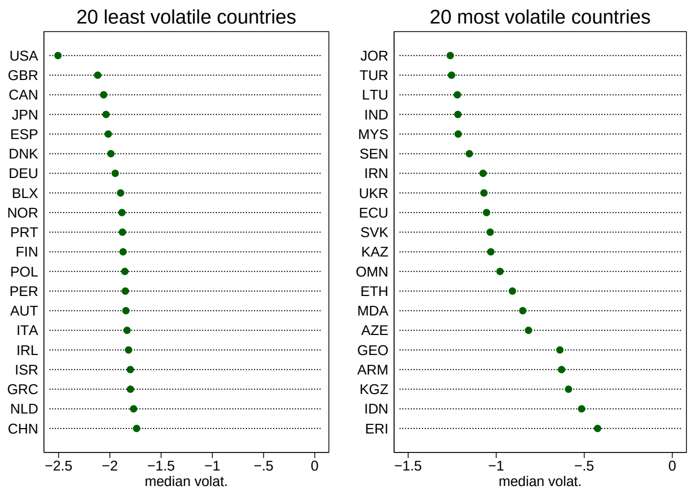
In Figure 1, we depict the median of expenditure volatility (in logs) across destina-

[8]The 4 sub-industries 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 and production of mineral waters.

[9]Another possibility would have been to compute time-invariant moments to capture cross-country and industry-specific differences in uncertainty, which are absorbed by our fixed effects. Ramondo et al. (2013), for instance, compute the volatility of a country's GDP over a 35-year period and study the effects of cross-country specific differences in uncertainty on the firm's choice to serve a foreign market through exports or through foreign affiliate sales.

tion markets for the 20 least and most volatile countries over the 2000-2009 period.[10] The United States (US) has very low volatility, as do the UK and Canada (in the left panel). By contrast, the most volatile countries (in the right panel) tend to be developing countries. Our volatility measure confirms that, on average, developed countries are less volatile than developing countries, as documented in Bloom (2014) and the World Development Report 2014 on risk and opportunity (World Bank, 2013).

Figure 1: Least and most volatile countries



Note: This figure reports the median of expenditure volatility (in logs) over the period 2000-2009 for the 20 least (left panel) and most (right panel) volatile countries.

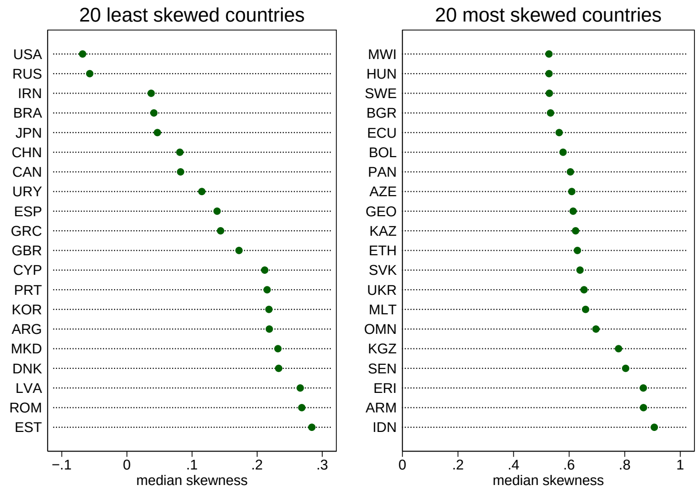
Similarly, Figure 2 reports the median skewness over the 2000-2009 period for the 20 least and most skewed countries. It appears that developed countries tend to be less skewed than developing countries, as documented in Bekaert and Popov (2012). The difference between developed and developing countries in terms of skewness seems, however, to be less pronounced than for volatility.[11] Two countries in our sample have negative median skewness: Russia and the US.

Expenditure volatility and skewness also vary across industries. Figure 3 depicts the distribution of expenditure volatility (in logs) and skewness across 2-digit industries. The ranking of industries differs for the two moments. For example, the food

[10]The distribution is computed for each destination using all 3-digit industries and years for which we are able to compute apparent consumption (we have, at most, 10 years * 57 three-digit industries = 570 observations per destination). We retain only countries for which we have at least 10% of the 570 possible observations.

[11]One limitation of our approach is that the number of industry-years for which we are able to compute volatility and skewness figures is smaller for developing countries than for developed countries, and this restriction may affect the median values.

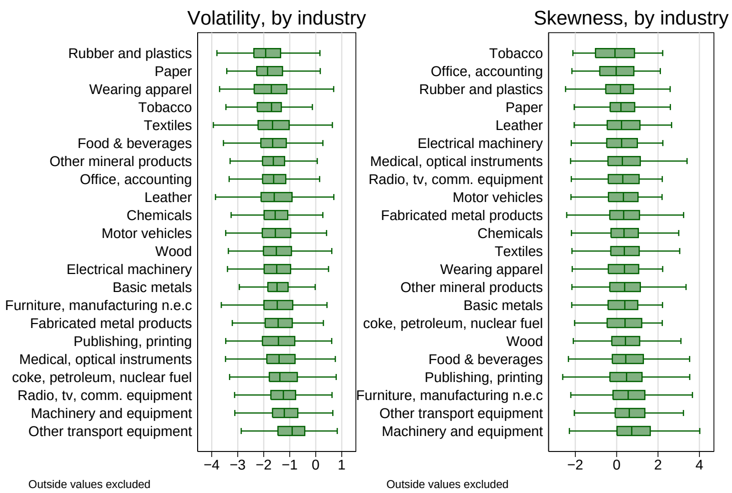
Figure 2: Least and most skewed countries



Note: This figure reports the median of skewness expenditure over the period 2000-2009 for the 20 least (left panel) and the 20 most (right panel) skewed countries.

and beverages category is among the most volatile industries, while its skewness is rather low. By contrast, the medical and optical instruments industry has relatively low volatility but high skewness. Only two industries (tobacco; office, accounting) have negative median skewness.

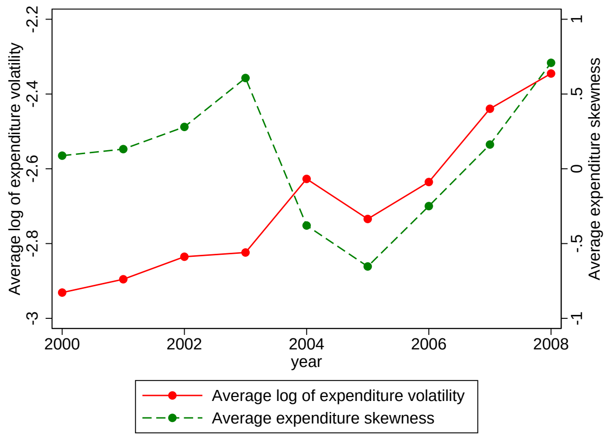
Figure 3: Distribution of volatility and skewness, by industry



Note: This figure reports the distribution of expenditure volatility (in logs) and skewness across 2-digit industries over the period 2000-2009.

A simple analysis of the variance of our volatility measure suggests that its variations occur primarily across countries and industries. Nevertheless, in accordance with the literature (Bloom, 2014), we also observe fluctuations in uncertainty over time. In particular, Figure 4 shows that the mean volatility of food and beverage expenditure in the US increased between 2000 and 2008 (plain line). This finding confirms a trend that has been documented in the literature on US food consumption (Gorbachev, 2011).[12] We also observe fluctuations in the skewness distribution that we use as a source of identification (dotted line).

Figure 4: Volatility and skewness of US expenditures on food and beverages, 2000-2008



The role of uncertainty: French exports to Canada and Mexico

We provide some practical examples to illustrate the usefulness of our approach. Consider Canada and Mexico, which are characterized by similar levels of demand for some products and by no significant difference in distance to France. Let us pick three 3-digit industries for which total expenditures reach comparable levels in each country in 2005 but exhibit different risk exposure. The first industry is chemical products (ISIC rev. 3 code 242) for which expenditures are comparable in size (approximately 4 billion US dollars) and distribution (variance of 0.13 and skewness of -0.4) in both countries. It appears that the wedge between French export volumes to Mexico and to Canada is relatively low (12 and 15 million tons, respectively). As French exporters of chemical products seem to face the same risk exposure in both countries, there is no significant difference in exports. In contrast, in our second industry (grain mill products and feeds; ISIC 153), expenditures in Canada and Mexico are similar (approximately

[12] Gorbachev (2011) shows that the mean volatility of household food consumption in the US increased between 1970 and 2004.

2 billion US dollars), while the volatility in Mexico is twice as high as that in Canada. Interestingly, the volume of French exports to Canada is 2.6 times as high as exports to Mexico (11.7 and 5.4 million tons, respectively). In this case, for a given level of mean expenditures, managers appear to differentiate between serving Canada and Mexico, as the risk exposure is higher in Mexico. In addition, managers can also be sensitive to downside losses, relative to upside gains. *Ceteris paribus*, managers might prefer to serve a country exhibiting a high probability of an extreme event associated with a high versus a low level of demand. For example, in our third industry (basic iron and steel; ISIC 271) expenditures in Canada and Mexico are similar (approximately 11 billion US dollars). However, the data show that the volatility is higher in Mexico than in Canada (0.38 and 0.22, respectively), whereas the skewness is positive in Mexico (1.83) and negative in Canada (-0.14). Despite a slight difference in volatility, the difference in skewness may explain why the volume of French exports to Mexico is higher than that to Canada (124 vs. 96 million tons). As Mexico exhibits a relatively more right-skewed distribution in this industry, it can be viewed as providing better downside protection or lower downside risk, which induces more exports. Hence, for a given level of market potential, firms face different expenditure distributions and risk exposure, thereby inducing different levels of exports.

2.4 Empirical Evidence

In this section, we provide evidence of a significant effect of foreign expenditure volatility and skewness on exports by controlling for demand size in destination markets. We also add different combinations of fixed effects to capture unobservable characteristics at the firm, industry, destination and year levels.

2.4.1 Industry-level Evidence

We first estimate the following equation at the industry level:

$$\ln q_{jt}^{k} = \beta_1 \ln \mathbb{E}(R_{jt}^{K}) + \beta_2 \ln \mathbb{V}(R_{jt}^{K}) + \beta_3 \mathbb{S}(R_{jt}^{K}) + \alpha_{jt} + \alpha_k + \varepsilon_{jt}^{k}, \tag{2}$$

where q_{jt}^k is the French export volumes to destination j aggregated at the 4-digit manufacturing level k (ISIC classification) in year t. Trade is related to the first three moments of expenditures in the destination at the 3-digit level K: the expected value $\mathbb{E}(R_{jt}^K)$, volatility $\mathbb{V}(R_{jt}^K)$, and skewness $\mathbb{S}(R_{jt}^K)$. A set of industry (α_k) and destination-time (α_{jt}) fixed effects controls for unobserved heterogeneity in industries and destination-year markets. The sample covers the period from 2000 to 2009. Here, ε_{jt}^k represents the error term.

The results are reported in the first column of Table 1. As expected, export volumes at the industry level are positively affected by the first and third central moments of the foreign expenditure distribution, i.e., the expected expenditure and its skewness. The third-moment effect suggests that exporters are sensitive to downside risk exposure. In contrast, exports are negatively affected by the second central moment of expenditure. For example, given that the export elasticity to expenditure volatility is 0.112, French exports to Canada in the grain mill industry would decrease by 11.2% if, *ceteris paribus*, its expenditure were as volatile as that of Mexico.[13]

Table 1: Industry-level evidence

Dependent variable:	Industry export volumes: $\ln q_{jt}^k$	
	(1)	(2)
Ln Mean 5-year Expenditure$_{j,t-1}^K$	0.275^a	0.275^a
	(0.033)	(0.033)
Ln Expenditure Volatility$_{jt}^K$	-0.112^a	-0.073^b
	(0.028)	(0.031)
Ln Expenditure Volatility$_{jt}^K$ $\times$ Ln Distance$_j$		0.079^a
		(0.022)
Expenditure Skewness$_{jt}^K$	0.035^a	0.036^a
	(0.011)	(0.011)
Observations	48,424	48,424
R^2	0.778	0.778
Sets of Fixed Effects:		
Destination.Time$_{jt}$	Yes	Yes
4-digit-Industry$_k$	Yes	Yes

Notes: dependent variable is aggregated export volumes in logs. Number of years: 10; Number of destinations: 90; Number of 4-digit industries: 119. 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-4-digit industry level, with [a] and [b] denoting significance at the 1% and 5% level, respectively.

[13]Recall that volatility in Mexico is twice as high as in Canada in the grain mill products and feeds industry (ISIC rev. 3 code 153. See Section 2.3.

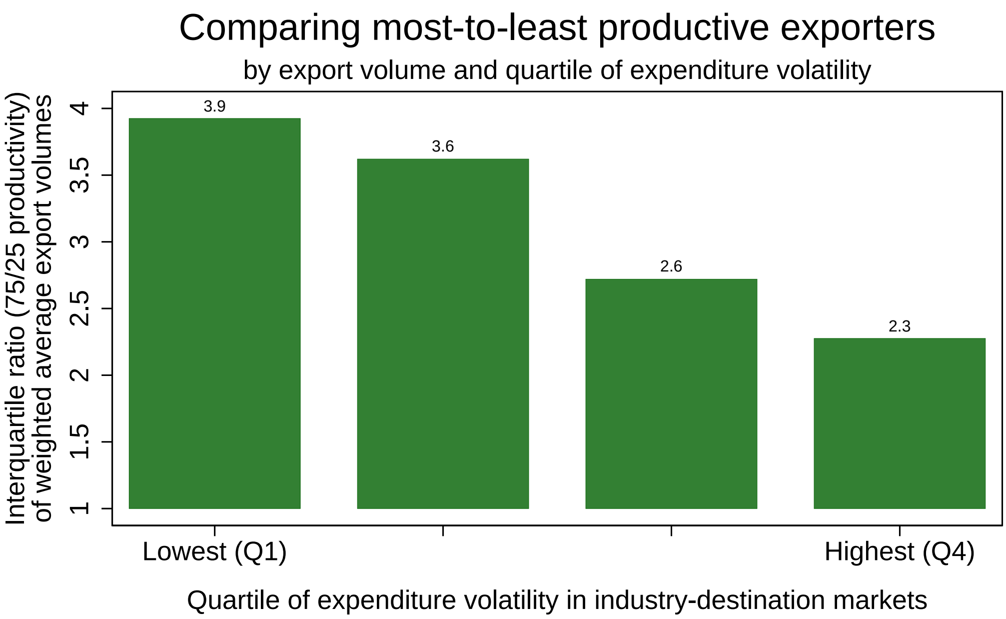
Column 2 of Table 1 investigates whether the negative effect of expenditure volatility on export quantities varies with trade costs. As shown below in the theoretical section, we expect this negative impact to be lower when trade costs increase. The intuition is that the marginal negative impact of volatility is higher the larger the market potential. Thus, destination markets in which trade costs are low receive relatively more exports and are thus more at risk. We use the geographical distance between France and the destination country as a proxy for trade costs and interact the volatility variable with distance.[14] Note that the separate effect of distance on French exports is captured by the destination-by-time fixed effects, which also absorb other time-variant and -invariant destination covariates such as common language, contiguity or regional trade agreement. The results confirm our expectations. The estimated coefficient on the interaction term between volatility and distance is positive and significant at the one percent level. Thus, higher trade costs tend to reduce the negative impact of expenditure volatility on exports.

We supplement the analysis by presenting reduced-form graphical evidence of the heterogeneous impact of volatility on exports. However, instead of using trade costs, we exploit differences in productivity across firms. The intuition is similar to that presented above: the more productive the firm is, the greater the export volumes and, therefore, the higher the risk at the margin. Figure 5 compares most to least productive exporters in terms of industry export volumes and expenditure volatility in destination markets between 2000 and 2009. Each industry-destination-year is binned based on the quartile of its expenditure volatility (x-axis), with bins from Q1 to Q4, where Q1 is the lowest and Q4 the highest quartile of volatility. The y-axis displays the interquartile ratio that compares the 25% most productive firms to the 25% least productive firms in terms of the weighted average export volumes for each quartile of expenditure volatility. The weighted average export volumes are computed at the 4-digit industry-destination-year level. The weights are the lagged mean expenditure of the industry-destination-year triplets. They are designed to account for the possible

[14] The relevant data are obtained from CEPII, and distance is computed as the distance between the main cities of both countries weighted by the share of the population living in each city.

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 most productive exporters. The 25% most productive firms export, on average, 3.9 times more than the 25% least productive firms in less volatile markets (Q1), while this difference shrinks to 2.3 in the most volatile markets (Q4). Our theoretical model will rationalize this cautionary or risk-averseness effect.

Figure 5: Export difference in volumes between least and most productive exporters
(Volatility in destination-year-industry markets – 2000-2009)



The figure compares most-to-least productive exporters in terms of export volumes and expenditure volatility in destination markets between 2000 and 2009: on average, the 25% most productive firms sell 3.9 times more than the 25% least productive ones in Q1 vs 2.3 in Q4. The x-axis displays the quartiles of expenditure volatility in 3-digit industry-destination-year triplets. 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 industry-destination-year level. The weights are the lagged mean absorption of the industry-destination-year triplets.

2.4.2 Firm-level Evidence

We now present our firm-level estimations on the intensive and extensive margins of trade, i.e., on firm export sales and entry/exit decisions. Then, in Section 2.5, we discuss how economically meaningful the estimates of volatility and skewness are.

Intensive Margin of Trade

We estimate the following specification at the firm level:

$$\ln q^k_{fjt} = \delta_1 \ln \mathbb{E}(R^K_{jt}) + \delta_2 \ln \mathbb{V}(R^K_{jt}) + \delta_3 \mathbb{S}(R^K_{jt}) + \mathbf{FE} + \varepsilon^k_{fjt}, \quad (3)$$

where q^k_{fjt} is now the export volume of French firm f to destination j at the 4-digit manufacturing level k in year t.[15] As previously described, $\mathbb{E}(R^K_{jt})$, $\mathbb{V}(R^K_{jt})$ and $\mathbb{S}(R^K_{jt})$ are the first three central moments of expenditure, and ε^k_{fjt} represents the usual error term.

Compared with the industry-level estimations, firm-level data offer considerably more observations and reduce concerns regarding the inefficiency of the panel estimator when introducing various combinations of fixed effects. Consequently, we use fairly demanding specifications with a vector **FE** of different combinations of fixed effects. The standard errors are clustered at the destination-4-digit-industry level. Because maintaining singleton groups in linear regressions where fixed effects are nested within clusters might lead to incorrect inferences, we exclude groups containing only one observation (Correia, 2015). Therefore, the number of observations differs across estimations.[16]

The results are reported in Table 2 according to the fluctuations in uncertainty across destination markets (column 1), industries (column 2), and years (column 3). Before presenting the differences between columns, note that in every specification, all coefficients are statistically significant (at the 1 percent confidence level) and exhibit the expected signs. The results clearly show that expenditure volatility is negatively correlated with firm export volumes. This confirms the industry evidence presented above. Moreover, as expected, the average size of expenditure, its skewness, and firm productivity are positively correlated with export volumes.

In the first column, we introduce firm-by-industry-by-year fixed effects (α_{fkt}), which

[15] We report estimations on firm export unit values in Appendix B. Results are in line with the theoretical predictions on export prices shown in Section 3. However, they are not robust across all specifications. One reason could be that unit values are noisy proxies for export prices.

[16] We use the Stata package REGHDFE developed by Correia (2014). The results are similar when retaining singleton groups and are available upon request.

Table 2: Intensive margin: Firm export volumes

Dependent variable:	Firm export volumes: $\ln q_{fjt}^{k}$		
	(1)	(2)	(3)
Ln Mean 5-year Expenditure$_{jt}^{K}$	0.068[a]	0.079[a]	0.200[a]
	(0.018)	(0.022)	(0.030)
Ln Expenditure Volatility$_{jt}^{K}$	-0.028[a]	-0.040[a]	-0.024[a]
	(0.009)	(0.012)	(0.008)
Expenditure Skewness$_{jt}^{K}$	0.012[a]	0.015[a]	0.009[a]
	(0.004)	(0.005)	(0.003)
Ln Productivity$_{ft}$	-	-	0.123[a]
			(0.004)
Observations	3,904,513	3,129,051	3,8754,22
R^2	0.708	0.534	0.861
Sets of Fixed Effects:			
Firm.(4-digit-)Industry.Time$_{fkt}$	Yes	-	-
Destination$_j$	Yes	-	-
Firm.Destination.Time$_{fjt}$	-	Yes	-
4-digit-Industry$_k$	-	Yes	-
Firm.Destination.(4-digit-)Industry$_{fjk}$	-	-	Yes
Time$_t$	-	-	Yes

Notes: dependent variable is firm-level export volumes in logs aggregated at the 4-digit k level. Number of years: 10; Number of destinations: 90; Number of 4-digit industries: 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-4-digit industry level, with [a] denoting significance at the 1% level.

capture all time-varying firm-specific determinants, such as productivity and debt, as well as any firm-industry heterogeneity. Our coefficients of interest on volatility and skewness are identified in the destination dimension. In other words, the estimation relies on firm-industry-year triplets with multiple destinations. We simply add a separate destination country fixed effect (α_j) to control for destination-specific factors.

In this setting, multi-destination firms may diversify their exports across markets in response to increased volatility. Despite this opportunity, we find a negative effect of expenditure volatility on firm-level exports. This implies that multi-destination firms only partly diversify their exports to different destinations.[17]

In the second column, we introduce firm-by-destination-by-year fixed effects (α_{fjt}). With this specification, we still absorb productivity differences across firms, but we also control for any time-varying firm-destination-specific factors. Our coefficients of

[17]Note that restricting the estimations to multi-destination and -industry exporters only marginally affects the estimates. These results are available upon request.

interest are now identified in the industry dimension. In other words, the estimation relies on firm-destination-year triplets with multiple industries. We simply add a separate 4-digit industry fixed effect (α_j) to control for industry-specific factors.

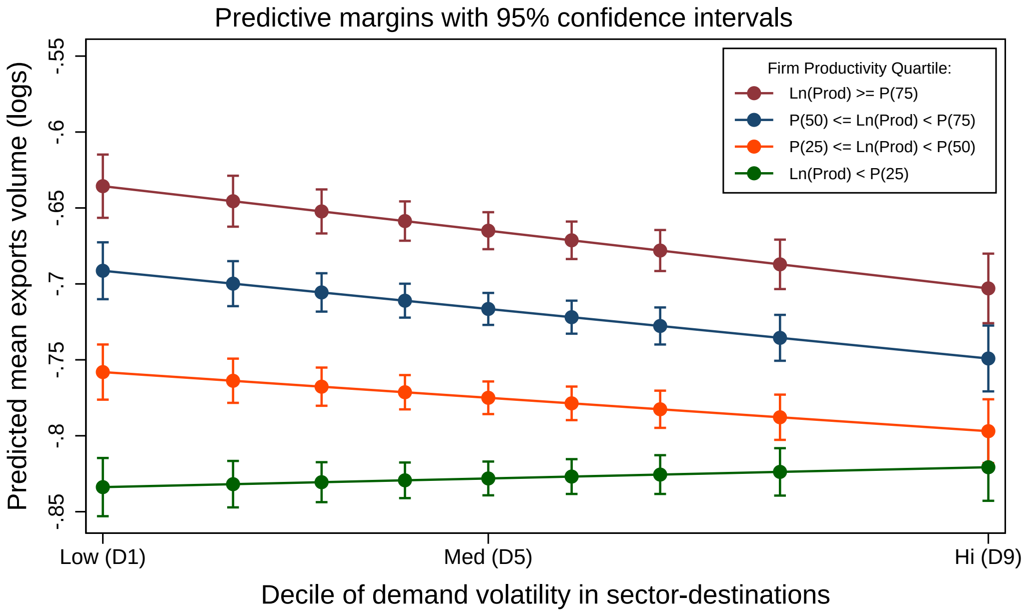
In this setting, by controlling for firm-by-destination-by-year fixed effects, we eliminate the possibility of firms diversifying across destinations. Unsurprisingly, the magnitude of the volatility estimate *increases* (from 0.028 in column 1 to 0.040 in column 2). Firms are more impacted because it is intuitively more difficult to diversify across industries of activity than across destinations when uncertainty increases. The magnitude of the skewness effect is also somewhat larger.

In the third column, we use firm-by-destination-by-industry fixed effects (α_{fjk}) and add a separate year fixed effect (α_t). We capture any differences that are maintained across our observation period at the firm-destination-industry level. However, this set does not control for time-varying firm characteristics, such as productivity, which is now introduced as an additional control and defined as the ratio of value added to the number of employees. The estimates in the third column 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-industry, an increase in volatility over time reduces firm's export volumes, while an increase in skewness raises exports.

Heterogeneous Intensive Responses of Firms to Expenditure Volatility

In this section, we assess the potential for heterogeneity in firm responses to volatility. Specifically, we evaluate whether expenditure uncertainty reduces the export difference between the least and the most productive firms, as depicted in the non-parametric Figure 5. In Figure 6, we construct a parametric version of this reallocation effect.

Figure 6: Volatility, productivity and export volumes



The figure compares exporters across different categories of productivity and demand volatility in terms of predicted export volumes between 2000 and 2009. The x-axis displays the deciles of demand volatility in 3-digit sector-destination-year triplets. The y-axis displays the predicted mean export volume in 4-digit sector-destination-year triplets. The predicted values are computed based on a variant of the second column of Table 5, where we split the log of productivity into quartiles that we interact with deciles of demand volatility. Then, based on the estimated parameters, we compute the predicted mean of export volumes (in logs) for each decile of volatility and quartiles of productivity.

We first divide firm productivity into quartiles and industry expenditure volatility into deciles. Then, we create new variables by interacting the productivity quartiles with the volatility deciles. Finally, we use an estimator that allows us to identify these interactions and to overcome the computational cost of calculating marginal effects. We run the regression by conditioning the firms' responses on destination-by-year and firm-by-industry (4-digit) fixed effects.[18] Based on the estimated parameters, we compute the predicted mean of export volume (in logs) for each decile of volatility and quartile of productivity. The different predictions for trade are plotted in Figure 6. This plot shows three interesting results: (1) the most productive firms export more than the others at any level of volatility; (2) the larger 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 increases for the most productive firms as volatility increases. These results imply that the export difference between the least and most productive firms decreases with volatility.

[18]Note that this estimator yields without the interactions the same estimates of volatility and skewness than in column 3 of Table 2

We pursue our investigation of the heterogeneous responses of firms to expenditure volatility using the same specifications as in Table 2 and adding a new covariate: the interaction between volatility and firm productivity. The results are reported in Table 3. Our estimates confirm that the most productive firms are more sensitive to a variation in expenditure volatility (across destinations, industries, and years).

Table 3: Intensive margin: reallocation of export volumes

Dependent variable:	Firm export volumes: $\ln q^k_{fjt}$		
	(1)	(2)	(3)
Ln Mean 5-year Expenditure$^K_{jt}$	0.065^a	0.078^a	0.200^a
	(0.018)	(0.021)	(0.030)
Ln Expenditure Volatility$^K_{jt}$	0.008	-0.017	-0.011
	(0.010)	(0.012)	(0.008)
Ln Volatility$^K_{jt}$ × Ln Productivity$_{ft}$	-0.011^a	-0.007^a	-0.004^a
	(0.002)	(0.001)	(0.001)
Expenditure Skewness$^K_{jt}$	0.012^a	0.015^a	0.009^a
	(0.004)	(0.005)	(0.003)
Ln Productivity$_{ft}$	-	-	0.117^a
			(0.004)
Observations	3,904,513	3,129,051	3,8754,22
R^2	0.708	0.534	0.861
Sets of Fixed Effects:			
Firm.(4-digit-)Industry.Time$_{fkt}$	Yes	-	-
Destination$_j$	Yes	-	-
Firm.Destination.Time$_{fjt}$	-	Yes	-
4-digit-Industry$_k$	-	Yes	-
Firm.Destination.(4-digit-)Industry$_{fjk}$	-	-	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 industries: 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-4-digit industry level, with ^{a} denoting significance at the 1% level.

Extensive Margin of Trade

We now investigate the impact of uncertainty on the extensive margin of trade. We follow the same identification strategy as above with a disaggregated left-hand side variable regressed on aggregated right-hand side expenditure moments. We distinguish between the entry of new French firms into the international market and the exit of incumbents from that market over the 2000-2009 period. Regarding entry, our dependent variable (y^k_{fjt}) is the probability that firm f begins exporting to destination j in 4-digit industry k and year t. Our counterfactual scenario considers the firms that do not enter in the same triplet jkt. This choice model can be written in the latent variable representation, with y^{*k}_{fjt} being the latent variable that determines whether a strictly positive export flow is observed for firm f in a destination-industry-year triplet. Our estimated equation is therefore as follows:

$$Pr(y^k_{fjt}|y^k_{fj,t-1} = 0) = \begin{cases} 1 & \text{if} \quad y^{*k}_{fjt} > 0, \\ 0 & \text{if} \quad y^{*k}_{fjt} \leq 0, \end{cases} \tag{4}$$

with

$$y^{*k}_{fjt} = \gamma_1 \ln \mathbb{E}(R^K_{jt}) + \gamma_2 \ln \mathbb{V}(R^K_{jt}) + \gamma_3 \mathbb{S}(R^K_{jt}) + \mathbf{FE} + \varepsilon^k_{fjt},$$

where, as previously described, $\mathbb{E}(R^K_{jt})$, $\mathbb{V}(R^K_{jt})$ and $\mathbb{S}(R^K_{jt})$ are the first three central moments of expenditure, whereas **FE** represents various combinations of fixed effects, and ε^k_{fjt} is the error term. In addition to the probability of entry, one can also study the exit transition. Higher volatility or lower upside gains may indeed increase the exit of firms from the export market. In that case, our dependent variable is the probability that firm f in destination j, industry k and year $t-1$ stops exporting products from industry k to this destination in year t. Our counterfactual scenario now considers the firms that continue to serve the same triplet jkt. The explanatory variables are the same as in the entry estimations.

We estimate the entry and exit equations using a linear probability model. The inclusion of fixed effects in a probit model would give rise to the incidental parameter problem. The linear probability model avoids this issue. As for the intensive margin, in all regressions, we account for the correlation of errors by clustering at the destination-4-digit-industry level. The results are reported in Table 4.

In accordance with the definition of our counterfactual scenarios, we investigate the effects of uncertainty across industries and destinations. In columns 1 and 3, we introduce destination (α_j) and firm-by-industry-by-year fixed effects (α_{fkt}). Our coefficients of interest on volatility and skewness are here identified in the destination dimension. In other words, regarding the probability of firm entry (column 1), we compare firms in a given industry k and year t entering an export market j versus those that are not. In columns 2 and 4, we introduce industry (α_k) and firm-by-destination-by-year fixed effects (α_{fjt}). Our coefficients of interest on volatility and skewness are now identified in the industry dimension. Regarding the probability of firm entry (column 3), we thus compare firms in a given destination j and year t entering industry k versus those that are not.

Table 4: Extensive margin: entry and exit probabilities

Dependent variable:	Proba. of entry		Proba. of exit	
	$Prob(y_{fjk,t}=1)\|Prob(y_{fjk,t-1}=0)$		$Prob(y_{fjk,t}=0)\|Prob(y_{fjk,t-1}=1)$	
	(1)	(2)	(3)	(4)
Ln Mean 5-year Expenditure$^K_{jt}$	0.002^a	0.001^a	-0.013^a	-0.008^a
	(0.0002)	(0.0002)	(0.002)	(0.002)
Ln Expenditure Volatility$^K_{jt}$	-0.0009^a	-0.0005^a	0.006^a	0.003^a
	(0.0002)	(0.0001)	(0.001)	(0.001)
Expenditure Skewness$^K_{jt}$	0.0002^b	0.0001^b	-0.0007	-0.0004
	(0.0001)	(0.0001)	(0.0005)	(0.0005)
Observations	45,240,557	36,133,419	3,320,672	2,411,537
R^2	0.088	0.354	0.372	0.424
Sets of Fixed Effects:				
Firm.(4-digit-)Industry.Time$_{fkt}$	Yes	-	Yes	-
Destination$_j$	Yes	-	Yes	-
Firm.Destination.Time$_{fjt}$	-	Yes	-	Yes
4-digit-Industry$_k$	-	Yes	-	Yes

Notes: dependent variable is probability for a firm to enter the export market (columns 1-2) and probability for a firm to exit the export market (columns 3-4). Entry sample: 9 years, 89 destinations, 119 4-digit industries, and 74,575 firms. Exit sample: 9 years, 88 destinations, 119 4-digit industries, and 72,694 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-4-digit industry level, with ^{a}, ^{b} denoting significance at the 1% and 5% level respectively.

Table 4 presents quite intuitive results. Average expenditure significantly increases the probability that a firm enters a destination j or an industry k while reducing its probability of exit (columns 3 and 4). As expected, the within firm-industry-time (columns 1 and 3) and within firm-destination-time (columns 3 and 4) dimensions react to the second- and third-order moment changes in expenditures. Expenditure volatility significantly decreases the probability of entry and increases the probability of exit. These results depict reallocation effects across destinations and industries in terms of export decisions. Interestingly, destination reallocation appears to be stronger (see columns 1 and 3 vs. columns 2 and 4). As noted for the intensive margin of trade, diversification and reallocation across destinations is easier than across industries, which may explain the difference in the magnitudes of coefficients. Thus, a smaller volatility effect on the intensive margin is consistent with a larger effect on the extensive margin. Note that skewness has a positive and significant impact on the probability of entry but no exit effect.

2.5 Discussion and Simulations

Our estimations reveal that expenditure volatility negatively affects the intensive and extensive margins of trade. In addition, the more productive firms seem to favor destinations or industries with low volatility. In contrast, low productivity exporters can increase their exports in the riskiest countries or industries due to a reallocation of market shares among firms. Our results also suggest that downside risk matters to exporters.

How economically meaningful are the estimates of volatility and skewness? The firm-level estimates are our preferred estimates. Compared with the industry-level estimations, the number of firm-level observations improves the efficiency of the panel estimator when various combinations of fixed effects are introduced. Nevertheless, the firm-level estimates likely underestimate the magnitude of the effects. Indeed, our estimations only consider variations along a single dimension (destination, industry, or time), whereas our measures of volatility and skewness vary along the three dimensions (see Section 2.3). In addition, our simulations focus only on the intensive margin, disregarding the effects on the extensive margin. Our simulations also neglect feedback effects on prices and demand. As a result, the magnitude of the positive effect of lower uncertainty can be viewed as a minimum threshold.

Based on the intensive margin estimates in Table 2, we aggregate the firm-level results at the country level and simulate how changes in expenditure moments affect aggregate exports. Other things being equal, we find that in 2005, a one-standard-deviation increase in the average volatility of China would reduce aggregate French exports to China by 1.5% to 2.4%.[19] Moreover, if US expenditure were as volatile as

[19] As expected, the smallest effect (1.5%) is based on the lowest volatility estimate reported in the third

Mexico's, French exports to the US would decrease by 3.2% to 4.5%. In contrast, holding other features constant, if US expenditure were as skewed as Mexico's, French exports to the US would increase by 1.4% to 1.8%. Further, if US expenditure were as volatile *and* skewed as Mexico's, French exports to the US would decrease by 1.8% to 2.8%. This result suggests that regardless of whether skewness matters, the risk premium is driven primarily by the second-order moment of the expenditure distribution.

As a final counterfactual, we consider what French exports would have been had there been virtually no volatility in destination markets. Thus, if the volatility of all destinations in 2005 were as low as that of the UK's textile industry (ISIC code 1711),[20] total French exports would have increased at the intensive margin by 5.3% to 7.6%. If we also assume zero skewness of each destination/industry expenditure, total French exports would still have increased by 4.1% to 6.8%.

3 Theory

In this section, we develop a new firm-based trade model in which risk-averse producers face the same industry-wide uncertainty over expenditures and make export decisions (entry/exit, quantity or price) before the resolution of that uncertainty.[21] This model rationalizes our empirical results on the role of uncertainty in trade. Note that our framework also matches traditional facts concerning the role of firm heterogeneity and trade costs in trade.

We assume that each firm producing a variety v located in country i faces a downward-sloping demand curve in country j given by $p_{ij}(v) = f[q_{ij}(v), R_j, .]$, where R_j denotes expenditure, and $p_{ij}(v)$ and $q_{ij}(v)$ are the price and the quantity of variety v, respectively. The demand curve is not known for certain at the time the contracts between exporters and importers are signed, as R_j is subject to random shocks. Numerous fac-

column of Table 2, while the highest effect (2.4%) is based on the estimate in column 2. Unsurprisingly, the volatility estimate reported in the first column gives an intermediate effect of 1.7%. This ranking is preserved in all subsequent simulations.

[20]The 4-digit ISIC industry 1711 is preparation and spinning of textile fibers; weaving of textiles. The volatility in this industry in the UK in 2005 was 0.024.

[21]In that respect, the role of uncertainty in our approach differs from the current firm-based trade literature. Unlike in Melitz (2003), producers know their level of productivity with certainty.

tors are beyond the producer's control and influence the expenditure realization, including climatic conditions and changes in consumer tastes, opinion leader attitudes, competing product popularity, and industrial policy. Formally, we assume that R_j is independently distributed with mean, variance, and skewness given by $\mathbb{E}(R_j)$, $\mathbb{V}(R_j)$, and $\mathbb{S}(R_j)$, respectively.[22] We also assume that shocks are not correlated across countries, i.e., $\text{Cov}(R_l, R_j) = 0$ for all $l \neq j$, for the sake of simplicity. The actual demand realization is therefore uncertain, i.e., R_j can be either high or low, when firms make their production or pricing decisions (q_{ij} or p_{ij}, respectively). As a result, the dependence of price on quantity (and *vice versa*) is given for every state of nature. In other words, the marginal revenue of each firm can reach different levels and is not known with certainty at the time strategic variables are chosen.

This section analyzes how risk-averse exporting managers react to industry-level uncertainty based on their characteristics and the features of the destination country. On the one hand, the level of output may decrease for all firms due to the uncertain demand curve in accordance with the standard theory of production under uncertainty. On the other hand, some producers may stop exporting because of expenditure fluctuations, such that market shares for the remaining exporters may rise due to reallocation effects. In addition, even if expenditure shocks are common to all firms, they may modify the relative prices of the varieties supplied by the surviving firms, leading to the reallocation of market shares. Hence, the effects of industry-specific uncertain demand on export performance at the firm level are *a priori* unclear.

3.1 Market Structure, Technology, and Firm Behavior

Consider a multi-country economy with one industry supplying a continuum of differentiated varieties indexed by v.[23] 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 individual producers are negligible in the

[22]Note that $\mathbb{E}(R_j)$ and $\mathbb{V}(R_j)$ are always positive, while $\mathbb{S}(R_j)$ can be either positive or negative.

[23]Note that we could easily consider a multi-sector economy. However, doing so increases the complexity of the formal exposition without providing new insights.

market, they behave as monopolists in their market, and their decisions do not account for the impact of their choice on aggregate statistics.

Labor is the only production factor, and it is assumed to be supplied inelastically. The production of $q_{ij}(v)$ units of variety v requires a quantity of labor equal to $\ell_{ij}(v) = \tau_{ij}q_{ij}(v)/\varphi$, where φ is labor productivity, and $\tau_{ij} > 1$ is an iceberg trade cost. We assume that labor productivity is known *a priori* but differs across firms. Thus, the marginal requirement for labor is specific to each firm and each destination but does not vary with production.

Under imperfect competition, the choice of action variable (quantity or price) merits discussion. If the choice of behavioral mode by a monopolistic firm is unimportant under certainty, this is no longer the case under uncertainty (Leland, 1972, Weitzman, 1974, and Klemperer and Meyer, 1986). The firm has two options: (i) set quantity before demand is known, and thereafter, the actual demand curve yields the market-clearing price; (ii) set price before demand is known, and thereafter, the actual demand curve yields the market-clearing quantity. Ideally, we would endogenously determine whether firms choose the quantity to produce or the price to charge, as in Klemperer and Meyer (1986). For simplicity, we assume that firms set quantity before demand is known. In Appendix C, we report on the case in which price is the strategic variable. We show that this configuration yields the same predictions as the case in which firms set quantity, although the levels of prices and quantities differ by the behavioral mode.

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

As the shocks to market expenditure are unobservable, the impact of quantity on price is uncertain. The expected export profit in a given market is described as follows:

$$\mathbb{E}\left[\pi_{ij}(v)\right] = \mathbb{E}\left[p_{ij}(v)\right] q_{ij}(v) - c_{ij}(v)q_{ij}(v), \tag{5}$$

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

The uncertain terminal profit of a firm producing variety v and located in country i, π_i, can be decomposed into two components: the profit from domestic sales π_{ii}, which is assumed to be certain for simplicity, and the uncertain profit from total exporting sales $\Sigma_j\pi_{ij}$, such that $\pi_i = \pi_{ii} + \Sigma_j\pi_{ij}$.

3.2 Uncertainty and Firm Behavior

We consider a risk-averse manager whose risk preferences are represented by a concave utility function $\mathrm{U}_m(\pi_i)$. 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 expected utility theory, where risk-aversion behavior is intrinsically equivalent to a preference for diversification (see Eeckhoudt et al., 2005). Assume that $\mathrm{U}_m(\pi_i)$ is continuously differentiable up to order 3, with $\mathrm{U}'_m(.) > 0, \mathrm{U}''_m(.) < 0$, and $\mathrm{U}'''_m(.) > 0$. Following the methodology developed in Eeckhoudt et al. (2005), a third-order Taylor expansion of $\mathrm{U}_m(\pi_i)$ is evaluated at $\mathbb{E}(\pi_i)$:

$$\mathrm{U}_m(\pi_i) \approx \mathrm{U}_m[\mathbb{E}(\pi_i)] + \mathrm{U}'_m\left[\pi_i - \mathbb{E}(\pi_i)\right] + \frac{1}{2}\mathrm{U}''_m\left[\pi_i - \mathbb{E}(\pi_i)\right]^2 + \frac{1}{6}\mathrm{U}'''_m\left[\pi_i - \mathbb{E}(\pi_i)\right]^3.$$

Taking the expectation and assuming that the first three moments of R_j exist yields:

$$\mathrm{U}_m(\pi_i) \approx \mathrm{U}_m[\mathbb{E}(\pi_i)] + \mathrm{U}'_m\left[\pi_i - \mathbb{E}(\pi_i)\right] + \frac{1}{2}\mathrm{U}''_m\left[\pi_i - \mathbb{E}(\pi_i)\right]^2 + \frac{1}{6}\mathrm{U}'''_m\left[\pi_i - \mathbb{E}(\pi_i)\right]^3.$$

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

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

where $\mathbb{V}(\pi_i) = \mathbb{E}[\pi_i - \mathbb{E}(\pi_i)]^2$ is the variance of profit and $\mathbb{S}(\pi_i) = \mathbb{E}[\pi_i - \mathbb{E}(\pi_i)]^3$ its skewness. According to expected utility theory, one way to measure a decision maker's degree of risk aversion is to ask her how much she is prepared to pay to eliminate the zero-mean risk. The answer to this question will be referred to as the risk premium Γ associated with that risk.[24] In our context, the risk premium Γ is defined as the certain amount of money that makes a manager indifferent between the risky return π_i and the non-random amount or certainty equivalent of the expected utility:

$$\mathbb{E}U_m(\pi_i) = U_m\left(\mathbb{E}(\pi_i) - \Gamma\right) \approx U_m\left(\mathbb{E}(\pi_i)\right) - \Gamma U_m', \tag{7}$$

where $\mathbb{E}U_m(\pi_i)$ is approximated by a first-order Taylor expansion. Using this approximation in equation (6) yields the following:

$$\Gamma \approx \rho_v\mathbb{V}(\pi_i) - \eta_v\mathbb{S}(\pi_i), \tag{8}$$

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 π_i to the risk premium Γ, respectively.

Several remarks are in order. First, ρ_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 has Decreasing Absolute Risk Aversion (DARA) preferences.[25] DARA requires that U_m''' be positive or that marginal utility be convex. A disadvantage 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

[24] As an illustration, for a random lottery x, the risk premium must satisfy the certainty equivalent condition $\mathbb{E}U_m(x) = U_m(\mathbb{E}(x) - \Gamma)$. In other words, the decision maker obtains the same welfare by either accepting the risk or paying the risk premium Γ.

[25] In contrast, $\eta_v = 0$ would imply Constant Absolute Risk Aversion (CARA) preferences.

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 disadvantages. Constant Relative Risk Aversion (CRRA) would measure the rate at which marginal utility decreases when wealth increases by one percent. However, this implies redefining the risk premium as Γ times the manager's wealth. Yet, the manager's wealth should not be considered as given but as endogenous to risk and economic conditions. An advantage of DARA preferences is that they capture relativeness without taking a stance on the manager initial wealth. Indeed, 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 Γ). In this case, private wealth accumulation and insurance motives are substitutes.

Next, note 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. $U_m''' > 0$ corresponds to a situation of downside risk aversion, implying that a decrease in $\mathbb{S}(\pi_i)$ tends to increase the willingness to pay to avoid risk (Menezes et al., 1980). Thus, for given $\mathbb{E}(\pi_i)$ and $\mathbb{V}(\pi_i)$, downside-risk-averse exporters will favor destination markets with positively skewed profits.

Finally, we know from expected utility theory that maximizing $\mathbb{E}U_m(\pi_i)$ is equivalent to maximizing the certainty equivalent payoff $\Pi_v(\pi_i) = \mathbb{E}(\pi_i) - \Gamma$. Since expression (8) provides a local approximation to the risk premium Γ, it follows that the objective function of a decision maker can always be approximated as follows:

$$\Pi_v(\pi_i) \approx \mathbb{E}(\pi_i) - \Gamma = \mathbb{E}(\pi_i) - \rho_v \mathbb{V}(\pi_i) + \eta_v \mathbb{S}(\pi_i). \tag{9}$$

This equation provides an intuitive interpretation of the risk premium (Γ) as a measure of the shadow cost of private risk bearing. It is a cost since it appears as a reduction in the expected gain $\mathbb{E}(\pi_i)$. This formulation of the objective function does not require full specification of the utility function $U_m(\pi_i)$. Furthermore, it allows us to advance beyond a simple mean-variance analysis in the investigation of export decisions under expenditure uncertainty. This is particularly useful in the analysis of downside risk exposure. However, the reader should bear in mind that the expression for $U_m(\pi_i)$ is valid only in the neighborhood of $\mathbb{E}(\pi_i)$. We thus consider only small risks. As the share of one destination in the total firm sales is usually low, this assumption is not particularly restrictive.

3.3 Preferences and Demand

Consumers in each country have the same preferences, and the utility resulting from the consumption of the differentiated good is given by a general additively separable utility:

$$U_{c_j} = \int_{v \in \Omega_j} u_j(v) \mathrm{d}v, \tag{10}$$

where the set Ω 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 differentiated product are additively separable across varieties and that $u_j(.)$ is thrice continuously differentiable, strictly increasing, and strictly concave on $(0, \infty)$. Formally, we have $u_j(0) = 0$, $u_j' \equiv \partial u(v)/\partial q(v) > 0$ and $u_j'' \equiv \partial^2 u(v)/\partial q(v)^2 < 0$. 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

$$\int_{\Omega_j} p_{ij}(v) q_{ij}(v) \mathrm{d}v = R_j, \tag{11}$$

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

$$p_{ij}(v) = u_j'(v)/\lambda, \tag{12}$$

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

Plugging (12) into (11) implies $\lambda = \Psi_j / R_j$ with:

$$\Psi_j \equiv \int_{\Omega_j} u_j'(v) q_{ij}(v) \mathrm{d}v, \tag{13}$$

where Ψ_j can be interpreted as a measure of industry supply. Consequently, the inverse demand for each variety is now:

$$p_{ij}(v) = R_j u_j'(v) \Psi_j^{-1}. \tag{14}$$

As expected, the price of each variety increases with expenditure (R_j) and decreases with both its own quantity ($\partial p_{ij}/\partial q_{ij} < 0$ as $u_j'' < 0$) and the quantity and quality of varieties supplied by rival firms (Ψ_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).

3.4 Risk Premium and Firm Size

Recall that R_j is not known for certain at the time the contracts between the exporters and the importers are signed. The expected price prevailing for each firm in the foreign market is therefore given by the following equation:

$$\mathbb{E}\left[p_{ij}(v)\right] = \mathbb{E}(R_j) u_j'(v) \Psi_j^{-1}, \tag{15}$$

whereas the expected market share for each firm in country j is

$$s_{ij}(v) = \frac{\mathbb{E}(p_{ij}) q_{ij}(v)}{\mathbb{E}(R_j)} = u_j'(v) q_{ij}(v) \Psi_j^{-1}. \tag{16}$$

The expected market share increases with output size. Indeed, we have $\frac{\partial s_{ij}(v)}{\partial q_{ij}(v)} = \Psi_j^{-1} \Lambda_{ij}(v) > 0$, 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 CES case, as in numerous trade models. For example, if $u_j(q_{ij}) = \theta_v q_{ij}^{\gamma}$, with $\theta_v > 0$ and $0 < \gamma < 1$, the elasticity of substitution between any pair of varieties is constant, as given by $1/(1-\gamma)$, and $\Lambda_{ij}(v) = \theta_v \gamma^2 q_{ij}^{\gamma-1} > 0$.

The risk premium for each firm is $\Gamma_v = \sum_j \Gamma_{ij}$, with Γ_{ij} defined by equation (9):

$$\Gamma_{ij} = \rho_v \mathbb{V}(\pi_{ij}) - \eta_v \mathbb{S}(\pi_{ij}), \tag{17}$$

as $\mathrm{Cov}(R_l, R_j) = 0$ for all $l \neq j$. Here, Γ_{ij} can be interpreted as the risk premium associated with a destination country j. It is straightforward to verify that the variance and skewness of the profit distribution are given, respectively, by:

$$\mathbb{V}(\pi_{ij}) = \mathbb{V}(R_j) s_{ij}^2 \quad \text{and} \quad \mathbb{S}(\pi_{ij}) = \mathbb{S}(R_j) s_{ij}^3, \tag{18}$$

The variance of the firm's profit increases with its output size (through a higher expected market share). The skewness of the profit distribution increases with the firm's output as long as $\mathbb{S}(R_j) > 0$. Hence, the impact of the output size on the risk premium is ambiguous when $\mathbb{S}(R_j) > 0$, as the risk premium depends negatively on the skewness of the expenditure distribution. The following Lemma summarizes our main results.

Lemma 1. *The variance of profit increases with output size, whereas the relationship between the risk premium and output size is ambiguous when $\mathbb{S}(R_j) > 0$.*

It is worth stressing that the variance and skewness of profits decrease with the industry's output size. Thus, the mass of rivals serving the same market has an ambiguous effect on a firm's export performance. Indeed, a rise in Ψ_j decreases the marginal revenue of a firm but reduces the variance of profits.

3.5 Intensive Margin

The firm's payoff is $\Pi_v(\pi_i) = \sum_j s_{ij} \mathbb{E}(R_{ij}) - c_{ij} q_{ij} - \sum_j \Gamma_{ij}$. Therefore, the marginal revenue is uncertain, while the marginal cost is known with certainty. The expected export sales $\mathbb{E}\left[p_{ij}(v)\right] q_{ij}(v)$ increase with q_{ij} but decrease with the industry's output size (captured by Ψ_j). The first-order condition for payoff maximization $\partial \Pi_v / \partial q_{ij} = 0$

implies

$$\frac{\partial s_{ij}}{\partial q_{ij}}\mathbb{E}(R_j)\left[1-\frac{\partial \Gamma_{ij}}{\partial s_{ij}(v)}\frac{1}{\mathbb{E}(R_j)}\right]-c_{ij}=0, \tag{19}$$

with

$$\frac{\partial s_{ij}}{\partial q_{ij}}=\frac{\mathbb{E}(p_{ij})}{\mathbb{E}(R_j}\left[1-\frac{-u_j''(v)q_j}{u_j'(v)}\right] \tag{20}$$

whereas the second-order condition requires $\partial^2 s_{ij}/\partial q_{ij}^2<0$ and $\partial^2\Gamma_{ij}/\partial q_{ij}^2>0$ to have $\partial^2\Pi_v/\partial q_{ij}^2<0$. Using (17), (19), and the implicit function theorem, the following is readily verifiable:

$$\frac{\partial q_{ij}}{\partial \mathbb{V}(R_j)}=-\frac{\partial^2\Pi_v}{\partial q_{ij}\partial \mathbb{V}(R_j)}\left(\frac{\partial^2\Pi_v}{\partial q_{ij}^2}\right)^{-1}<0.$$

As a result, in accordance with the standard literature on producer theory under uncertainty, risk-averse firms produce less than they would under certainty, for a given mass of exporters. The *certainty equivalent export quantity* q_{ij} incorporates the risk premium composed of $\rho_v\mathbb{V}(R_j)>0$. However, we should also account for 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:

$$\frac{\partial q_{ij}}{\partial \mathbb{S}(R_j)}=-\frac{\partial^2\Pi_v}{\partial q_{ij}\partial \mathbb{S}(R_j)}\left(\frac{\partial^2\Pi_v}{\partial q_{ij}^2}\right)^{-1}>0.$$

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

Further, we can readily verify 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 and trade costs is 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 verify:

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

when $\rho_v > 0$. For a given ρ_v, the negative effect of expenditure volatility is strengthened when firm productivity is high and trade costs are low. Recall 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 18). As $\partial q_{ij}/\partial\varphi > 0$ and $\partial q_{ij}/\partial\tau_{ij} < 0$, the profit variance of a firm increases with its productivity and decreases with trade costs for a given mass of firms. However, standard calculations also show that

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

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

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

More generally, the market shares of large firms are more affected by an increase in expenditure volatility than are those of small firms when the skewness is unchanged, as $\partial^2 s_{ij}/\partial\varphi\partial\mathbb{V}(R_j) < 0$, leading to the reallocation of market shares from the most productive to the least productive exporters.

Equilibrium Prices

The first-order condition (19) can be rewritten as follows:

$$\mathbb{E}\left[p_{ij}(v)\right] = c_{ij}(v)\left[1 - \frac{-u_j''(v)q_j}{u_j'(v)}\right]^{-1}\left[1 - \frac{\partial\Gamma_{ij}(v)}{\partial s_{ij}(v)}\frac{1}{\mathbb{E}\left(R_j\right)}\right]^{-1}, \tag{21}$$

where

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

as $\frac{\partial q_{ij}}{\partial s_{ij}} < 0$ and $\frac{\partial^2 \Gamma_{ij}}{\partial s_{ij}^2} > 0$ according the first- and second-order conditions, respectively. This implies that, at the equilibrium supply, the expected price is equal to the marginal cost ($c_{ij} = w_i \tau_{ij} / \varphi$) times a markup that includes the marginal risk premium. Specifically, the markup increases with the variance of the expenditure. Under expenditure 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). The markup is thus higher, on average, than that prevailing under certainty due to expenditure fluctuations. Hence, an uncertain demand curve increases prices through a higher markup.

Note that, unlike models of monopolistic competition without uncertainty, the markup is not constant. Under uncertainty, firms charge variable markups even with CES preferences. In other words, *expenditure uncertainty and risk-averse firms allow for variable markups despite the demand curve being isoelastic*. Markup depends on expenditure volatility, firm productivity and features of the origin and destination countries. The markup increases with firm productivity (φ) and decreases with trade costs (τ_{ij}) and the mass of rivals (captured by Ψ_j). These findings are consistent with industrial organization theory. However, the mechanisms at work are different. Our results are related to the existence of demand fluctuations and risk aversion. As the profit variance is high for the most productive firms, they charge larger markups. Similarly, small market size induces low variance of profits, and thus, the markup is smaller for destinations with low-potential markets. Hence, although preferences exhibit isoelastic demand, markups vary by destination and firm. The next proposition summarizes our results on export prices.

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

Two comments are in order. First, the data provide information on *ex post* prices. In our framework, *ex post* equilibrium prices are given by $p_{ij}(v) = R_j u_j'(v) \Psi_j^{-1}$, leading to $p_{ij}(v) = \frac{R_j}{\mathbb{E}(R_j)} \mathbb{E}\left[p_{ij}(v)\right]$. This implies that estimating unit prices requires considering not only the expected expenditure value $\mathbb{E}(R_j)$ but also the observed value R_j. Second, Propositions 1 and 2 are related to the intensive margin of trade, i.e., variation in trade through existing trade relationships. However, departing from equilibrium, an exogenous increase in volatility may lead to an adjustment in the industry supply (Ψ_j) through the adjustment of quantities produced by competitors. This adjustment may modify the relationship between volatility, prices and quantity. Before determining the volatility effects on industry equilibrium in Section 3.7, we examine the role of uncertainty on the extensive margin of trade, i.e., on the existence of trade relationships (non-zero trade flows).

3.6 Export Decisions

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 into destination market j is subject to a fixed cost f_{ij}, which accounts for the cost of maintaining a presence in foreign markets, e.g., maintenance of distribution and service networks, minimum freight and insurance charges, and costs to monitor foreign customs procedures and product standards. The decision to serve a foreign market is made on the basis of the expected payoff. A firm exports to destination j if and only if the variable payoff (not including the fixed cost) is higher than the fixed cost, i.e., $\Pi_{ij} \equiv \mathbb{E}(\pi_{ij}) - \Gamma_{ij} > w_i f_{ij}$. It is straightforward to verify in our general framework that, first, 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 second, a firm is more likely to serve a country whose expenditure distribution exhibits low variance and high skewness, as $\partial\Pi_{ij}/\partial\mathbb{V}(R_j) < 0 < \partial\Pi_{ij}/\partial\mathbb{S}(R_j)$ evaluated at the equilibrium output. The following proposition summarizes the result.

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

3.7 Ex post Adjustments in Intensive and Extensive Margins

Having established the choices of firms, we examine the effect on the extensive and intensive margins of increasing expenditure volatility when Ψ_j adjusts. In other words, we consider not only the direct effects of expenditure volatility on prices and quantities but also the indirect effects through a change in Ψ_j.

For simplicity and tractability, we assume that $u_j(q_{ij}) = \theta_v q_{ij}^{1/2}$ in equation (10), where $\theta_v > 0$ can be interpreted as a measure of product quality, and $\eta_v = 0$.[26] Under this configuration, the equilibrium *certainty-equivalent quantities* are given by:

$$q_{ij}(v)^{\frac{1}{2}} = \frac{\mathbb{E}(R_j)\theta_v\varphi}{2w_i\tau_{ij}}\Psi_j^{-1}\left[1+\rho_v\mathbb{V}(R_j)\Psi_j^{-2}\frac{\theta_v^2\varphi}{w_i\tau_{ij}}\right]^{-1}. \tag{22}$$

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

$$r_{ij}(\varphi) = \frac{\mathbb{E}(R_j)^2}{2}\left[\frac{w_i\tau_{ij}}{\theta_v^2\varphi}\Psi_j^2+\rho_v\mathbb{V}(R_j)\right]^{-1}. \tag{23}$$

As a result, $\Pi_v(\pi_{ij}) = 0$ when $\varphi = 0$ and $\partial\Pi_v/\partial\varphi > 0$. However, contrary to the case without uncertainty ($\mathbb{V}(R_j) = 0$), the expected payoff reaches a finite limit, given by $\frac{\mathbb{E}(R_j)^2}{4\rho_v\mathbb{V}(R_j)}$, when $\varphi = \infty$. This means that a high productivity is a necessary condition, but not a sufficient condition, for a firm to export.

Let $\xi \equiv 1/(\theta_v^2\varphi) \geq 0$ be an inverse measure of the quality-adjusted productivity cutoff $\theta_v^2\varphi$ above which a firm serves country j, and $\mu(\xi)$ the distribution of ξ. The cutoff for exporting $\widehat{\xi}_{ij}$ is such that $\Pi_v(\widehat{\xi}_{ij}) = w_i f_{ij}$ or equivalently:

$$\widehat{\xi}_{ij} \equiv \left[\frac{\mathbb{E}(R_j)^2}{4w_i f_{ij}}-\rho_v\mathbb{V}(R_j)\right]\frac{\Psi_j^{-2}}{w_i\tau_{ij}}. \tag{24}$$

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

[26] This implies that *downside* and *upside* risks are not distinguished, such that the manager has a CARA utility function instead of DARA utility function. See above for the details.

ability of exporting. However, unlike trade models with heterogeneous firms, the exporting zero-payoff cutoff condition $\widehat{\xi}_{ij}$ can be non-positive because of the existence of a positive risk premium ($\rho_v \mathbb{V}(R_j)$). No firm finds it *a priori* profitable to serve country j if the expected income $\mathbb{E}(R_j)$ is insufficient relative 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 about the distribution of productivity across firms. Helpman et al. (2008) also allow for zero bilateral trade volumes, as they assume that the most productive firms exhibit a level of productivity below the exporting threshold.

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

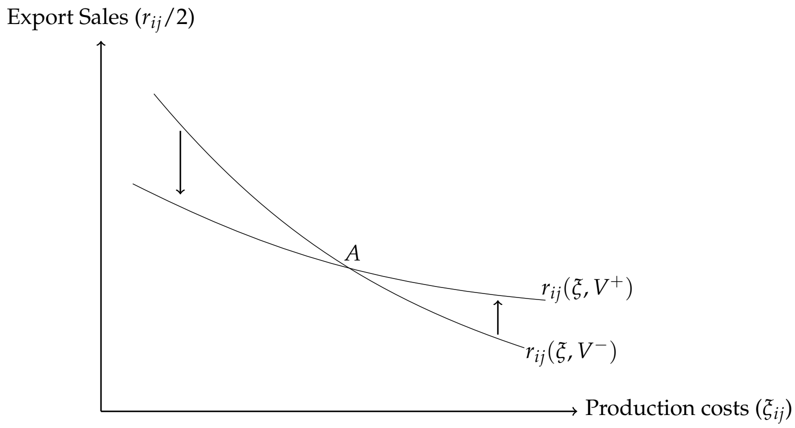
$$\epsilon_{\Psi_j} \equiv -\frac{\mathbb{V}(R_j)}{\Psi_j}\frac{\partial \Psi_j}{\partial \mathbb{V}(R_j)} > 0,$$

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

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

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 increased expenditure volatility induces the reallocation of market shares from larger to smaller firms, as $\mathrm{d}r_{ij}/\mathrm{d}\mathbb{V}(R_j)$ increases with ξ. Hence, the aggregate productivity of exporters can decrease, *ceteris paribus*, given greater uncertainty, which is consistent with empirical facts (see Bloom, 2014). In addition, as the largest firms reduce their export sales by a high proportion when demand fluctuations increase, the export sales of smaller exporters may expand at their expense (see Figure 7).

Figure 7: Productivity and reallocation of export sales when expenditure volatility increases



Note: V^- and V^+ mean low and high expenditure volatility, respectively.

The effect of expenditure volatility on the probability of exporting is also ambiguous. Standard calculations reveal the following:

$$\frac{\mathrm{d}\widehat{\xi}_{ij}}{\mathrm{d}\mathbb{V}(R_j)} = \frac{\partial\widehat{\xi}_{ij}}{\partial\mathbb{V}(R_j)} + \frac{\partial\widehat{\xi}_{ij}}{\partial\Psi_j}\frac{\partial\Psi_j}{\partial\mathbb{V}(R_j)} = \left[\frac{\mathbb{E}(R_j)^2}{4w_i f_{ij}} - \rho_v \mathbb{V}(R_j)\left(1 + \frac{1}{2\epsilon_{\Psi_j}}\right)\right]\frac{2\epsilon_{\Psi_j}\Psi_j^{-2}}{\mathbb{V}(R_j)w_i\tau_{ij}},$$

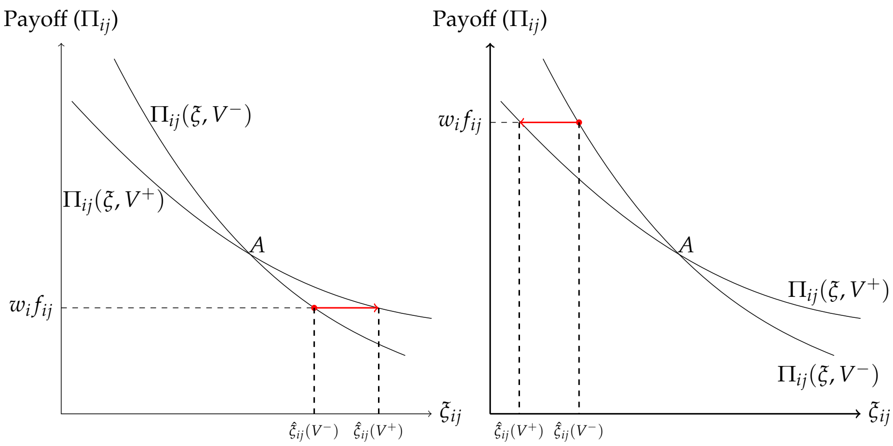
where $\partial\widehat{\xi}_{ij}/\partial\mathbb{V}(R_j) < 0$ while $\partial\widehat{\xi}_{ij}/\partial\Psi_j < 0$ and $\partial\Psi_j/\partial\mathbb{V}(R_j) < 0$ (see above). Hence, the probability of serving a country decreases with the volatility of its demand, provided that fixed trade costs or expenditure volatility are not prohibitively high. If fixed trade costs are low enough, more small and medium-sized firms export when demand/expenditure fluctuations rise, as the export sales of large firms decrease (see Figure 8).

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

$$\frac{\mathrm{d}q_{ij}(v)}{\mathrm{d}\mathbb{V}(R_j)} = \frac{q_{ij}(v)}{\mathbb{V}(R_j)}\frac{w_i\tau_{ij}\xi - \rho_v\mathbb{V}(R_j)\Psi_j^{-2}(1+\epsilon_{\Psi_j})}{w_i\tau_{ij}\xi + \rho_v\mathbb{V}(R_j)\Psi_j^{-2}} \quad \text{and} \quad \frac{\partial^2 q_{ij}}{\partial\varphi\partial\mathbb{V}(R_j)} < 0 < \frac{\partial^2 q_{ij}}{\partial\tau\partial\mathbb{V}(R_j)}.$$

Hence, the effects of $\mathbb{V}(R_j)$ on $q_{ij}(v)$ when Ψ_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

Figure 8: The impact of higher expenditure volatility on exporting cutoff



(a) Low export fixed costs $w_i f_{ij}$ (b) High export fixed costs $w_i f_{ij}$

Notes: V^- and V^+ mean low and high volatility, respectively. ξ_{ij}: production costs.

(rising productivity) less effective, in accordance with Bloom (2014).

The next proposition summarizes our results on the increase in expenditure volatility.

Proposition 4 *For a given skewness, a rise in the industry-level expenditure uncertainty of the foreign market decreases industry export sales, on average, but with heterogeneous effects across firms:*

(i) it decreases the export sales of the most productive exporters and increases the market share of the least productive incumbents;

(ii) it increases the probability of exporting and the export sales of low productivity firms when trade costs are not prohibitively high.

4 Conclusion

In firm-based theoretical and empirical studies on trade, the expenditures of foreign markets are typically assumed to be known with certainty. Firm surveys suggest, however, that expenditure uncertainty is a crucial business driver, and little is known about how firms cope with this uncertainty in foreign markets. Foreign demand uncertainty provides incentives for firms to reduce their risk exposure by adjusting not only their extensive but also their intensive margins of trade.

Using French firm-level data, we establish two key features of trade and demand uncertainty: (i) firm trade volumes are negatively associated with the volatility of foreign demand and positively with its skewness; (ii) the most productive exporters are more likely to be affected by higher volatility than are the least productive firms. Our results are robust to different sized panels and to the inclusion of a plethora of fixed effects and additional controls.

Even if the largest firms have access to better risk management strategies, they can only partially diversify against risk. In addition, according to production theory under uncertainty, the variance of firm profit is proportional to the square of expected output, meaning that the average risk premium increases with firm size. Hence, our results suggest that risk exposure would disadvantage the largest firms.

To explain our two key empirical features, we propose a trade model with industry-wide uncertainty over expenditure in which decision makers are (1) averse to both risk and downside losses and (2) make entry/exit and production/pricing decisions before uncertainty over market expenditure is resolved. In accordance with our empirical findings, we show that higher expenditure uncertainty can reduce the positive impact of higher productivity or lower trade costs on export sales. This implies that a rise in expenditure volatility induces a reallocation of market shares from the most productive (and largest) to the least productive (and smallest) incumbents. The export sales of the smallest incumbent exporters may thus grow when demand volatility increases. However, this effect is weakened with increasing skewness of the foreign expenditure distribution. These results hold for a large class of consumer utility functions, including CES utility.

Our goal has been to provide both new empirical facts and a new trade model to explain how firm-level export decisions adjust to industry-wide uncertainty. An interesting area of future research would be to estimate consumer preferences and manager risk aversion parameters using our theoretical framework and simulation-based econometric inference techniques. The objective would be to compute the risk premium for each firm implied by the estimates.

References

ACEMOGLU, D., S. JOHNSON, J. ROBINSON, AND Y. THAICHAROEN (2003): "Institutional causes, macroeconomic symptoms: volatility, crises and growth," *Journal of Monetary Economics*, 50, 49–123.

ANTRÀS, P. AND C. F. FOLEY (2015): "Poultry in Motion: A Study of International Trade Finance Practices," *Journal of Political Economy*, 123, 853–901.

ARMENTER, R. AND M. KOREN (2015): "Economies of Scale and the Size of Exporters," *Journal of the European Economic Association*, 13, 482–511.

BEKAERT, G. AND A. POPOV (2012): "On the Link between the Volatility and Skewness of Growth," Working Paper 18556, National Bureau of Economic Research.

BLOOM, N. (2014): "Fluctuations in Uncertainty," *Journal of Economic Perspectives*, 28, 153–175.

BLOOM, N., S. BOND, AND J. VAN REENEN (2007): "Uncertainty and investment dynamics," *Review of Economic Studies*, 74, 391–415.

CORREIA, S. (2014): "REGHDFE: Stata module to perform linear or instrumental-variable regression absorbing any number of high-dimensional fixed effects," Statistical Software Components, Boston College Department of Economics.

——— (2015): "Singletons, Cluster-Robust Standard Errors and Fixed Effects: A Bad Mix," Technical Note, Duke University.

DE SOUSA, J., T. MAYER, AND S. ZIGNAGO (2012): "Market access in global and regional trade," *Regional Science and Urban Economics*, 42, 1037–1052.

DI COMITE, F., J.-F. THISSE, AND H. VANDENBUSSCHE (2014): "Verti-zontal differentiation in export markets," *Journal of International Economics*, 93, 50 – 66.

DIXIT, A. K. AND J. E. STIGLITZ (1977): "Monopolistic Competition and Optimum Product Diversity," *American Economic Review*, 67, 297–308.

EATON, J., S. KORTUM, AND F. KRAMARZ (2011): "An Anatomy of International Trade: Evidence From French Firms," *Econometrica*, 79, 1453–1498.

EECKHOUDT, L., C. GOLLIER, AND H. SCHLESINGER (2005): *Economic and Financial Decisions under Risk*, Princeton University Press.

ESPOSITO, F. (2016): "Risk Diversification and International Trade," Working paper, Yale.

FAJGELBAUM, P., G. M. GROSSMAN, AND E. HELPMAN (2011): "Income Distribution, Product Quality, and International Trade," *Journal of Political Economy*, 119, 721–765.

FENG, L., Z. LI, AND D. L. SWENSON (2016): "Trade Policy Uncertainty and Exports: Evidence from China's WTO Accession," Working Paper 21985, National Bureau of Economic Research.

FOSTER, L., J. HALTIWANGER, AND C. SYVERSON (2008): "Reallocation, firm turnover, and efficiency: Selection on productivity or profitability?" *American Economic Review*, 98, 394–425.

GIOVANNI, J. D. AND A. A. LEVCHENKO (2009): "Trade openness and volatility," *Review of Economics and Statistics*, 91, 558–585.

GORBACHEV, O. (2011): "Did household consumption become more volatile?" *American Economic Review*, 101, 2248–2270.

GREENWALD, B. C. AND J. E. STIGLITZ (1993): "Financial Market Imperfections and Business Cycles," *Quarterly Journal of Economics*, 108, 77–114.

GROSSMAN, S. J. AND O. D. HART (1981): "Implicit contracts, moral hazard, and unemployment," *American Economic Review*, 71, 301–307.

HANDLEY, K. (2014): "Exporting under trade policy uncertainty: theory and evidence," *Journal of International Economics*, 94, 50–66.

HANDLEY, K. AND N. LIMAO (2013): "Policy Uncertainty, Trade and Welfare: Theory and Evidence for China and the US," Working Paper 19376, National Bureau of Economic Research.

HELPMAN, E., M. MELITZ, AND Y. RUBINSTEIN (2008): "Estimating Trade Flows: Trading Partners and Trading Volumes," *Quarterly Journal of Economics*, 123, 441–487.

HELPMAN, E. AND A. RAZIN (1978): *A theory of international trade under uncertainty*, Academic Press, Harcourt Brace Jovanovitch.

KLEMPERER, P. AND M. MEYER (1986): "Price competition vs. quantity competition: the role of uncertainty," *RAND Journal of Economics*, 17, 618–638.

KOREN, M. AND S. TENREYRO (2007): "Volatility and Development," *Quarterly Journal of Economics*, 122, 243–287.

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

LELAND, H. E. (1972): "Theory of the firm facing uncertain demand," *American Economic Review*, 62, 278–291.

LEWIS, T. L. (2014): "Exports versus Multinational Production under Nominal Uncertainty," *Journal of International Economics*, 94, 371–386.

MELITZ, M. J. (2003): "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, 71, 1695–1725.

MELITZ, M. J. AND S. POLANEC (2015): "Dynamic Olley-Pakes productivity decomposition with entry and exit," *RAND Journal of Economics*, 46, 362–375.

MENEZES, C., C. GEISS, AND J. TRESSLER (1980): "Increasing Downside Risk," *American Economic Review*, 70, 921–932.

NGUYEN, D. X. (2012): "Demand uncertainty: Exporting delays and exporting failures," *Journal of International Economics*, 86, 336–344.

NOVY, D. AND A. M. TAYLOR (2014): "Trade and Uncertainty," Working Paper 19941, National Bureau of Economic Research.

PANOUSI, V. AND D. PAPANIKOLAOU (2012): "Investment, idiosyncratic risk, and ownership," *Journal of Finance*, 67, 1113–1148.

RAMONDO, N., V. RAPPOPORT, AND K. J. RUHL (2013): "The Proximity-Concentration Tradeoff under Uncertainty," *Review of Economic Studies*, 80, 1582–1621.

TURNOVSKY, S. J. (1974): "Technological and price uncertainty in a Ricardian model of international trade," *Review of Economic Studies*, 41, 201–217.

WEI, S.-J. (1999): "Currency hedging and goods trade," *European Economic Review*, 43, 1371–1394.

WEITZMAN, M. L. (1974): "Prices vs. quantities," *Review of Economic Studies*, 41, 477–491.

WORLD BANK (2013): *World Bank Development Report 2014: Risk and Opportunity.*

ZHELOBODKO, E., S. KOKOVIN, M. PARENTI, AND J.-F. THISSE (2012): "Monopolistic competition: Beyond the constant elasticity of substitution," *Econometrica*, 80, 2765–2784.

Appendices

A Data Appendix

Industry classification: The International Standard Industrial Classification (ISIC) rev. 3 of manufacturing activities is the United Nations' system for classifying economic data into 22 2-digit, 59 3-digit and 125 4-digit industries, as depicted in Table 5. We use this classification to distinguish between 3-digit K industries and 4-digit k sub-industries.

Table 5: Industry classification of manufacturing (ISIC classification)

2-digit	Industries	3-digit	4-digit
15	Food products and beverages	151	1511-4
		152	1520
		153	1531-3
		154	1541-4; 1549
		155	1551-4
16	Tobacco products	160	1600
17	Textiles	171	1711-2
		172	1721-3; 1729
		173	1730
18	Wearing apparel; dressing and dyeing of fur	181	1810
		182	1820
19	Tanning and dressing of leather	191	1911-12
		192	1920
20	Wood and of products of wood and cork, except furniture	201	2010
		202	2021-3; 2029
21	Paper and paper products	210	2101-2; 2109
22	Publishing, printing and reproduction of recorded media	221	2211-3; 2219
		222	2221-2
		223	2230
23	Coke, refined petroleum products and nuclear fuel	231	2310
		232	2320
		233	2330
24	Chemicals and chemical products	241	2411-3
		242	2421-4; 2429
		243	2430
25	Rubber and plastics products	251	2511; 2519
		252	2520
26	Other non-metallic mineral products	261	2610
		269	2691-6; 2699
27	Basic metals	271	2710
		272	2720
		273	2731-2
28	Fabricated metal products, except machinery and equipment	281	2811-3
		289	2891-3; 2899
29	Machinery and equipment n.e.c.	291	2911-5; 2919
		292	2921-7; 2929
		293	2930
30	Office, accounting and computing machinery	300	3000
31	Electrical machinery and apparatus n.e.c.	311	3110
		312	3120
		313	3130
		314	3140
		315	3150
		319	3190
32	Radio, television and communication equipment	321	3210
		322	3220
		323	3230
33	Medical, precision and optical instruments	331	3311-3
		332	3320
		333	3330
34	Motor vehicles, trailers and semi-trailers	341	3410
		342	3420
		343	3430
35	Other transport equipment	351	3511-2
		352	3520
		353	3530
		359	3591-2; 3599
36	Furniture; manufacturing n.e.c.	361	3610
		369	3691-4; 3699

B Intensive Margin: Export Unit Values

Table 6: Intensive margin: export unit values

Dependent variable:	Firm export prices: $\ln p^k_{fjt}$		
	(1)	(2)	(3)
Ln Expenditure Volatility$^K_{jt}$	0.004	0.002	0.016^b
	(0.003)	(0.007)	(0.006)
Expenditure Skewness$^K_{jt}$	-0.001	-0.004	-0.006^a
	(0.001)	(0.002)	(0.002)
Ln Mean 5-year Expenditure$^K_{jt}$	-0.005	-0.001	-0.022
	(0.005)	(0.011)	(0.015)
Ln Productivity$_{ft}$	-	-	0.026^a
	-	-	(0.002)
Observations	3,904,513	3,129,051	3,875,422
R^2	0.838	0.737	0.875
Sets of Fixed Effects:			
Firm.(4-digit-)Industry.Time$_{fkt}$	Yes	-	-
Destination$_j$	Yes	-	-
Firm.Destination.Time$_{fjt}$	-	Yes	-
4-digit-Industry$_k$	-	Yes	-
Firm.destination.(4-digit-)Industry$_{fjk}$	-	-	Yes
Time$_t$	-	-	Yes

Notes: dependent variable is firm-level export unit values in logs aggregated at the 4-digit k level. Number of years: 10; Number of destinations: 90; Number of 4-digit industries: 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-4-digit industry level, with ^{a}, ^{b} denoting significance at the 1% and 5% level respectively.

C Price Setting

We show in this Appendix that we obtain similar predictions when the firm sets price instead of quantity before demand is known. For simplicity, we consider that $u_j(q_{ij}) = \theta_v q_{ij}^{1/2}$ in equation (10). Therefore, 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:

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

implying that the demand for a variety can be rewritten as follows:

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

with

$$P_j \equiv \left[\int_{\Omega_j} \theta_v^2 p_{ij}(v)^{-1} \mathrm{d}v \right]^{-1}.$$

Hence, the export profit is:

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

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:

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

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 equals 2 times the marginal cost c_{ij}, while the variance is minimized when the price equals the marginal cost.

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

$$\Phi(p_{ij}) \equiv -\left(p_{ij} - 2c_{ij}\right)\mathbb{E}(R_j) + \rho_v \left(p_{ij}^2 - 2c_{ij}^2\right) 2p_{ij}^{-2} P_j \theta_v^2 \mathbb{V}(R_j), \tag{25}$$

while the second-order condition implies

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

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

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

Without uncertainty, the equilibrium price would be $p_{ij} = 2c_{ij}$, which is identical to the price prevailing when firms strategically determine the quantity. However, under uncertainty, $p_{ij} = 2c_{ij}$ is not an equilibrium as long as $\rho_v > 0$. Introducing $p_{ij} = 2c_{ij}$ into (25) implies $\Phi(p_{ij}) > 0$, so the equilibrium price under uncertainty is higher than $2c_{ij}$. Using the envelope theorem:

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

As result, higher volatility induces higher prices and, in turn, lower production. Even if the prices and quantities differ according to the behavioral mode, we obtain similar conclusions.

D Industry Supply and Income Volatility

In this Appendix, we show that $\partial \Psi_j / \partial \mathbb{V}(R_j) < 0$. According to (13) and (22), we have $\Lambda[\Psi_j, \mathbb{V}(R_j)] = 0$, with:

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

where $\partial \Lambda_j / \partial \mathbb{V}(R_j) > 0$ because both $\theta_v q_{ij}^{1/2}$ and $\widehat{\xi}_{ij}$ decrease with $\mathbb{V}(R_j)$. The envelope theorem implies:

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

as $\partial\Lambda/\partial\mathbb{V}(R_j) > 0$. Standard calculations show:

$$\frac{\partial\Lambda}{\partial\Psi_j} = \begin{array}{c} 1 - \Psi_j^{-1}\sum_\ell M_\ell \int_0^{\widehat{\xi}_{\ell j}} \theta_v \left[q_{\ell j}(\xi)\right]^{\frac{1}{2}} \frac{\rho_v \mathbb{V}(R_j)\Psi_j^{-2} - w_\ell \tau_{\ell j}\xi}{\rho_v \mathbb{V}(R_j)\Psi_j^{-2} + w_\ell \tau_{\ell j}\xi} \mu(\xi)\mathrm{d}\xi \\ -\frac{\partial\widehat{\xi}_{\ell j}}{\partial\Psi_j}\theta_v \left[q_{\ell j}(\widehat{\xi}_{\ell j})\right]^{\frac{1}{2}}, \end{array} \tag{26}$$

where $\partial\Lambda/\partial\Psi_j > 0$ as the second term on the right-hand side of (26) is less than 1, and $\partial\widehat{\xi}_{\ell j}/\partial\Psi_j < 0$. As a result:

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