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Export Decision under Risk

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Export Decision under Risk

Abstract

Using firm and industry data, we unveil two empirical regularities: (i) Demand uncertainty not only reduces export probabilities but also decreases export quantities and increases export prices; (ii) The most productive exporters are more affected by higher industry-wide expenditure volatility than are the least productive exporters. We rationalize these regularities by developing a new firm-based 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 costs weaken this effect. Our results hold for a large class of consumer utility functions.

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

JEL Classification: D21, D22, F12, F14

Décision d'exportation en environnement risqué

Résumé

En utilisant les données d'entreprise et d'industrie, nous mettons e évidence deux régularités empiriques : (i) L'incertitude de la demande étrangère réduit les ventes à l'exportation, la probabilité d'exporter, et l'efficacité des politiques commerciales; (ii) Les grandes entreprises sont les exportateurs les plus affectés par l'incertitude. Nous rationalisons ces régularités à l'aide d'un nouveau modèle de commerce international dans lequel les entreprises agissent dans un environnement incertain. On montre qu'une plus grande incertitude induit une réallocation des parts de marché des entreprises productives vers les moins productives. Cependant, des barrières aux échanges élevés réduit ce phénomène de réallocation. Nos résultats tiennent pour une large classe de fonctions d'utilité.

Mots-clés: exportations de firmes, incertitude de la demande, aversion au risque aversion, politique commerciale

Classification JEL: D21, D22, F12, F14

Export Decision under Risk

1. Introduction

We study the impact of demand uncertainty on firm export decisions.[1] Most trade theory assumes that demand in foreign markets is known with certainty. Accordingly, firms know their exact demand functions, and only market size plays a key role in export performance. However, recent surveys of leading companies note that market/demand uncertainty is their top business driver.[2] This view is consistent with empirical evidence of the impact of demand uncertainty on a wide variety of economic outcomes, such as investment, production, and pricing decisions (see Bloom, 2014).

Despite a growing and recent literature on the impact of uncertainty on trade, little is known about how firms respond to demand uncertainty in foreign markets. In this paper, we study the impact of demand uncertainty in foreign markets on firms' export quantities and prices (intensive margin) and export entry/exit decisions (extensive margin).

Our theory is motivated by reduced-form evidence of the effect of foreign expenditure uncertainty on French manufacturing exports. 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 absorption:[3] the expected value, the variance (or volatility), and the skewness.

We unveil two empirical regularities regarding the role of industry-wide expenditure uncertainty in the intensive and extensive margins of firm exports. First, firm export decisions in a destination market are significantly affected by the central moments of the expenditure distribution of that destination. The expected values of expenditure (the first moment) and skewness (the third moment) positively affect both the probability of entry and the export quantities while reducing the prices and the probability of exit. By contrast, the volatility – or variance – of expenditure (the second moment) produces the opposite effects, reducing both the probability of entry and the export quantities while increasing prices and the probability of exit.

Second, the responses of exporting firms to industry-wide expenditure uncertainty are heterogeneous. As firms differ in size and productivity, they might be differently affected by uncertainty. Our estimations reveal that an increase in expenditure volatility reduces the differ-

[1] 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.

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

[3] Absorption or apparent consumption is calculated as total production plus imports minus exports.

ence in export sales between high- and low-productivity firms. More precisely, for a given industry-destination-year triplet, the decrease in export sales due to volatility is greater for high-productivity firms than for low-productivity ones. We also highlight that, for a given industry-year pair, the more productive firms favor destination countries with low volatility and high skewness.

Interestingly, this first empirical regularity shows that uncertainty affects not only the export entry/exit decisions but also the quantities exported and prices. Explaining the effects of uncertainty on both the intensive and the extensive margins of trade is theoretically challenging. Real option effects may explain the extensive margin result. Given the sunk costs of accessing foreign markets, uncertainty makes firms more cautious about serving a new market and delays the entry of exporters into new markets. However, having entered, reducing or increasing quantities and prices does not lead to the loss of an option value (from waiting to enter). The intensive margin is an easily reversible action. By assuming risk-averse managers, we develop a new theory allowing us to rationalize these empirical regularities.

The model features three key ingredients: (i) managers are averse to both risk and downside losses, (ii) firms face the same industry-wide uncertainty over expenditures, and (iii) managers make decisions about entry/exit *and* production/prices before expenditure uncertainty 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 choose strategic variables (price or quantity) before the output reaches the market. Therefore, foreign expenditures or market prices can change between the time quantities are set and the time of delivery due to random shocks, such as changes in consumer preferences, income, climatic conditions, opinion leaders' attitudes, or competing products' popularity.

One question is why are firm managers risk averse? Managers and shareholders of exporting firms might be risk averse because if uncertainty is common to all firms, risk is non-diversifiable (Grossman and Hart, 1981). However, there are various reasons why 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 firms they manage (Bloom, 2014). Thus, in making all of their economic decisions, managers take into account their risk exposure (Panousi and Papanikolaou (2012)).

To capture managers' willingness to pay a risk premium to avoid uncertainty, we draw on expected utility theory and conduct a mean-variance-skewness analysis. 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) raises the risk premium and decreases output when the decision maker is risk averse (Klemperer and Meyer, 1986). Nevertheless, the variance does not distinguish between upside and downside risk, while managers can be more sensitive to downside losses than to upside gains (Menezes *et al.*, 1980). Skewness can provide information about the asymmetry of the expenditure distribution and, thus, about downside risk exposure. For a given mean and variance, countries with more right-skewed expenditure distributions provide better downside protection or less downside risk.

Our model leads to theoretical predictions that rationalize our reduced-form estimations. As expected, the probability of exporting decreases with expenditure volatility but increases with its mean and skewness. 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 volatility, we show that they do react differently to an increase in volatility. In this case, risk aversion and differences in productivity lead to the reallocation of market shares. An increase in expenditure volatility may impede the entry of some producers into the international market and force others to cease exporting, which in turn, may increase the market shares of incumbent exporting firms. Additionally, changes in volatility modify the relative prices of the varieties supplied, leading to the reallocation of market shares across incumbent exporters.

Hence, the effects of industry-specific volatility uncertainty on the export performance of individual firm are not *a priori* clear. A key result is that an increase in volatility induces the reallocation of market shares from the most to the least productive exporters. The reason is that greater expenditure volatility makes the most productive exporters the most exposed. As high-productivity firms produce larger quantities, their profits are more sensitive to an increase in expenditure variation. Consequently, they reduce their certainty-equivalent quantities relatively more than low-productivity exporters. The market shares of the least productive exporters may thus grow.[4] However, the reallocation effect is weakened when trade barriers increase or/and the expenditure distribution becomes more right-skewed.

It is worth stressing that our model matches traditional facts concerning the role of trade costs and firm heterogeneity in the trade literature. The main results hold for a large class of consumer utility functions, and 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 constant elasticity of substitution

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

(CES) preferences).

Related Literature

This paper complements a recent body of the literature on the *heterogeneous* effects of macroeconomic uncertainty on individual firms. First, Bloom *et al.* (2007) highlight a "cautionary effect" such that greater uncertainty reduces the responsiveness of firms' R&D and investments to changes in productivity. The investment behavior of large firms is consistent with a partial irreversibility model in which uncertainty dampens the short-run adjustment of investment to demand shocks. In a different setting, we also capture a cautionary effect or "risk-averseness effect" of expenditure uncertainty on export behavior such that greater uncertainty reduces the responsiveness of firms' exports to changes in productivity. This effect leads to the reallocation of market shares from the most to the least productive exporters. In this way, we provide a new explanation for declines in aggregate productivity growth following uncertainty shocks. As the reallocation of resources across heterogeneous firms is a key factor in explaining aggregate productivity growth (Foster *et al.*, 2008; Melitz and Polanec, 2015), higher expenditure uncertainty can slow productivity growth.

Second, Fillat and Garetto (2015) document that exporters and multinationals, which are typically large firms, face higher risk exposure that makes their profits more sensitive to the state of the global economy. The reason is that entering a foreign market is a source of risk exposure when aggregate demand is subject to fluctuation and entry involves a sunk cost. Following a negative shock, risk-averse large firms are reluctant to exit the foreign market because they would forgo the sunk cost they paid to enter. This higher risk exposure commands a higher return in equilibrium for exporters and multinationals compared to domestic firms. We adopt a different perspective by focusing on the role of uncertainty in extensive and intensive export decisions. We argue that firms face aggregate expenditure uncertainty when the strategic variables are chosen. The larger the firms, the more they produce and the more exposed they are to *ex post* price variation because of expenditure variation.

Our paper is also related to the literature on risk and trade. Expected utility theory was used to analyze international trade under risk by Turnovsky (1974) and Helpman and Razin (1978) but with perfect competition. More recently, the trade literature has witnessed renewed interest in studying uncertainty with imperfect competition (e.g., Nguyen, 2012; Ramondo *et al.*, 2013; Handley, 2014; Lewis, 2014; Novy and Taylor, 2014; Feng *et al.*, 2016; Héricourt and Nedoncelle, 2017; Handley and Limao, ming). Following a line of reasoning similar to ours, Esposito (2016) and Gervais (2016) also assume risk averse managers. Gervais (2016) develops a model of international trade in homogeneous intermediate inputs with uncertainty in the delivery of inputs, while Esposito (2016) focuses on demand complementarities across markets under uncertainty. By contrast, our paper 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 patterns of trade at the extensive and intensive margins.

The remainder of the 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 a multi-country model of trade with heterogeneous firms under imperfect competition in Section 3. Section 4 concludes.

2. Reduced-form Evidence on Trade and Uncertainty

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

2.1. Data

We combine two types of data. 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 quantity (in tons) and value (in thousands of euros) of exports for each destination-product-year triplet. To match these data with other sources, we aggregate them at the industry level (4-digit ISIC code)[5]. We thus obtain the exports of each firm for each destination-industry-year triplet. Prices, proxied by unit values, are computed as the ratio of export values to export quantities. 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 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.[6]

In addition to firm-level data, we use annual destination country–industry (4-digit ISIC 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

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

[6] The turnover is also high for firms that do not exhibit any extensive margin change in a destination-industry during the whole study period. This sub-sample includes 9,326 different "continuing" firms present in 51 destinations and 110 industries. On average, these firms export to 1.50 industries per destination-year and to 3.19 destinations per industry-year.

2009. Such destination-industry-year data allow us to define a consumption expenditure variable R, which is also known as apparent consumption or absorption, computed 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 industry k, and year t. The intention here is to capture industry consumption expenditure that is used in a destination for any purpose.[7]

2.2. Identification

Our objective is to study the impact of uncertainty on export performance. If firms produce under demand or expenditure uncertainty, they make their choices 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 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 expenditure affect 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 UK beverages (K=155). However, some 3-digit industries are composed of only one 4-digit sub-industry (see Table 6 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 the 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.

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

Different empirical measures of the expected value $\mathbb{E}(R_{jt}^K)$, variance $\mathbb{V}(R_{jt}^K)$, and skewness $\mathbb{S}(R_{jt}^K)$ are suggested in the literature. We could, for instance, consider that exporters use all information to form expectations about consumers' expenditures. However, to keep matters simple, we assume that agents use a subset of information to make decisions (because information acquisition is costly). Thus, the expected value $\mathbb{E}(R_{jt}^K)$ 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 no unique definition of demand or expenditure 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 $\mathbb{V}(R_{jt}^K)$ in industry K and year t is computed in two steps. First, we compute yearly growth rates of R (equation 1) over 6-year rolling periods at each 4-digit sub-industry k of industry K. Then, volatility is simply the standard deviation of these yearly growth rates.[8] 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).[9] First, for each sub-industry k, we compute the yearly growth rates of apparent consumption from 1995 to 2000. Then, we calculate $\mathbb{V}(R_{\text{UK},2000}^{155})$ as the standard deviation of all computed growth rates for the 4 sub-industries. Note that we exploit fluctuations in uncertainty over time by computing a time-variant volatility measure.[10]

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 $\mathbb{S}(R_{jt}^K)$ 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 $\mathbb{S}(R_{jt}^K)$ is positive (negative), the expenditure distribution is right skewed (left skewed).

2.3. Descriptive Statistics

We first present some descriptive statistics on the expenditure moments and their variations across (i) destination markets and (ii) industries, and over (iii) time. Specifically, we show that these moments match some facts advanced in the literature on uncertainty. Then, we provide

[8] As a robustness check, we also use 5-year and 7-year rolling periods.

[9] 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.

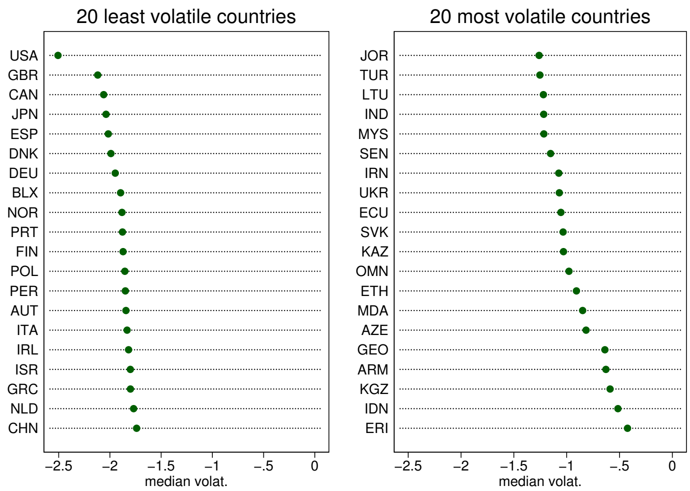
[10] Another possibility is to compute time-invariant moments to capture cross-country and industry-specific differences in uncertainty, which are absorbed by our fixed effects. Ramondo *et al.* (2013), for instance, compute the volatility of a country's GDP over a 35-year period and study the effects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

some practical examples comparing French exports to those of Canada and Mexico to illustrate the usefulness of our approach.

Variation across Markets, Industries, and Years

In Figure 1, we depict the median of expenditure volatility (in logs) across destination markets for the 20 least and most volatile countries over the 2000-2009 period.[11] 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 World Bank (2013) and Bloom (2014).

Figure 1: Least and most volatile countries



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

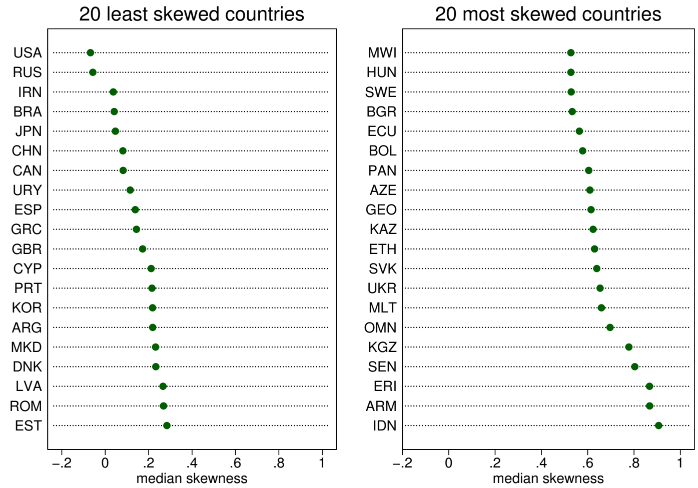
Similarly, Figure 2 reports the median skewness over the 2000-2009 period for the 20 least and most skewed countries. Developed countries tend to be less skewed than developing countries, as reported in Bekaert and Popov (2012). The difference between developed and developing countries in terms of skewness seems, however, less pronounced than the difference in volatility.[12] 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 and beverages category is among the most volatile industries, while its skewness is rather low. By contrast, the medical and op-

[11]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.

[12]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.

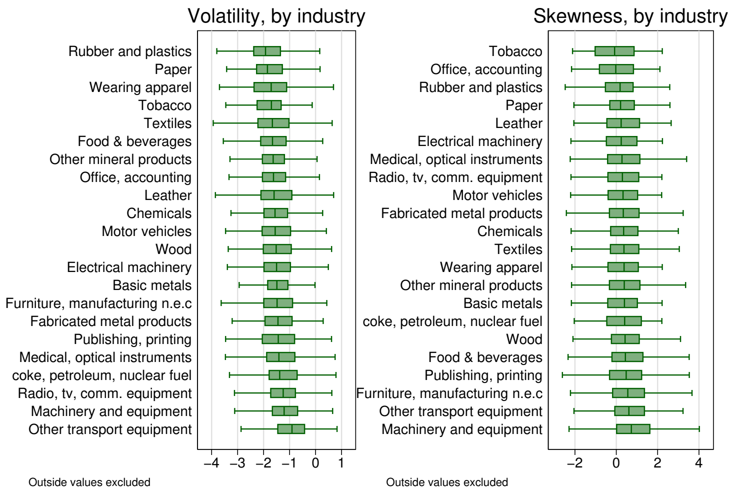
Figure 2: Least and most skewed countries



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

tical 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



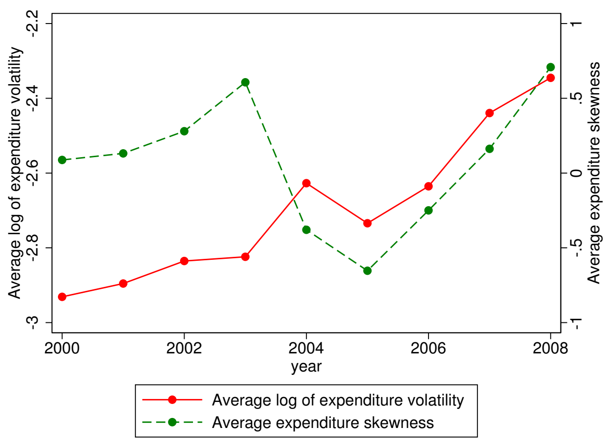
Note: This figure reports the distribution of expenditure volatility (in logs) and skewness across 2-digit industries over the period 2000-2009.

A simple analysis of the variance of our volatility measure suggests that 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 expenditures 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).[13] We also observe variation in the skewness distribution,

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

which is used for identification (dotted line).

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



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 industries and are both seemingly distant markets in the American continent for French exporters. Let us pick three 3-digit industries for which total expenditures in 2005 are comparable in each country but risk exposure differs.

The first industry is chemical products (ISIC rev. 3 code 242). 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 quantities to Mexico and to Canada is relatively low (12 and 15 million tons, respectively). This limited wedge could be explained by the same perceived risk exposure of French exporters in both countries.

By contrast, in the second industry (grain mill products and feeds; ISIC 153), expenditures in Canada and Mexico are similar (approximately 2 billion US dollars), but the volatility in Mexico is twice as high as that in Canada. Interestingly, the quantity 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 Canada and Mexico, as the risk exposure of serving Mexico is higher.

Finally, managers can also be more sensitive to downside losses than to upside gains. For a given mean and variance, managers might prefer to serve a country exhibiting a high probability of an extreme event associated with a high or low level of demand. For instance, in the 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 quantity of French exports to Mexico is higher than that to Canada (124 vs. 96 million tons, respectively). As Mexico exhibits a 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

We provide industry- and firm-level evidence of a significant effect of foreign expenditure volatility and skewness on exports.

2.4.1. Industry-level Evidence

This section presents our industry-level estimations on the intensive margin (export quantities by industry-destination-year) and extensive margin (number of firms per industry-destination-year) of trade.

Intensive Margin of Trade
We first estimate the following equation at the industry level:

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

where q_{jt}^{k} is the French export quantity to destination j aggregated at the 4-digit manufacturing level k (ISIC classification) in year t. The sample covers the period from 2000 to 2009. Trade is related to the first three moments of the expenditure distribution of the destination and defined at the 3-digit level K: expected value $\mathbb{E}(R_{jt}^{K})$, volatility $\mathbb{V}(R_{jt}^{K})$, and skewness $\mathbb{S}(R_{jt}^{K})$.[14] $\mathbf{FE}$ is a vector of different combinations of fixed effects, and ε_{jt}^{k} represents the error term. The standard errors are clustered at the destination-4-digit-industry level. We first consider industry (α_k) and destination-time (α_{jt}) fixed effects, which control for unobserved heterogeneity in industries and destination-year markets. These sets of fixed effects are selected according to a simple variance analysis suggesting that most of the variation in the volatility measure arises across countries and industries. The results are reported in the first column of Table 1.

Export quantities 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

[14] 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. This explains why we use the logarithmic form only for the first two central moments.

Table 1: Intensive and extensive margins: Industry export quantities and number of firms

Dependent variable:	Industry export quantities: $\ln q_{jt}^{k}$			Nb. of firms: $\ln nb_{jt}^{k}$
	(1)	(2)	(3)	(4)
Ln Mean Expenditure$_{jt}^{K}$	0.293^{a}	0.293^{a}	0.293^{a}	0.118^{a}
	(0.032)	(0.032)	(0.032)	(0.012)
Ln Expenditure Volatility$_{jt}^{K}$	-0.117^{a}	-0.078^{b}	-0.078^{b}	-0.084^{a}
	(0.028)	(0.031)	(0.035)	(0.011)
Ln Expenditure Volatility$_{jt}^{K}$ $\times$ Ln Distance$_{j}$		0.081^{a}		
		(0.022)		
Ln Expenditure Volatility$_{jt}^{K}$ $\times$ FTA$_{j}$			-0.101^{b}	
			(0.044)	
Expenditure Skewness$_{jt}^{K}$	0.039^{a}	0.040^{a}	0.040^{a}	0.019^{a}
	(0.011)	(0.011)	(0.011)	(0.004)
Observations	47,858	47,858	47,858	47,858
R^2	0.774	0.774	0.774	0.891
Sets of Fixed Effects:				
Destination.Time$_{jt}$	Yes	Yes	Yes	Yes
(4-digit-)Industry$_{k}$	Yes	Yes	Yes	Yes

Notes: dependent variable is aggregated export quantities in logs (columns 1-3) and the number in logs of firms per (4-digit-)industry-destination-year triplet (column 4). 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. Distance is the geographical distance between France and the destination country. FTA includes all trade agreements in force between France and its trade partners. 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.

example, given that the export elasticity to expenditure volatility is 0.117, French exports to Canada in the grain mill industry would decrease by 11.7% if, *ceteris paribus*, its expenditure were as volatile as that of Mexico.[15]

Columns 2 and 3 of Table 1 investigate whether the negative effect of expenditure volatility on export quantities varies with trade barriers and trade policy in general. We know from Bloom *et al.* (2007) that the responsiveness of investment to policy stimulus may be weaker in periods of high uncertainty. We wonder whether the positive effects of trade policy on exports are weaker when expenditure uncertainty increases. The basic intuition is that the marginal negative impact of volatility is magnified when market potential is higher. Thus, destination markets for which trade costs are low receive relatively more exports, which, in turn, implies a higher variance of profits. We use the geographical distance between France and the destination country, as well as the free trade agreements (FTA) in force between France and its trade partners, to proxy for trade costs. In the regressions, we interact the volatility variable with distance (column 2) and with the FTA dummy variable indicating whether at least one FTA with destination j has been in force since 2000, the beginning of our sample period (column 3).[16]

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

[16] The distance to the destination country is obtained from CEPII and computed as the distance between the major cities of each country weighted by the share of the population living in each city. The data on FTA membership

Note that the separate effects of distance and FTA on French exports are captured by the destination-by-time fixed effects, which also absorb other time-variant and -invariant destination covariates, such as a common language and contiguity. The estimated coefficient associated with the interaction term between volatility and distance is positive and significant at the one percent level. It also appears that FTAs significantly magnify the negative effect of expenditure volatility. In other words, higher expenditure uncertainty tends to shrink the positive impact of trade policy (lower trade barriers) on exports.

Extensive Margin of Trade

We now investigate the extensive margin of trade at the industry level and run the following estimation:

$$\ln\,(\text{nb firms})^k_{jt} = \beta_1 \ln \mathbb{E}(R^K_{jt}) + \beta_2 \ln \mathbb{V}(R^K_{jt}) + \beta_3 \mathbb{S}(R^K_{jt}) + \ \mathbf{FE} + \varepsilon^k_{jt}, \tag{3}$$

where $(\text{nb firms})^k_{jt}$ denotes the number (in logs) of French exporting firms in a destination-(4-digit-)industry-year triplet. The number of French exporters is regressed on the first three moments of the expenditure distribution of the destination at the 3-digit level K, $\mathbb{E}(R^K_{jt})$, $\mathbb{V}(R^K_{jt})$, and $\mathbb{S}(R^K_{jt})$. As previously, ε^k_{jt} represents the error term, and the standard errors are clustered at the destination-(4-digit-)industry level. The results reported in column 4 of Table 1 control for unobserved heterogeneity in industries and destination-year markets by including industry (α_k) and destination-time (α_{jt}) fixed effects. The number of French exporters in a destination-industry-year triplet is positively influenced by the expected demand and the skewness and negatively influenced by the volatility.

Heterogeneous Impact of Volatility on Exports

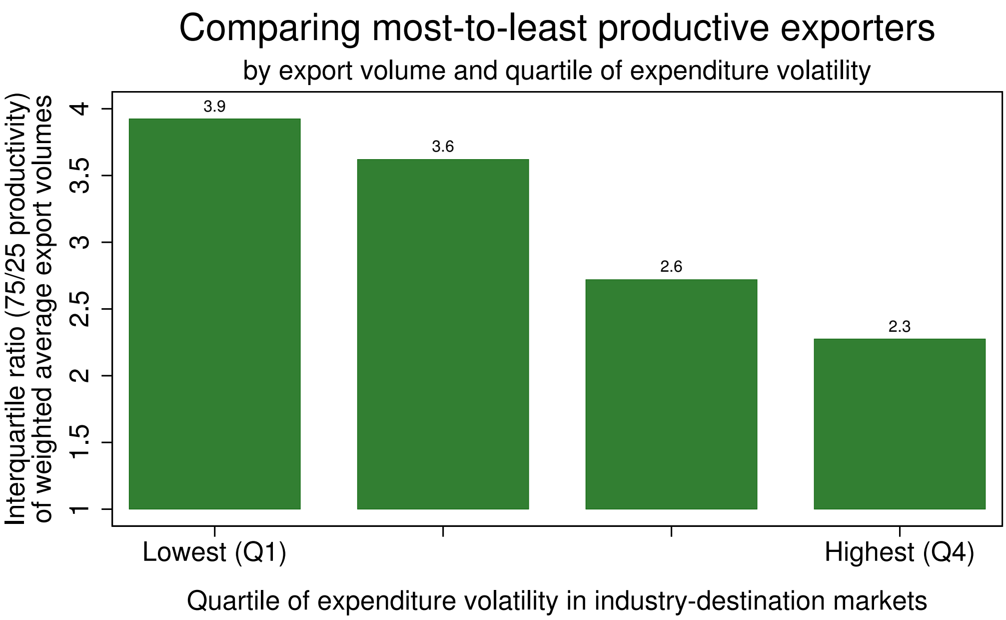
We supplement the analysis by presenting reduced-form graphical evidence of the heterogeneous impact of volatility on exports. However, instead of using trade costs, we exploit differences in productivity across firms. The intuition is similar to that presented above: the more productive the firm, the greater the export quantities and, therefore, the higher the risk at the margin. Figure 5 compares the most to the least productive exporters in terms of industry export quantities 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 of the 25% most productive firms to the 25% least productive firms in terms of the weighted average export quantities for each quartile of expenditure volatility. The weighted average export quantities are computed at the 4-digit industry-destination-year level. The weights are the mean expenditures of the industry-destination-year triplets $\mathbb{E}(R^K_{jt})$,

come from De Sousa (2012) (see http://jdesousa.univ.free.fr/data.htm). The countries with at least one FTA with France in force since 2000 are Eastern European countries, EU15 countries, Israel, Morocco, Norway, South Africa, Switzerland, Tunisia, and Turkey.

as defined in section 2.2. They are designed to account for possible self-selection of firms into destinations with different levels of expenditure. The figure depicts an interesting and striking result: expenditure volatility reduces the export difference between the least and the most productive 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 quantities 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, respectively. Then, in Section 2.5, we discuss the economic meaningfulness of the estimates of volatility and skewness.

Intensive Margin of Trade

We estimate two intensive margins of trade: first on quantities and then on unit values.

Quantities. We estimate the following specification of firm-level export quantities at the destination-year-(4-digit-)industry triplet:

$$\ln q^k_{fjt} = \delta_1 \ln \mathbb{E}(R^K_{jt}) + \delta_2 \ln \mathbb{V}(R^K_{jt}) + \delta_3 \mathbb{S}(R^K_{jt}) + \mathbf{FE} + \varepsilon^k_{fjt}, \quad (4)$$

where q^k_{fjt} is now the export quantity of French firm f to destination j at the 4-digit manufacturing level k in year t. 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 the expenditure distribution, and ε^k_{fjt} represents the usual error term. Compared with the industry-level estimations, firm-level data offer considerably more observations and mitigate concerns about the inefficiency of the panel estimator when introducing various combinations of fixed effects. Consequently, we use fairly demanding specifications with a vector $\mathbf{FE}$ of different combinations of fixed effects. The standard errors are clustered at the destination-4-digit-industry level.[17]

The results are reported in Table 2 according to the main source of variation in expenditure: across destination markets (column 1), industries (column 2), and years (column 3). Before discussing the differences across 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 quantities. This confirms the industry evidence presented above. Moreover, as expected, average expenditures, skewness, and firm productivity are positively correlated with the export quantities.

In the first column, we introduce firm-by-industry-by-year fixed effects (α_{fkt}), which capture all time-varying firm-specific determinants, such as productivity and debt, as well as any firm-industry heterogeneity. The 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 add a separate destination-country fixed effect (α_j) to control for destination-specific factors. In this way, we investigate whether multi-destination firms favor countries with low volatility and high skewness. That is, this estimation neutralizes the ability of firms to manage their risk exposure by adjusting their (4-digit) product lines.

In this fixed effects setting, we find a negative effect of expenditure volatility and a positive effect of expenditure skewness on firm-level exports. Hence, multi-destination firms manage their risk exposure by favoring countries with low expenditure variance and high skewness.[18] In other words, firms avoid a high-risk market j by diverting exports to other markets with lower risk.

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 interest are now identified in

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

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

Table 2: Intensive margin: Firm export quantities

Dependent variable:	Firm export quantities: $\ln q^k_{fjt}$ (1)	(2)	(3)
Ln Mean Expenditure$^K_{jt}$	0.068^a	0.079^a	0.200^a
	(0.018)	(0.022)	(0.030)
Ln Expenditure Volatility$^K_{jt}$	-0.028^a	-0.040^a	-0.024^a
	(0.009)	(0.012)	(0.008)
Expenditure Skewness$^K_{jt}$	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	3,875,422
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 quantities 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.

the industry dimension. In other words, the estimation relies on firm-destination-year triplets with multiple 4-digit industries. We add a separate 4-digit industry fixed effect (α_j) to control for industry-specific factors. Hence, we estimate whether firms favor the exports of industries with low volatility and high skewness for a given firm-destination-year triplet. In this setting, by controlling for firm-by-destination-by-year fixed effects, we eliminate the possibility that firms diversify 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 affected because it is intuitively more difficult to diversify across industries 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 triplet, an increase in volatility over time reduces the firm's export quantities, while an increase in skewness increases exports.

Table 7 of Appendix B tests the robustness of our results by considering alternative time spans for the construction of the expenditure moments. Instead of using a 6-year time window, volatility and skewness are calculated over 5-year and 7-year rolling periods, respectively. The results for firm-export quantities are robust to these alternatives, and the previous conclusions remain unchanged.

Prices. We now check whether the three moments of the expenditure distribution influence prices. We estimate the following specification for firm-level export prices for destination-year-(4-digit-)industry triplets:

$$\ln p^k_{fjt} = \delta_1 \ln \mathbb{E}(R^K_{jt}) + \delta_2 \ln \mathbb{V}(R^K_{jt}) + \delta_3 \mathbb{S}(R^K_{jt}) + \text{quality}^k_{fjt} + \textbf{FE} + \varepsilon^k_{fjt}, \tag{5}$$

where p^k_{fjt} is now the export price of French firm f to destination j at the 4-digit manufacturing level k in year t. $\mathbb{E}(R^K_{jt})$, $\mathbb{V}(R^K_{jt})$, and $\mathbb{S}(R^K_{jt})$ are the first three central moments of the expenditure distribution, and ε^k_{fjt} is the usual error term. Prices p^k_{fjt} are proxied by unit values and defined as the ratio of export value to export quantity. Unit values are known to include a quality component in addition to productivity. More productive firms have lower marginal costs but may export at higher prices due to quality. Omitting the quality component may reverse the empirical conclusions. We account for potential contamination of prices by quality by using the strategy of Khandelwal *et al.* (2013). For a given price in an industry(4-digit)-destination-year triplet, a variety with a higher quantity is assigned a higher quality. Quality$^k_{fjt}$ is thus estimated for each firm-industry-destination-year observation as the residual of the following OLS regression:

$$\ln q^k_{fjt} + \ln \widetilde{p}^{\,k}_{fjt} = \alpha_{jt} + \alpha_k + \varepsilon^k_{fjt}, \tag{6}$$

where q^k_{fjt} is the export quantity, $\widetilde{p}^{\,k}_{fjt}$ is the substitution-adjusted export price,[19] α_{jt} and α_k are destination-year and industry (4-digit) fixed effects, respectively.

The results are reported in Table 3 according to the same source of variation in expenditure used in Table 2: destination markets (column 1), industries (column 2), and years (column 3). As expected, quality is positively correlated with prices. The first and third central expenditure moments are also positively correlated with prices, while a negative correlation is observed for the second moment. A plausible and coherent explanation for the expenditure moment estimates is linked to the risk premium and to pro-competitive effects. For instance, the higher the demand and skewness, the higher the competition in the market, and thus, the lower the price. By contrast, the higher the volatility, the higher the risk premium, the lower the competition, and the higher the price. Furthermore, in column 3, controlling for the quality and expenditure

[19] In Khandelwal *et al.* (2013), the left-hand side variable of equation (6) is equal to $\ln q^k_{fjt} + \sigma \ln p^k_{fjt}$, where σ is the elasticity of substitution such that $\widetilde{p}^{\,k}_{fjt} = p^k_{fjt} \exp^{\sigma}$. Quality is estimated as quality$^k_{fjt} = \hat{\varepsilon}^k_{fjt}/(\sigma - 1)$ using the assumption of Khandelwal *et al.* (2013) that $\sigma = 4$.

moments, an increase in productivity implies a lower marginal cost and a price decrease. Our results suggest that decision makers care about expenditure uncertainty when they decide the quantity to export or the prices.

Table 3: Intensive margin: Firm export prices

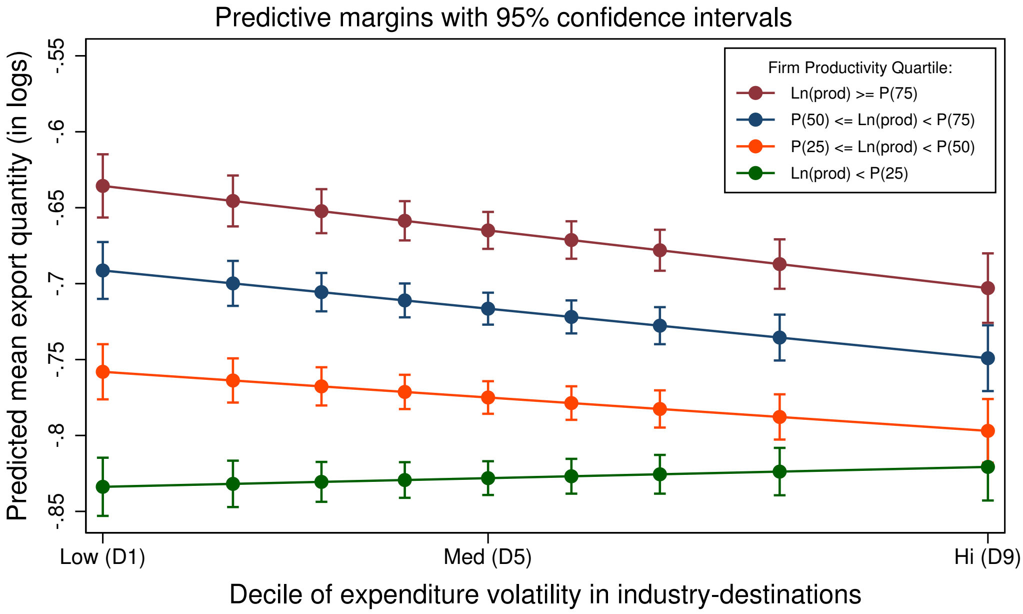
Dependent variable:	Firm export prices: $\ln p^k_{fjt}$		
	(1)	(2)	(3)
Ln Mean Expenditure$^K_{jt}$	-0.017^a	-0.017^a	-0.062^a
	(0.004)	(0.005)	(0.009)
Ln Expenditure Volatility$^K_{jt}$	0.005^b	0.009^a	0.004
	(0.002)	(0.003)	(0.002)
Expenditure Skewness$^K_{jt}$	-0.003^a	-0.004^a	-0.002^a
	(0.001)	(0.001)	(0.001)
Ln Quality$_{fjkt}$	0.644^a	0.640^a	0.750^a
	(0.003)	(0.003)	(0.002)
Ln Productivity$_{ft}$	-	-	-0.030^a
	-	-	(0.001)
Observations	3,904,513	3,129,051	3,875,422
R^2	0.945	0.917	0.973
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. Quality$_{fjkt}$ is computed using Khandelwal *et al.* (2013)'s approach. The productivity of firm f in year t is measured using the value-added per employee. 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.

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 quantities



Notes: The figure compares exporters across categories of productivity (prod) and expenditure volatility in terms of predicted export quantities between 2000 and 2009. The x-axis displays the deciles of expenditure volatility in 3-digit industry-destination-year triplets. The y-axis displays the predicted mean export quantity in 4-digit industry-destination-year triplets. See the text for estimation details.

We first divide firm productivity into quartiles and industry expenditure volatility into deciles. Then, we create new variables by interacting each productivity quartile 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 firm responses on the destination-by-year and firm-by-industry (4-digit) fixed effects.[20] Based on the estimated parameters, we compute the predicted mean of export quantity (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 greater the expenditure volatility, the smaller the export quantities 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 the most productive firms decreases with volatility.

We pursue our investigation of the heterogeneous responses of firms to expenditure volatility using the same specifications as in Table 2 and a new covariate: the interaction between volatility and firm productivity. The results are reported in Table 4. Our estimates confirm that the most productive firms are more sensitive to variation in expenditure volatility (across destinations,

[20]Note that this estimator yields the same estimates of volatility and skewness as those presented in column 3 of Table 2 without the interactions.

industries, and years).

Table 4: Intensive margin: Reallocation of export quantities across firms

Dependent variable:	Firm export quantities: $\ln q^k_{fjt}$		
	(1)	(2)	(3)
Ln Mean 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$^K_{jt}$ $\times$ 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 quantities 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. The productivity of firm f in year t is measured using the value-added per employee. 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 as a 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:

$$Pr(y^k_{fjt}|y^k_{fj,t-1}=0) = \begin{cases} 1 & \text{if} \quad y^{*k}_{fjt} > 0, \\ 0 & \text{if} \quad y^{*k}_{fjt} \leq 0, \end{cases} \tag{7}$$

with

$$y^{*k}_{fjt} = \gamma_1 \ln \mathbb{E}(R^K_{j,t-1}) + \gamma_2 \ln \mathbb{V}(R^K_{jt}) + \gamma_3 \mathbb{S}(R^K_{jt}) + \mathbf{FE} + \varepsilon^k_{fjt},$$

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 the expenditure distribution, $\mathbf{FE}$ represents various combinations of fixed effects, and ε^k_{fjt} is the error term. In addition to the probability of entry, one can 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 (LPM). The inclusion of fixed effects in a probit model would give rise to the incidental parameter problem. The LPM avoids this issue. Furthermore, the use of an LPM allows us to directly interpret the coefficients. 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 5.

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}). Here, our coefficients of interest on volatility and skewness are 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 entering that market. 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 entering that industry.

Table 5 presents quite intuitive results. The average expenditure significantly increases the probability that a firm enters a destination j or an industry k, while reducing the probability of exit (columns 3 and 4). As expected, the within firm-industry-time (columns 1 and 3) and 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 diversification across industries, which may explain the difference in the magnitudes of the 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.

Table 5: Extensive margin: Firm entry and exit probabilities

Dependent variable:	Proba. of entry $Prob(y_{fjk,t}=1)\|Prob(y_{fjk,t-1}=0)$		Proba. of exit $Prob(y_{fjk,t}=0)\|Prob(y_{fjk,t-1}=1)$	
	(1)	(2)	(3)	(4)
Ln Mean Expenditure$_{jt}^{K}$	0.002^a	0.001^a	-0.013^a	-0.008^a
	(0.0002)	(0.0002)	(0.002)	(0.002)
Ln Expenditure Volatility$_{jt}^{K}$	-0.0009^a	-0.0005^a	0.006^a	0.003^a
	(0.0002)	(0.0001)	(0.001)	(0.001)
Expenditure Skewness$_{jt}^{K}$	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.

We check the robustness of our results in Table 8 of Appendix C by selecting alternative time spans for the construction of the expenditure moments (5- and 7-year rolling periods instead of a 6-year time window). The results are similar to those reported in Table 5 and are therefore not driven by the time span chosen for the expenditure moments.

2.5. Discussion and Simulations

Our estimations reveal that expenditure volatility negatively affects the intensive and extensive margins of trade. In addition, 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 the 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 variation 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 price 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%.[21] Moreover, if US expenditures were as volatile as those of Mexico, French exports to the US would decrease by 3.2% to 4.5%. In contrast, holding other features constant, if US expenditures were as skewed as those of Mexico, French exports to the US would increase by 1.4% to 1.8%. Further, if US expenditures were as volatile *and* skewed as those of Mexico, 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),[22] total French exports would have increased at the intensive margin by 5.3% to 7.6%. If we also assume zero skewness for each destination/industry expenditure, total French exports would still have increased by 4.1% to 6.8%.

3. Theory

As in Esposito (2016) and Gervais (2016), we consider that risk-aversion effects offer a promising framework through which to study the impact of uncertainty on trade. Before presenting our theory, we briefly discuss the two other main channels through which uncertainty potentially alters export decisions: (*i*) real-option effects and (*ii*) Oi-Hartman-Abel effects. In the real-option effects approach, the decision whether and when to export may be similar to an investment decision under uncertainty à la Dixit-Pindyck. This approach has offered fruitful contributions on the role of uncertainty in the extensive margin of trade and in the entry decisions of multinational firms. Given the sunk costs of accessing foreign markets, uncertainty makes firms more cautious about serving a new market and delays the entry of exporters into new markets. However, our empirical analysis shows that demand or expenditure uncertainty also affects export prices and quantities. Having entered, reducing or increasing quantities and prices does not lead to the loss of an option value (of waiting to export). The intensive margin is easily reversible. For instance, if labor cannot be considered as a perfect flexible input at the firm level, it can be flexibly allocated from one product-destination to another. As a result, the real-option approach

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

[22] 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.

seems to be less relevant to explaining the role of uncertainty in pricing/production decisions. In the Oi-Hartman-Abel approach (Oi, 1961; Hartman, 1972; Abel, 1983), uncertainty can decrease the expected profit when the relationship between profits and the stochastic variable is concave (Klemperer and Meyer, 1986). Nevertheless, under imperfect competition (and non-decreasing returns), the relationships between profits and uncertain parameters associated with demand or productivity are convex, and profits increase with uncertainty. To account for a negative effect of uncertainty on expected profits and quantities, strong diseconomies of scale in production are assumed. Such an assumption clashes with the empirical evidence, as exporters are typically large companies. In our theoretical framework, we assume risk-averse managers and show that expenditure uncertainty affects not only the entry and exit decisions but also the production and pricing decisions, leading to the reallocation of market shares.

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.[23] 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 trade costs and firm heterogeneity in trade models.

3.1. Uncertain demand curve

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 when the contracts between exporters and importers are signed, as R_j is subject to random shocks. Numerous factors are beyond the producer's control and influence the expenditure realization, including climatic conditions and changes in consumer tastes/incomes, opinion leader attitudes, competing product popularity, and industrial policy. Formally, we assume that R_j depends on transitory shocks ω_j, which are independent and identically distributed with mean, variance, and skewness $\mathbb{E}(\omega_j)$, $\mathbb{V}(\omega_j)$, and $\mathbb{S}(\omega_j)$, respectively. The actual expenditure can be approximated as follows:

$$R_j(\omega_j) = \mathbb{E}\left(R_j\right) + \left.\frac{\partial R_j}{\partial \omega_j}\right|_{\omega_j=\mathbb{E}(\omega_j)} [\omega_j - \mathbb{E}(\omega_j)] = \mathbb{E}\left(R_j\right) + \varepsilon_j \mathbb{E}(R_j)\frac{\omega_j - \mathbb{E}(\omega_j)}{\mathbb{E}(\omega_j)}, \tag{8}$$

where $\mathbb{E}(R_j)$ is the expected expenditure, and ε_j is the expenditure elasticity to shocks ω_j prevailing in the exporting country (evaluated at the mean value). Denoting by $\dot{R}_j$ the change

[23] In this 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.

in expenditure relative to the non-stochastic steady state (*e.g.*, the growth rate), we obtain:

$$\dot{R}_j \equiv \frac{R_j - \mathbb{E}\left(R_j\right)}{\mathbb{E}\left(R_j\right)} = \varepsilon_j \frac{\omega_j - \mathbb{E}(\omega_j)}{\mathbb{E}(\omega_j)}, \tag{9}$$

so $\mathbb{V}(\omega_j) = \mathbb{V}(\dot{R}_j)\left[\frac{\mathbb{E}(\omega_j)}{\varepsilon_j}\right]^2$ and $\mathbb{S}(\omega_j) = \mathbb{S}(\dot{R}_j)\left[\frac{\mathbb{E}(\omega_j)}{\varepsilon_j}\right]^3$. Assuming that R_j is subject to multiplicative shocks, with $R_j = \omega_j \times \mathbb{E}\left(R_j\right)$, where $\mathbb{E}(\omega_j) = 1$ and using (8), we obtain:

$$\mathbb{V}[R_j(\omega_j)] = \mathbb{V}(\dot{R}_j) \quad \text{and} \quad \mathbb{S}[R_j(\omega_j)] = \mathbb{S}(\dot{R}_j). \tag{10}$$

Hence, we provide a microfoundation for the computation of the variance and the skewness of expenditures in terms of growth rates, as in the empirical section. Therefore, the distribution of expenditure in each country is such that its mean, variance, and skewness are given by $\mathbb{E}(R_j)$, $\mathbb{V}(\dot{R}_j)$, and $\mathbb{S}(\dot{R}_j)$, respectively.

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 when the strategic variables are chosen.

3.2. Market Structure, Technology, and Firm Behavior

Consider a multi-country economy with one industry supplying a continuum of differentiated varieties indexed by v.[24] Varieties are provided by heterogeneous firms engaged in monopolistic competition. Each variety is produced by a single firm, and each firm supplies a single variety. This means that individual producers are negligible in the 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, which 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 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; Klemperer and Meyer,

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

1986). The firm has two options: (i) set the quantity before demand is known after which the actual demand curve yields the market-clearing price; (ii) set the price before demand is known, after which 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 the quantity before demand is known. In Appendix D, 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 the quantity q_{ij} to serve destination market j before they know 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. The 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 export is made *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:

$$\mathbb{E}\left[\pi_{ij}(v)\right] = \mathbb{E}\left[p_{ij}(v)\right] q_{ij}(v) - c_{ij}(v) q_{ij}(v), \tag{11}$$

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 π_i of a firm producing variety v and located in country 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 $\pi_i = \pi_{ii} + \Sigma_j \pi_{ij}$.

3.3. 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 premium to avoid risk in some destination markets. We follow expected utility theory, where risk-averse 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 $\mathbb{E}(\pi_i)$:

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

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

$$\mathbb{E}\mathrm{U}_m(\pi_i) \approx \mathrm{U}_m[\mathbb{E}(\pi_i)] + \frac{1}{2}\mathrm{U}''_m\mathbb{V}(\pi_i) + \frac{1}{6}\mathrm{U}'''_m\mathbb{S}(\pi_i), \tag{12}$$

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.[25] In our context, the risk premium Γ is defined as the 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:

$$\mathbb{E}\mathrm{U}_m(\pi_i) = \mathrm{U}_m\left(\mathbb{E}(\pi_i) - \Gamma\right) \approx \mathrm{U}_m\left(\mathbb{E}(\pi_i)\right) - \Gamma\mathrm{U}'_m, \tag{13}$$

where $\mathbb{E}\mathrm{U}_m(\pi_i)$ is approximated by a first-order Taylor expansion. Using this approximation in equation (12) yields the following:

$$\Gamma \approx \rho_v\mathbb{V}(\pi_i) - \eta_v\mathbb{S}(\pi_i), \tag{14}$$

where $\rho_v = -\mathrm{U}''_m/2\mathrm{U}'_m > 0$ and $\eta_v = -\mathrm{U}'''_m/6\mathrm{U}'_m < 0$ are the marginal contributions of the variance and skewness of π_i, respectively, to the risk premium Γ.

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 managers have decreasing absolute risk aversion (DARA) preferences.[26] 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 which marginal utility decreases when wealth increases by one dollar. However, a unit-free measurement of sensitivity is not without disadvantages. Constant relative risk aversion (CRRA) would measure the rate at which marginal utility decreases when wealth increases by one percent. Nonetheless, this implies redefining the risk premium as Γ times the manager's wealth. Yet, the manager's wealth should not be considered given but en-

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

[26] In contrast, $\eta_v = 0$ would imply constant absolute risk aversion (CARA) preferences.

dogenous 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 $\mathrm{U}_m''' > 0$), 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 $\mathrm{U}_m''' > 0$, the term $\eta_v = -\mathrm{U}_m'''/6\mathrm{U}_m' < 0$ captures a preference for positive skewness. It implies a lower probability of obtaining a large negative return compared to a symmetric distribution. This entails absolute risk aversion of the exporter that decreases with its level of domestic sales. Moreover, $\mathrm{U}_m''' > 0$ corresponds to a situation of downside risk aversion, implying that an increase in $\mathbb{S}(\pi_i)$ tends to decrease the willingness to pay to avoid risk (Menezes *et al.*, 1980). Thus, for a 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 $\mathbb{E}\mathrm{U}_m(\pi_i)$ is equivalent to maximizing the certainty equivalent payoff $\Pi_v(\pi_i) = \mathbb{E}(\pi_i) - \Gamma$. Since expression (14) provides a local approximation of the risk premium Γ, it follows that the objective function of a decision maker can always be approximated as follows:

$$\Pi_v(\pi_i) \approx \mathbb{E}(\pi_i) - \Gamma = \mathbb{E}(\pi_i) - \rho_v \mathbb{V}(\pi_i) + \eta_v \mathbb{S}(\pi_i). \tag{15}$$

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 $\mathrm{U}_m(\pi_i)$. 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 $\mathrm{U}_m(\pi_i)$ is valid only in the neighborhood of $\mathbb{E}(\pi_i)$. We thus consider only small risks.[27] Notice also that the firm's risk premium is viewed as the amount that makes a manager indifferent between a risky return and the certainty equivalent of its expected utility in which only variance and skewness play a role. Contrary to the literature on capital asset pricing, we do not consider the role of covariance of shocks to demand across countries in the risk premium. Despite its interest, such a consideration appears unnecessary to rationalizing our empirical facts.

[27] It is empirically challenging to determine how small are these risks, but each (4-digit)industry-destination represents a fairly small amount of firm's exports (in our sample, the mean share of each industry-destination in firm's total exports is 9.3% and the median share equals 0.6%).

3.4. Preferences and Demand

We now specify consumers preferences. 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:

$$\mathrm{U}_{c_j} = \int_{v\in\Omega_j} u_j(q(v))\mathrm{d}v, \tag{16}$$

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

$$\int_{\Omega_j} p_{ij}(v)q_{ij}(v)\mathrm{d}v = R_j, \tag{17}$$

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:

$$p_{ij}(v) = u'_j[q_{ij}(v)]/\lambda, \tag{18}$$

where λ is the Lagrange multiplier (corresponding to the marginal utility of income). Plugging (18) into (17) implies $\lambda = \Psi_j/R_j$ with:

$$\Psi_j \equiv \int_{\Omega_j} u'_j[q_{ij}(v)]q_{ij}(v)\mathrm{d}v, \tag{19}$$

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

$$p_{ij}(v) = R_j u'_j[q_{ij}(v)]\Psi_j^{-1}. \tag{20}$$

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 of varieties supplied by rival firms (Ψ_j). Exporting firms face a downward-sloping demand curve in destination j, which is characterized by a random shift parameter R_j (common to all firms) under uncertainty.

Note that the utility function (equation 16) nests the CES function, which allows us to infer product quality following Khandelwal *et al.* (2013) (see empirical section 2.4.2). Indeed, if $u_j(q_{ij}) = [\theta_{ij}q_{ij}]^\gamma$, with $0 < \gamma < 1$ and $\theta_v > 0$ being the quality perceived by consumers, the elasticity of substitution between any pair of varieties is constant and given by $1/(1-\gamma) \equiv \sigma$. Under this configuration, it is straightforward to check that $\ln q_{ij}(v) + \ln \tilde{p}_{ij}(v) = \ln q_{ij}(v) +$

$\sigma \ln p_{ij}(v) = (\sigma - 1)\ln\theta_{ij} + \ln R_j^{\frac{1}{1-\gamma}} \Psi_j^{\frac{-1}{1-\gamma}}$, which is equivalent to equation (6).

3.5. Risk Premium and Firm Size

Recall that $R_j(\omega_j)$ is not known for certain when the contracts between the exporters and the importers are signed. Since our aim is to build the simplest possible model to rationalize our empirical findings, we assume that shocks are not correlated across countries, i.e., $\mathrm{Cov}(\omega_l, \omega_j) = 0$ for all $l \neq j$.[28]

The expected price prevailing for each firm in the foreign market is therefore given by the following equation:

$$\mathbb{E}\left[p_{ij}(v)\right] = \mathbb{E}(R_j)u_j'[q_{ij}(v)]\Psi_j^{-1}, \tag{21}$$

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

$$\frac{\mathbb{E}(p_{ij})q_{ij}(v)}{\mathbb{E}(R_j)} = u_j'[q_{ij}(v)]q_{ij}(v)\Psi_j^{-1} \equiv s_{ij}(v). \tag{22}$$

The expected market share increases with output. Indeed, we have $\frac{\partial s_{ij}(v)}{\partial q_{ij}(v)} = \Psi_j^{-1}\Lambda_{ij}[q_{ij}(v)] > 0$, with $\Lambda_{ij}[q_{ij}(v)] \equiv u_j'[q_{ij}(v)] + u_j''[q_{ij}(v)]q_{ij}(v) > 0$, 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 $0 < \gamma < 1$, then $\Lambda_{ij}(v) = \theta_v^\gamma \gamma^2 q_{ij}^{\gamma-1} > 0$.

According to equation (15), the risk premium for each firm is $\Gamma_v = \rho_v \mathbb{V}(\pi_i) - \eta_v \mathbb{S}(\pi_i)$. This expression can be rewritten as $\Gamma_v = \sum_j \Gamma_{ij}$, where Γ_{ij} is the risk premium associated with a destination j:

$$\Gamma_{ij} = \rho_v \mathbb{V}(\pi_{ij}) - \eta_v \mathbb{S}(\pi_{ij}), \tag{23}$$

as $\mathrm{Cov}(R_l, R_j) = 0$ for all $l \neq j$. It is straightforward to verify that the variance and skewness of the profit distribution are given, respectively, by:

$$\mathbb{V}(\pi_{ij}) = \mathbb{V}(\dot{R}_j)s_{ij}^2 \quad \text{and} \quad \mathbb{S}(\pi_{ij}) = \mathbb{S}(\dot{R}_j)s_{ij}^3. \tag{24}$$

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

[28] Allowing the shocks to be correlated across markets would be appealing but would render the model much less tractable from an analytic perspective. This assumption is not required to rationalize all our empirical findings.

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

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

3.6. Firm Decisions

Supply Decision

The firm's payoff is $\Pi_v(\pi_i) = \sum_j (s_{ij}\mathbb{E}(R_{ij}) - c_{ij}q_{ij} - \Gamma_{ij})$. Therefore, the marginal revenue is uncertain, while the marginal cost is known with certainty. The expected export sales $\mathbb{E}[p_{ij}(v)]\, q_{ij}(v)$ increase with q_{ij} but decrease with the industry's output (captured by Ψ_j). As we assume a continuum of firms, each one is negligible. When choosing the quantity to serve country j, each firm neglects the impact of its decision over Ψ_j. The first-order condition for payoff maximization $\partial\Pi_v/\partial q_{ij} = 0$ implies:

$$\frac{\partial s_{ij}}{\partial q_{ij}}\mathbb{E}(R_j)\left[1 - \frac{\partial\Gamma_{ij}}{\partial s_{ij}(v)}\frac{1}{\mathbb{E}(R_j)}\right] - c_{ij} = 0, \tag{25}$$

with

$$\frac{\partial s_{ij}}{\partial q_{ij}} = \frac{\mathbb{E}(p_{ij})}{\mathbb{E}(R_j)}\left[1 - \frac{-u_j''(.)q_{ij}}{u_j'(.)}\right], \tag{26}$$

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 $\partial^2\Pi_v/\partial q_{ij}^2 < 0$. As the second and third moments of the expenditure distribution do not affect $\partial s_{ij}/\partial q_{ij}$, risk aversion is essential to our results. Without risk aversion, only the expected expenditures play a role in supply decision. Using (23), (25), and the implicit function theorem, the following is readily verifiable:

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

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 $\rho_v\mathbb{V}(\dot{R}_j) > 0$. 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:

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

Regardless of the sign of $\mathbb{S}(\dot{R}_j)$, each exporter has an incentive to increase its output for a given $\mathbb{V}(\dot{R}_j)$ 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 quantity and trade cost is negative and convex ($\partial q_{ij}/\partial\tau_{ij} < 0$ and $\partial^2 q_{ij}/\partial\tau_{ij}^2 > 0$). More importantly, it is straightforward to verify that:

$$\frac{\partial^2 q_{ij}}{\partial\varphi\partial\mathbb{V}(\dot{R}_j)} < 0 < \frac{\partial^2 q_{ij}}{\partial\tau\partial\mathbb{V}(\dot{R}_j)}$$

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 dedicated to that foreign country (see equation 24). 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:

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

as $\partial q_{ij}/\partial\varphi > 0$ and $\partial q_{ij}/\partial\tau > 0$. The magnitude of the positive impact of a higher $\mathbb{S}(\dot{R}_j)$ 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_j), 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, in accordance with our empirical results, 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 $\partial^2 s_{ij}/\partial\varphi\partial\mathbb{V}(\dot{R}_j) < 0$, leading to the reallocation of market shares from the most productive to the least productive exporters.

Expected Equilibrium Prices

The first-order condition (25) can be rewritten as follows:

$$\mathbb{E}\left[p_{ij}(v)\right] = c_{ij}(v)\left[1 - \frac{-u_j''(.)q_{ij}}{u_j'(.)}\right]^{-1}\left[1 - \frac{\partial\Gamma_{ij}(v)}{\partial s_{ij}(v)}\frac{1}{\mathbb{E}\left(R_j\right)}\right]^{-1}, \tag{27}$$

where

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

as $\frac{\partial q_{ij}}{\partial s_{ij}} < 0$ and $\frac{\partial^2 \Gamma_{ij}}{\partial s_{ij}^2} > 0$ according to 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. It follows that, as expected, the marginal risk premium increases with expenditure volatility and decreases when the expenditure distribution becomes skewed to the right. Note that under expenditure certainty, the markup is simply equal to $1 + u_j''(.)q_{ij}/u_j'(.)$ (which is equal to $1/\gamma$ when the substitution elasticity is constant). In contrast, under uncertainty, the markup increases with the variance of the expenditure. It is thus higher, on average, than that prevailing under certainty due to expenditure variation. Hence, an uncertain demand curve increases prices through a higher markup due to the marginal risk premium.

The next proposition summarizes our results for export prices.

Proposition 2 *Export prices increase with higher* industry-level *foreign expenditure volatility for large firms and for markets with low trade costs.*

Note that, unlike monopolistic competition models 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 an isoelastic demand curve*. The markup increases with firm productivity (φ) and volatility 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 expenditure variation and risk aversion. As the profit variance is high for the most productive firms, they charge larger markups. Similarly, a small market induces low profit variance, 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 mechanisms associated with Propositions 1 and 2 rationalize the empirical facts related to the intensive margin of trade. 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).

Entry Decision

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 of monitoring 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. Second, a firm is more likely to serve a country whose expenditure distribution exhibits low variance and high skewness, as $\partial \Pi_{ij} / \partial \mathbb{V}(\dot{R}_j) < 0 < \partial \Pi_{ij} / \partial \mathbb{S}(\dot{R}_j)$ 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 the expenditure distribution is unchanged.*

3.7. Impact of Uncertainty on Intra-Industry Reallocation

Having established the individual choices of firms taking the decision of their rivals (Ψ_j is treated as an exogenous parameter by firms) as given, we now determine how market shares and entry/exit decisions adjust when demand or expenditure uncertainty changes. In this case, we have to consider the direct and indirect effects (through a change in Ψ_j) of uncertainty. For simplicity and tractability, we now define the utility function (16) as $u_j(q_{ij}) = \theta_v q_{ij}^{1/2}$, where $\theta_v > 0$ can be interpreted as a measure of product quality, and $\eta_v = 0$.[29] Under this configuration, the equilibrium *certainty-equivalent quantities* are given by:

$$q_{ij}(v)^{\frac{1}{2}} = \frac{\mathbb{E}(R_j)\theta_v \varphi}{2 w_i \tau_{ij}} \Psi_j^{-1} \left[1 + \rho_v \mathbb{V}(\dot{R}_j) \Psi_j^{-2} \frac{\theta_v^2 \varphi}{w_i \tau_{ij}} \right]^{-1}. \tag{28}$$

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:

$$r_{ij}(\varphi) = \frac{\mathbb{E}(R_j)^2}{2} \left[\frac{w_i \tau_{ij}}{\theta_v^2 \varphi} \Psi_j^2 + \rho_v \mathbb{V}(\dot{R}_j) \right]^{-1}. \tag{29}$$

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 ($\mathbb{V}(\dot{R}_j) = 0$), the expected payoff has a finite limit given by $\frac{\mathbb{E}(R_j)^2}{4 \rho_v \mathbb{V}(\dot{R}_j)}$ when $\varphi = \infty$. This means that high productivity is a necessary but not 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 $\mu(\xi)$ is 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:

$$\widehat{\xi}_{ij} \equiv \left[\frac{\mathbb{E}(R_j)^2}{4 w_i f_{ij}} - \rho_v \mathbb{V}(\dot{R}_j) \right] \frac{\Psi_j^{-2}}{w_i \tau_{ij}}. \tag{30}$$

[29] 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.

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 probability 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 ($\rho_v \mathbb{V}(\dot{R}_j)$). 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 $\mathbb{V}(\dot{R}_j)$. Hence, we provide a rationale for the prevalence of zeros in bilateral trade without making an *ad hoc* assumption about the support of the distribution of productivity across firms. Helpman *et al.* (2008) also allow for zero bilateral trade quantities, 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 $\mathbb{V}(\dot{R}_j)$ and the total effect of $\mathbb{V}(\dot{R}_j)$. We show in Appendix E that:

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

or equivalently, $\partial \Psi_j / \partial \mathbb{V}(\dot{R}_j) < 0$. As expected, an increase in the volatility of expenditure reduces the aggregate supply to destination market j, which in turn, affects equilibrium prices. Hence, equilibrium prices increase with expenditure variation through two effects: (i) the direct effect of risk aversion (through $\rho_v \mathbb{V}(\dot{R}_j)$, 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 $\mathbb{V}(\dot{R}_j)$:

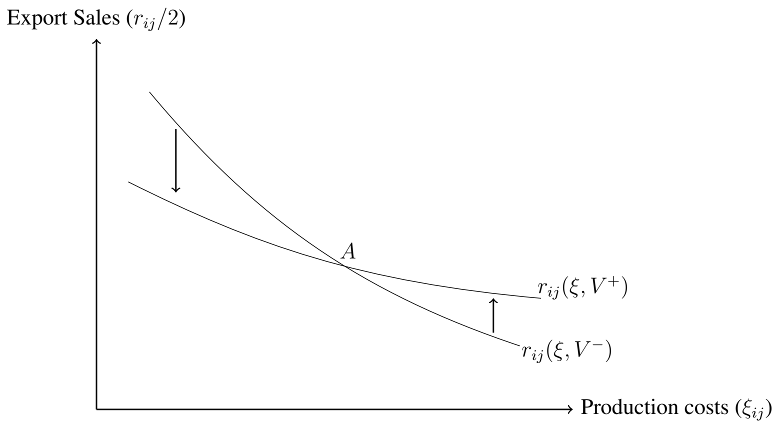
$$\frac{\mathrm{d}r_{ij}(\varphi)}{\mathrm{d}\mathbb{V}(\dot{R}_j)} = \frac{\partial r_{ij}(\varphi)}{\partial \mathbb{V}(\dot{R}_j)} + \frac{\partial r_{ij}(\varphi)}{\partial \Psi_j}\frac{\partial \Psi_j}{\partial \mathbb{V}(\dot{R}_j)} = \frac{r_{ij}(\varphi)}{\mathbb{V}(\dot{R}_j)}\frac{2w_i\tau_{ij}\xi\epsilon_{\Psi_j}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

where $\partial r_{ij}/\partial \mathbb{V}(\dot{R}_j) < 0$, while $\partial r_{ij}/\partial \Psi_j < 0$ and $\partial \Psi_j / \partial \mathbb{V}(\dot{R}_j) < 0$ (see above). It follows that increased expenditure volatility induces the reallocation of market shares from larger to smaller firms, as $\mathrm{d}r_{ij}/\mathrm{d}\mathbb{V}(\dot{R}_j)$ increases with ξ. Hence, the aggregate productivity of exporters can decrease, *ceteris paribus*, given greater uncertainty, which is consistent with the empirical facts (see Bloom, 2014). In addition, as the largest firms reduce their export sales by a high proportion when expenditure variation increases, the export sales of smaller exporters may expand at their expense (see Figure 7).

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

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

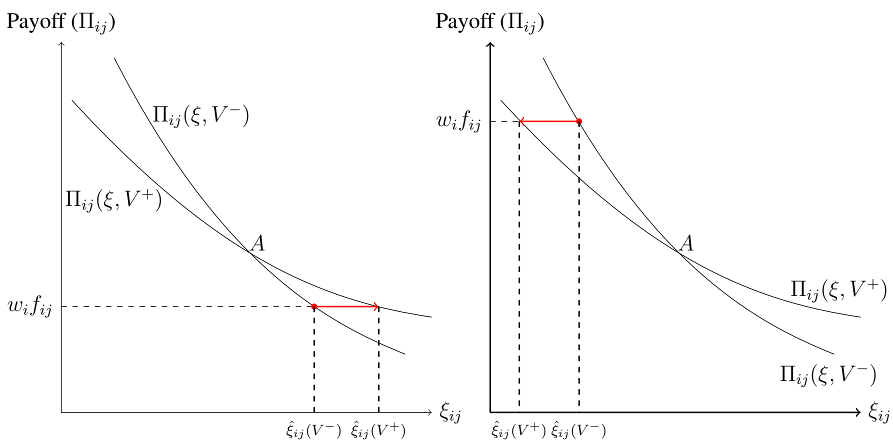
Figure 7: Productivity and reallocation of export sales when expenditure volatility increases



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

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

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.

When we focus on the total effect of expenditure variation on quantity, it appears that:

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

Hence, the effects of $\mathbb{V}(\dot{R}_j)$ 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 (rising productivity) less effective, in accordance with Bloom (2014).

The next proposition summarizes our results for an increase in expenditure volatility.

Proposition 4 *For a given skewness, an increase 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 shares 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 expenditure uncertainty provides incentives for firms to reduce their risk exposure by adjusting not only their extensive but also their intensive margins of trade. It follows that the responsiveness of firms to trade policy (lower trade costs) and R&D policy (higher productivity) can be altered in the context of uncertainty.

Using French firm-level data, we establish two key features of trade and demand uncertainty: (i) greater expenditure uncertainty not only reduces export sales and exporting probabilities but also makes exports less sensitive to trade policy; (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 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 is a disadvantage for 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 (i) averse to both risk and downside losses and (ii) make entry/exit and production/pricing decisions before the uncertainty over market expenditure is resolved. We examine how risk-averse exporting managers react to industry-level uncertainty based on their characteristics and the features of the origin and destination countries. 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 firms may stop exporting because of expenditure variation such that the market shares of the remaining exporters increase 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 exporters, 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.

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 an increase in expenditure volatility induces the reallocation of market shares from the most productive (and largest) to the least productive (and smallest) incumbents. However, this effect is weakened with increasing skewness of the foreign expenditure distribution and higher trade barriers. These results hold for a large class of consumer utility functions, including CES functions.

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 for 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.

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Appendix 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 6. We use this classification to distinguish between 3-digit K industries and 4-digit k sub-industries.

Table 6: 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

Appendix B Firm-level Estimations at the Intensive Margin of Trade: Alternative Time Spans for the Expenditure Moments

Table 7: Intensive margin: Firm export quantities - Alternative time spans for the expenditure moments

Dependent variable:	Firm export quantities: $\ln q_{fjt}^{k}$					
	5-year span			7-year span		
	(1)	(2)	(3)	(4)	(5)	(6)
Ln Mean Expenditure$_{jt}^{K}$	0.066^{a}	0.079^{a}	0.198^{a}	0.071^{a}	0.082^{a}	0.194^{a}
	(0.019)	(0.022)	(0.030)	(0.018)	(0.021)	(0.028)
Ln Expenditure Volatility$_{jt}^{K}$	-0.023^{a}	-0.029^{a}	-0.018^{a}	-0.028^{a}	-0.044^{a}	-0.028^{a}
	(0.008)	(0.010)	(0.006)	(0.010)	(0.013)	(0.010)
Expenditure Skewness$_{jt}^{K}$	0.009^{a}	0.011^{b}	0.006^{b}	0.013^{a}	0.016^{a}	0.009^{a}
	(0.003)	(0.004)	(0.002)	(0.004)	(0.005)	(0.003)
Ln Productivity$_{ft}$	-	-	0.123^{a}	-	-	0.126^{a}
			(0.004)			(0.004)
Observations	3,859,547	3,090,001	3,826,666	4,053,611	3,265,330	4,030,956
R^2	0.708	0.535	0.861	0.707	0.533	0.861
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	-
Firm.Destination.(4-digit-)Industry$_{fjk}$	-	-	Yes	-	-	Yes
Time$_{t}$	-	-	Yes	-	-	Yes

Notes: The dependent variable is firm-level export quantities 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 the computational details of the expenditure moments. Variations over 5-year (columns 1-3) and 7-year (columns 4-6) rolling periods are used for the computation of the volatility and the skewness. Robust standard errors are in parentheses, clustered at the destination-4-digit industry level, with ^{a} and ^{b} denoting significance at the 1% and 5% level respectively.

Appendix C Firm-level Estimations at the Extensive Margin of Trade: Alternative Time Spans for the Expenditure Moments

Table 8: Extensive margin: Entry and exit probabilities - Alternative time spans for the expenditure moments

Dependent variable:	Proba. of entry		Proba. of exit		Proba. of entry		Proba. of exit	
	5-year span				7-year span			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln Mean Expenditure$_{jt}^{K}$	0.002^a	0.001^a	-0.014^a	-0.008^a	0.002^a	0.002^a	-0.013^a	-0.008^a
	(0.0002)	(0.0002)	(0.002)	(0.002)	(0.0002)	(0.0002)	(0.002)	(0.002)
Ln Expenditure Volatility$_{jt}^{K}$	-0.0008^a	-0.0004^a	0.005^a	0.002^b	-0.0010^a	-0.0006^a	0.006^a	0.004^a
	(0.0002)	(0.0001)	(0.001)	(0.001)	(0.0002)	(0.0001)	(0.001)	(0.001)
Expenditure Skewness$_{jt}^{K}$	0.0002^a	0.0001^b	-0.0006	-0.0003	0.0001	0.0001^c	-0.0007	-0.0005
	(0.0001)	(0.0001)	(0.0005)	(0.0005)	(0.0001)	(0.0001)	(0.0005)	(0.0005)
Observations	44,761,475	35,694,964	3,281,680	2,381,030	46,504,694	37,361,565	3,459,591	2,526,764
R^2	0.089	0.354	0.373	0.424	0.088	0.351	0.370	0.423
Sets of Fixed Effects:								
Firm.(4-digit-)Industry.Time$_{fkt}$	Yes	-	Yes	-	Yes	-	Yes	-
Destination$_j$	Yes	-	Yes	-	Yes	-	Yes	-
Firm.Destination.Time$_{fjt}$	-	Yes	-	Yes	-	Yes	-	Yes
4-digit-Industry$_k$	-	Yes	-	Yes	-	Yes	-	Yes

Notes: The dependent variable is the probability that a firm enters the export market (columns 1-2) and the probability that a firm exits 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 the computational details of the expenditure moments. Variations over 5-year (columns 1-3) and 7-year (columns 4-6) rolling periods are used for the computation of the volatility and the skewness. Robust standard errors are in parentheses, clustered by destination-4-digit industry level, with ^{a}, ^{b} and ^{c} denoting significance at the 1%, 5% and 10% level respectively.

Appendix D 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 $u_j(q_{ij}) = \theta_v q_{ij}^{1/2}$ in equation (16). 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

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

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 $\Phi(p_{ij}) = 0$:

$$\Phi(p_{ij}) \equiv -\left(p_{ij} - 2c_{ij}\right)\mathbb{E}(R_j) + \rho_v \left(p_{ij}^2 - 2c_{ij}^2\right) 2p_{ij}^{-2} P_j \theta_v^2 \mathbb{V}(\dot{R}_j), \tag{31}$$

while the second-order condition implies:

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

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 (31) implies that $\Phi(p_{ij}) > 0$, so the equilibrium price under uncertainty is higher than $2c_{ij}$. Using the envelope theorem:

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

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.

Appendix E Industry Supply and Income Volatility

In this Appendix, we show that $\partial\Psi_j/\partial\mathbb{V}(\dot{R}_j) < 0$. According to (19) and (28), we have $\Lambda[\Psi_j, \mathbb{V}(\dot{R}_j)] = 0$, with:

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

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

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

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

$$\frac{\partial\Lambda}{\partial\Psi_j} = \begin{array}{c} 1 - \Psi_j^{-1} \sum_\ell M_\ell \int_0^{\widehat{\xi}_{\ell j}} \theta_v \left[q_{\ell j}(\xi)\right]^{\frac{1}{2}} \frac{\rho_v \mathbb{V}(\dot{R}_j)\Psi_j^{-2} - w_\ell \tau_{\ell j}\xi}{\rho_v \mathbb{V}(\dot{R}_j)\Psi_j^{-2} + w_\ell \tau_{\ell j}\xi} \mu(\xi)\mathrm{d}\xi \\ -\frac{\partial\widehat{\xi}_{\ell j}}{\partial\Psi_j}\theta_v \left[q_{\ell j}(\widehat{\xi}_{\ell j})\right]^{\frac{1}{2}}, \end{array} \tag{32}$$

where $\partial\Lambda/\partial\Psi_j > 0$, as the second term on the right-hand side of (32) is less than 1, and $\partial\widehat{\xi}_{\ell j}/\partial\Psi_j < 0$. As a result:

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

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