Export Decision under Risk*

José De Sousa, Anne-Célia Disdier and Carl Gaigné†

February 15, 2015

Very preliminary - Please do not quote without authors' permission

Abstract

Does demand volatility matter for exports? How do exporting firms deal with skewed demand? A simple model of risk aversion shows that exporters react to an increase in demand volatility in destination markets by increasing their export prices and decreasing their export volumes. In sharp contrast, exporters decrease prices and increase volumes when demand skewness rises. We also show that the moments of the distribution of demand affect the extensive margin of trade. These theoretical predictions are put to the test by using French firm-level exports across destination markets with different levels of demand volatility and skewness. The firm-level results, over the period 2000-2009, are broadly consistent with our predictions.

JEL classification: D81, F12, L25
Keywords: Uncertainty, Demand volatility, Firm exports, Skewness

1 Introduction

Does demand volatility matter for exporters supply decisions? According to the Capgemini 2011 survey of large companies, 40% of respondents say that demand volatility is their number one business driver. Indeed, in numerous industries, sellers need to decide production levels or input procurements before the output is marketed or the market price for output is known. Demand cannot be known for certain at the time the contracts with

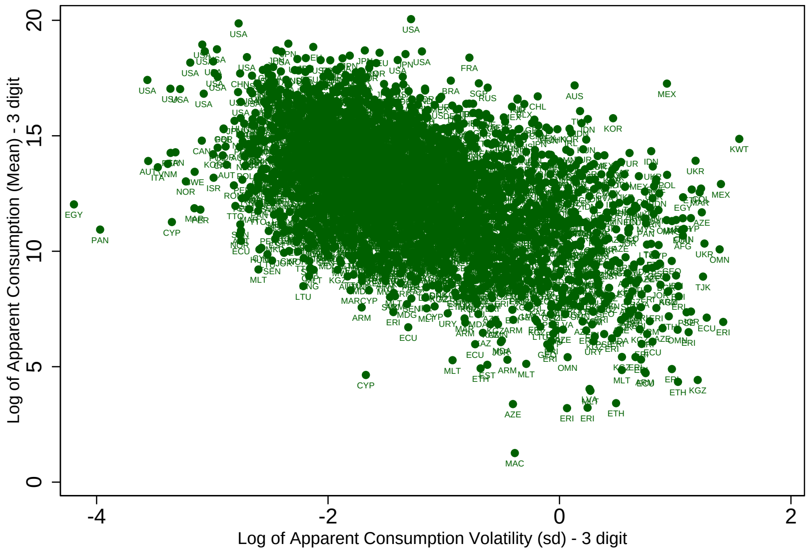
*We thank Holger Breinlich, Gabriel Felbermayr, Keith Head, Gianmarco Ottaviano, John Morrow, Denis Novy, Mathieu Parenti, Veronica Rappoport, Daniel Sturm and seminar and conference participants at CEPII, U. of Caen, London School of Economics, U. of Munich (ETSG), U. of Strathclyde, and U. of Tours for their helpful comments. This work is supported by the French National Research Agency, through the program Investissements d'Avenir, ANR-10-LBX-93-01.

†José De Sousa: Université Paris-Sud, RITM and Sciences-Po Paris, LIEPP, jose.de-sousa@u-psud.fr. Anne-Célia Disdier: Paris School of Economics-INRA, anne-celia.disdier@ens.fr. Carl Gaigné: INRA, UMR1302 SMART, Rennes (France) and Université Laval, CREATE, Québec (Canada). Email: carl.gaigne@rennes.inra.fr.

the importers are signed as expenditures for an industry are subject to random shocks. In this paper, we analyze how demand volatility affect the export decision at the firm level.

In most of the trade literature, the firm knows the state of demand function with certainty and only the *level* of foreign market size plays a key role in firm export performance. However, for a same level of demand (apparent absorption), we observe a significant demand *volatility* in destination markets. This point is illustrated in Figure (1) from data on world sectoral-level data.

Figure 1: Demand (apparent consumption) level and demand volatility

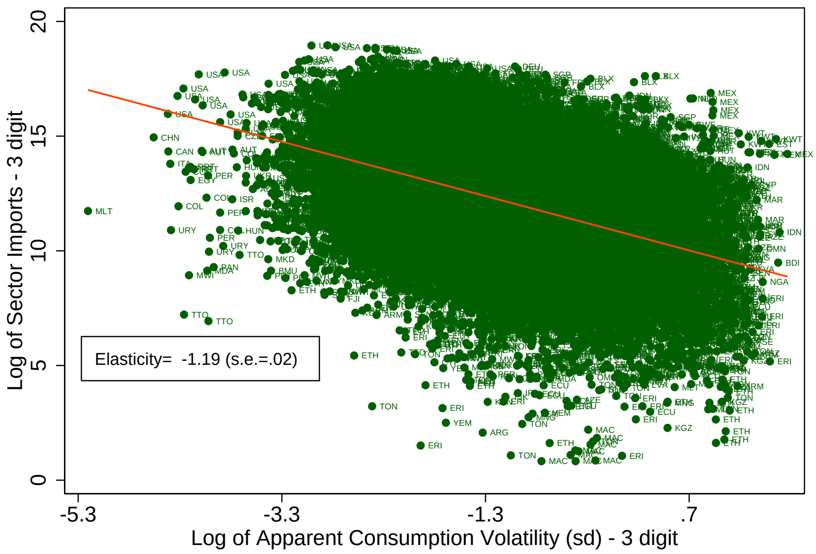


Note: 82 countries, 62 sectors, 2005.

Under demand or price uncertainty, risk-averse firms have to manage their risk exposure. Indeed, there exists some delay between the time an export decision is made and the time the corresponding output reaches the market. Hence, during this delay, the foreign demand or market price can change so that there is an uncertainty that the decision-maker has to manage when a production is made. The literature on production decision under risk shows that an increase in risk (as measured by a higher volatility) has a negative effect on output size when the decision maker is averse to risk.

As a result, if firms are risk-averse, they should export less to a country with more volatile demand, *ceteris paribus*. In other words, a country with higher demand volatility should import less. Using the same database of world sectoral-level data, we find *prima* *facie* evidence of a negative relationship between demand volatility and imports, as depicted in Figure (2). This evidence is supported by an adjusted partial residual plot, controlling for year and country fixed effects. The corresponding elasticity of demand volatility is 0.3 (p<0.01) suggesting that an 1% increase in volatility in a destination country is associated with a 0.3% decrease in imports.

Figure 2: Relationship between imports and demand volatility



Note: 100 countries, 63 sectors, 2000-09.

However, risk-averse firms react differently to uncertainty according to their characteristics. Indeed, demand fluctuation may force some producers to cease exporting and, in turn, the demand for the remaining exporters may rise. Additionally, change in uncertainty may modify the relative prices among varieties supplied leading to a reallocation of market shares among the surviving firms. Hence, the effects of industry-specific uncertain demand on export performance at the firm level are not *a priori* clear.

Further, managers can be sensitive to downside losses, relatively to upside gains. It has been shown that macroeconomic fluctuations are skewed rather than symmetric (see e.g., Popov 2011). *Ceteris paribus*, managers might prefer to serve a country exhibiting a high probability of an extreme event associated with a high level of demand than a country with a high probability of an extreme event associated with a very low demand. Yet, the variance does not distinguish between upside risk versus downside risk Skewness (the third central moment of a distribution) can be used a measure of downside risk. Indeed, the sign of the skewness provides information on the asymmetry of the demand distribution, and thus on downside risk exposure. For a same mean and variance, countries with a demand distribution which is more skewed to the right can be viewed as providing better downside protection or smaller downside risk. A basic intuition is that an increase in skewness involves a smaller probability for low (or large negative) returns. A distribution exhibiting more downside risk than another is less skewed to the right. [1] For a same mean and variance, a decision-maker prefer a distribution with the highest skewness.

To illustrate our point, consider the demand pattern of two hypothetical countries A and B. Each country exhibits a demand distribution with the same mean 6000 and same variance. Assume that, in country A, the level of demand is either 4000 k€ with a probability 3/4 or 12000 k€ with a probability 1/4 while, in country B, the level of demand is either 0 k€ with a probability 1/4 or 8000 k€ with a probability 1/2.[2] Despite an equal demand variance in each country, the manager may prefer to serve the country with a higher skewness (country A) because of a lower exposure to downside risk. In this case, the decision-maker is averse to downside risk. As a result, a manager prefers to serve a country with a large mean demand, a small variance and a large (unweighted) skewness.

In this paper, we study theoretically and empirically how firms adjust their intensive and extensive margins to a change in the volatility foreign demand. To achieve our goal, we first build a trade model where heterogeneous firms producing under imperfect competition face same industry-wide uncertainty over foreign demand. We adopt a mean-variance-skewness analysis so that firms are assumed to be averse both to risk and to downside risk. A comment is in order. By adopting this decomposition analysis, we consider a "small" risk. Indeed, export sales in a foreign country represent a low share in total sales of firms.

Our theory leads to the following predictions. A higher variance of foreign income raises the unit prices set by firms for each destination through a change in their markup.

[1] However, the converse is not necessarily true (Menezes, Geiss, and Tressler, 1980).

[2] A similar example can be found in Eeckhoudt, Gollier, and Schlesinger (2005) in a different context.

The magnitude of this positive effect increases with the productivity of firms but decreases with trade costs. We also show that, even though a higher foreign demand volatility reduce industry export sales, its effect on the probability of exporting (extensive margins) and on the level of export sales at the firm level (intensive margins) is ambiguous. Indeed, a rise in demand volatility induces a reallocation of market share from most productive (and largest) firms to smaller firms. As a result, the probability of exporting may increase when fixed trade costs are not too high. Under this configuration, the export sales of medium-sized firms (or the smallest exporters) may grow. However, this effect is weakened when the skewness of foreign income increases.

To test our predictions, we use firm-level data from the French customs over the period 1995-2012. This database reports the volume (in tons) and value (in euros) of exports for each product (combined nomenclature) and destination, for each firm located on the French metropolitan territory. Our different estimations confirm our main predictions. Hence, decision-makers seem to act as if they were risk-averse and averse to downside risk. Our results are robust over different sized panels and to the inclusion of a plethora of fixed effects, additional controls, and the use of instrumental variables.

2 Related literature

Although macroeconomic volatility plays a key role in a wide variety of economic outcomes (in long-run growth, investment and production decisions, welfare), rather little consideration has been given to its impact on export decision.

The determinants of macroeconomic volatility has received much attention. In particular, it has been argued that freer trade increases volatility at the country level. Industries more open to international trade are more volatile even though the industries exporting in foreign countries or importing from different countries depends less on the domestic shocks (Giovanni and Levchenko 2009). On the one side, the industries exporting (or importing) a large fraction of their production (or their intermediate products) are vulnerable to world demand shocks (or supply shocks). On the other side, trade openness leads to a less diversified production structure, implying a greater specialization and, in turn, an increase in volatility. In addition, trade openness can exacerbate domestic volatility through a decline in the number of firms (Gabaix, 2011). Indeed, since lowering trade barriers induce an exit of small firms and boost the size of large firms (Melitz, 2003), the economy becomes more and more dependent on the shocks at the firm level.

In contrast, the macroeconomic volatility is a source of uncertainty which potentially influences the export decision. Indeed, trade decision can be made before the resolution of uncertainty. When an export commitment is made, the price which received is unknown. The expected utility theory has been used to analyze international trade under risk and perfect competition (see Helpman and Razin 1978). More recently, the framework supplied by real option theory (Dixit and Pindyck 1994) has been introduced in trade model under imperfect competition. Given export sunk costs, the decision whether and when to export is very similar to an investment decision. For example, Baldwin and Krugman (1989) explained trade hysteresis despite large exchange rate fluctuations. In addition, Handley and Limao (2013) model trade policy uncertain as a rare event to explain world trade patterns. A standard assumption in new trade theory is that firms are risk-neutral.

A recent literature emphasizes that uncertainty shocks may affect the choice to serve a foreign market through exports or affiliate sales. Lewis (2014) considers nominal uncertainty. He finds that when multinational sales are priced in the local currency while exports are priced in the producer currency, destination volatility benefits exporters: during a foreign nominal contraction, the foreign exchange rate appreciates, causing exports to be relatively cheaper. Exporters gain non-linearly through demand, making profit convex in prices. Ramondo, Rappoport, and Ruhl (2013) consider real uncertainty and changes in relative costs between exporters and multinationals. Exporters hire labor at home compared to affiliates. Exporters' expected profits are thus increasing in the volatility of production costs in the destination country.

Our approach differ in several ways. First, we consider that when a firm chooses a certain quantity to serve a foreign market, the price that will obtain in the market is uncertain. The real value taken by foreign demand for each product is not known ahead of time. Second, we consider firms are averse to risk and more particularly to downside risk. Third, we develop a model where firms are heterogeneous in productivity supplying a differentiated product (horizontal and vertical differentiation). Our approach differs from the current trade literature since we consider that managers know the productivity of their firm but do not have perfect information about the level of foreign demand.

3 Theory

In this section, we develop a multi-country model of trade with heterogeneous firms under imperfect competition. Firms differ in productivity, but unlike Melitz (2003), they know with certainty their production technology. Firms face instead an industry-wide uncertainty over foreign demand. Industry-specific demand is uncertain because industry level expenditures in destination country j, denoted by R_j, are subject to random shocks. Factors beyond the firm's control that influence the demand realization are climatic conditions, changes in consumer tastes, opinion leaders' attitudes, popularity of competing products, etc. We assume that R_j is independently distributed with a mean, a variance, and a skewness given by $\mathbb{E}(R_j)$, $\mathbb{V}(R_j)$, and $\mathbb{S}(R_j)$ respectively. Note that $\mathbb{E}(R_j)$ and $\mathbb{V}(R_j)$ are always positive while $\mathbb{S}(R_j)$ can be positive or negative. The economic interpretation of these three moments of R_j distribution is discussed below.

Hence, each firm located in country i and producing a variety v faces a downward sloping demand curve in destination country j given by $p_{ij}(v) = f[q_{ij}(v), R_j, .]$, where $p_{ij}(v)$ and $q_{ij}(v)$ are the price and the quantity of variety v respectively. We assume that the demand is not known for certain at the time the contracts with the importers are signed. As above-mentioned R_j is subject to random shocks that cannot be observed at the time strategic variables (p_{ij} or q_{ij}) are chosen. The actual demand realization is therefore uncertain, and can be either higher or lower than the average expenditures, $\mathbb{E}(R_j)$. 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 is volatile and not known with certainty at the time the contracts are signed.

Our objective is to analyze how risk-averse firms react to *industry-level* uncertainty in export decisions (both at the intensive and extensive margins), according to their characteristics and the features of destination country. On the one hand, the level of output may decrease for all firms due to demand fluctuations in accordance with the standard theory of production under uncertainty. On the other hand, some producers may cease to export because of these fluctuations so that the demand for the remaining exporters may rise (due to a reallocation of demand). In addition, even if the demand shocks are common for all firms within an industry, it may modify the relative prices among varieties supplied by the surviving firms in this industry, leading to a reallocation of market shares. Hence, the effects of industry-specific uncertain demand on export performance at the firm level are not *a priori* clear.

Market structure, technology, and firm behavior

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

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

Under imperfect competition, the choice of the action variables (quantity or price) merits a discussion. We know from Leland (1972) and Klemperer and Meyer (1986) that, if the choice of behavioral mode by a monopolistic firm is unimportant under certainty, this is no longer the case under uncertainty. The firm has two options: (i) set quantity before demand is known and thereafter the actual demand curve yields the market clearing price or (ii) set price before demand is known and thereafter the actual demand curve yields the market clearing quantity. Ideally, we would determine endogenously if firms choose either a quantity to produce or a price to charge, as in Klemperer and Meyer (1986). In this section, we consider that firms set quantity first, before demand is known.

In Appendix (A), we report the case where price is the strategic variable. We show that this configuration yields the same predictions than the case where firms set quantity even if the level of prices and quantities differ according to the behavioral mode.

Hence, without loss of generality, we assume that firms determine quantity, q_{ij}, for each destination j before knowing the value of R_j. Equilibrium prices p_{ij} are determined *ex post* in accord with realized demand. We assume that firms cannot adjust *ex post* quantity with respect to the demand shock. The decision to produce for exports has been taken *ex ante* and thus *ex post* adjustments of quantity are not feasible. The producer cannot refuse the deal *ex post* once the price is realized. This implies that products cannot be sent back. They are sold once exported.

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

$$\mathbb{E}\left[\pi_{ij}(v)\right] = \mathbb{E}\left[p_{ij}(v)\right] q_{ij}(v) - \frac{w_i \tau_{ij}}{\varphi} q_{ij}(v) - w_i f_{ij}, \tag{1}$$

where w_i is the wage rate prevailing in the exporting country i. Firms located in country i serving the destination country j have to pay a fixed cost f_{ij} to serve foreign markets, which are the costs to maintain a presence, (*i.e.*, maintaining a distribution and service network, minimum freight and insurance charges, costs of monitoring foreign customs procedures and product standards, etc.).

We assume that markets are segmented and that shocks are not correlated across countries, such that the covariance between π_{ij} and π_{ik}, with $k \neq j$, is zero as $\mathrm{Cov}(R_k, R_j) = 0$. The uncertain terminal profit of a firm producing variety v and located in country i, π_i, can be decomposed into two parts: the profit of domestic sales π_{ii} and the profit of total exporting sales $\Sigma_j \pi_{ij}$, such that $\pi_i = \pi_{ii} + \Sigma_j \pi_{ij}$. Throughout, we assume that the domestic profit π_{ii} is known with certainty.

Uncertainty and firm behavior

We consider an utility function of a manager $\Pi(\pi_i)$ representing his/her risk preferences with $\Pi'(\pi_i) > 0$. The manager is made better off by an increase in his/her terminal profit.

Assume that the utility function $\Pi(\pi_i)$ is continuously differentiable up to order 3. We follow the methodology developed in Eeckhoudt, Gollier, and Schlesinger (2005). A third order Taylor series expansion of $\Pi(\pi_i)$ evaluated at $\mathbb{E}(\pi_i)$ gives

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

Taking the expectation and assuming that the moments exist lead to

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

According to the expected utility theory, in the neighborhood of $\mathbb{E}(x)$ where x is a random variable, we have $\mathbb{E}\Pi(x) = \Pi(\mathbb{E}(x) - \Gamma)$ where Γ is the risk premium. In our case, the risk premium Γ is defined as the sure amount of money a manager would be willing to receive to become indifferent between receiving the risky return π_i versus receiving the sure amount $\mathbb{E}(\pi_i) - \Gamma$. Because $\mathbb{E}\Pi(\pi_i)$ can also be approximated as follows $\mathbb{E}\Pi(\pi_i) = \Pi[\mathbb{E}(\pi_i)] - \Gamma\Pi'$, we have

$$\Gamma \approx -\frac{1}{2}\frac{\Pi''}{\Pi'}\mathbf{V}(\pi_i) - \frac{1}{6}\frac{\Pi'''}{\Pi'}\mathbf{S}(\pi_i), \tag{2}$$

where $-\Pi''/2\Pi'$ and $-\Pi'''/6\Pi'$ are the marginal contributions of variance ($\mathbf{V}(\pi_i) = \mathbb{E}[\pi_i - \mathbb{E}(\pi_i)]^2$) and skewness ($\mathbf{S}(\pi_i) = \mathbb{E}[\pi_i - \mathbb{E}(\pi_i)]^3$) of π_i to the risk premium Γ, respectively. The term $-\Pi''/2\Pi'$ is known as the so-called Arrow–Pratt absolute risk aversion coefficient. The term $-\Pi'''/6\Pi'$ captures a preference for positive skewness when $\Pi''' > 0$, because it implies a low probability of obtaining a large negative return. Note that skewness to the left ($\mathbf{S}(\pi) < 0$) is associated with "downside risk" exposure, while skewness to the right ($\mathbf{S}(\pi) > 0$) is associated with "upside risk" exposure.

Two remarks are in order. First, risk aversion can decrease with wealth of the individuals. Under this configuration, decision makers exhibit decreasing absolute risk aversion (DARA preferences) implying $\Pi''' > 0$. This entails that risk aversion of the exporter decreases with its level of domestic sales. Second, $\Pi''' > 0$ corresponds to "downside risk aversion", implying that a rise in downside risk (a decrease in $\mathbf{S}(\pi)$) would tend to increase the willingness to pay to avoid risk (Menezes, Geiss, and Tressler, 1980).

Finally, we know from expected utility theory that maximizing $\mathbb{E}\Pi(x)$ is equivalent to maximizing the certainty equivalent $\mathbb{E}(x) - \Gamma$. Since expression (2) provides a local approximation to the risk premium Γ, it follows that the objective function of a decision-maker can always be approximated by

$$\Pi_v(\pi_i) \approx \mathbb{E}(\pi_i) - \rho_v \mathbf{V}(\pi_i) + \eta_v \mathbf{S}(\pi_i), \tag{3}$$

with $\rho_v \equiv -\Pi^{''}/2\Pi^{'}$ and $\eta_v \equiv \Pi^{'''}/6\Pi^{'}$. Remember that $\rho_v > 0$ expresses the absolute degree of the firm's risk aversion. If $\rho_v = 0$, firms are risk neutral. This general formulation does not require a full specification of the utility function $\Pi_v(\pi)$ and it allows us going beyond a simple mean-variance analysis in the investigation of export decision under demand uncertainty. This may be particularly useful in the analysis of "downside risk" exposure. However, the reader should keep in mind that expression $\Pi_v(\pi)$ is valid only in the neighborhood of the point $\mathbb{E}(\pi_i)$. In other words, we only consider small risk. Given that the share of export sales in one country to total sales is low, this assumption is not too restrictive.

Preferences and demand

To study the effect of uncertainty on export decision, we use a simple and tractable utility function yielding a specific demand curve.[3] The consumer preferences are identical and the utility of the consumption of the differentiated good is given by

$$U_j = \int_{v \in \Omega_j} u_j(v) \mathrm{d}v, \tag{4}$$

[3] We could use the general setting in which the demand curve is $p_{ij} = f(q_{ij}, R_j)$. However, this increases the complexity of the formal developments while the gains in results are limited. What matters for most of our results is that export prices (1) decrease in export quantities ($\partial p_{ij}/\partial q_{ij} < 0$), (2) increase in destination income ($\partial p_{ij}/\partial R_j > 0$), (3) with a diminishing marginal effect as export quantities increase $\partial^2 p_{ij}/(\partial R_{ij} \partial q_{ij}) < 0$.

where Ω_j is the set of available varieties v in country j. Hence, as in Dixit and Stiglitz (1977), Krugman (1979) and Zhelobodko *et al.* (2012), we assume that preferences over the differentiated product are additively separable across varieties. To keep things simple, we consider $u_j(.) = \theta_v q_j(v)^{1/2}$ where θ_v is the quality of variety v and $q(v)$ is the quantity consumed. Given that $\partial u(v)/\partial q(v) > 0$ and $\partial^2 u(v)/\partial q(v)^2 < 0$, consumers exhibit a preference for variety.

The budget constraint faced by a consumer is given by

$$\int_{\Omega_j} p_{kj}(v) q_{kj}(v) \mathrm{d}v = R_j, \tag{5}$$

where R_j represents the income of the consumer and its total expenses, while $p_{kj}(v)$ is the price of variety v produced in country k with $k = i, j, ..K$.[4] Notice that deviations from expected demand in individual foreign markets, due to random shocks, may lead to potential gains and losses. By neglecting their effect on total income, which may cancel out, we adopt a partial equilibrium approach.

Maximizing (4) under the budget constraint (5) leads to the inverse demand:

$$p_{ij}(v) = \frac{\theta_v}{2\lambda} q_{ij}(v)^{\frac{-1}{2}}, \tag{6}$$

where λ is the Lagrange multiplier. Plugging (6) into (5) implies $\lambda = \Psi_j/2R_j$ with

$$\Psi_j \equiv \int_{\Omega_j} \theta_v q_{kj}(v)^{\frac{1}{2}} \mathrm{d}v. \tag{7}$$

The expression Ψ_j can be interpreted as a measure of industry supply. As a consequence, the inverse demand for each variety is now

$$p_{ij}(v) = R_j \theta_v q_{ij}(v)^{\frac{-1}{2}} \Psi_j^{-1}. \tag{8}$$

As expected, the price of a variety increases with its quality (θ_v) and the market size (R_j)

[4] Note that we could extend easily this framework by considering the case where U is embodied in a Cobb-Douglas upper-tier utility.

but decreases with its quantity (q_{ij}) and rivals' quantity and quality of products (Ψ_j).

Intensive margin of exports with no uncertainty

We start by analyzing briefly the export decision with no uncertainty before introduction uncertainty. Each firm maximizes its profit (1) by setting its output $q_{ij}(v)$ to serve market j and by taking into account its impact on prices $p_{ij}(v)$ given in (8). Profit-maximizing quantity is given by

$$q_{ij}(v)^{\frac{1}{2}} = \frac{R_j}{2} \frac{\varphi\theta_v}{w_i\tau_{ij}} \Psi_j^{-1}, \tag{9}$$

so that

$$p_{ij}(v) = 2\frac{w_i\tau_{ij}}{\varphi}.$$

Thus, under certainty, the equilibrium price is equal to the marginal cost $w_i\tau_{ij}/\varphi$ times a constant (equals to 2), while exports (in value and quantity) increases with productivity, quality and income.

In what follows, we analyze how uncertain demand curve affect equilibrium prices and quantities at the firm level.

Intensive margin of exports with uncertainty

Under uncertainty, remember that exporting firms face a downward sloping demand curve characterized by a random shift parameter R_j (common to all firms in a given industry). R_j is not known for certain at the time the contracts with the importers are signed. The expected price prevailing for each firm in the foreign market is therefore given by

$$\mathbb{E}\left[p_{ij}(v)\right] = \mathbb{E}(R_j)\theta_v q_{ij}(v)^{\frac{-1}{2}}\Psi_j^{-1}. \tag{10}$$

For the sake of clarity, we first consider a mean-variance utility function such that $\eta_v = 0$ (i.e., *downside* and *upside* risks are not accounted for). Then, we will consider the role of skewness with $\eta_v \neq 0$. The payoff of each firm when $\eta_v = 0$ is as follows:

$$\Pi_v(\pi_i) = \mathbb{E}(\pi_i) - \rho_v \mathbf{V}(\pi_i) = \sum\nolimits_j \mathbb{E}(\pi_{ij}) - \rho_v \sum\nolimits_j \mathbf{V}(\pi_{ij}),$$

where $\mathbb{E}(\pi_{ij})$ is given by (1) and $\Sigma_j \mathbf{V}(\pi_{ij}) = \mathbf{V}(\pi_i)$ because $\mathrm{Cov}(R_k, R_j) = 0$ for all $k \neq j$. Hence, the marginal revenue is uncertain while the marginal cost is known with certainty. The expected export sales $\mathbb{E}\left[p_{ij}(v)\right] q_{ij}(v)$ increases with q_{ij} but decreases with the industry's output size (captured through Ψ_j). The profit variance is

$$\mathbf{V}(\pi_{ij}) = \mathbf{V}(R_j)\theta_v^2 q_{ij}(v)\Psi_j^{-2}, \tag{11}$$

which increases with the firm's output size q_{ij} and decreases with the industry's output size. Hence, the mass of rivals serving the same market has an ambiguous effect on the export performance at the firm level. Indeed, a rise in Ψ_j decreases the marginal revenue of the firm but reduces the variance of profits.

First order condition $\partial \Pi_v / \partial q_{ij} = 0$ implies

$$\frac{1}{2}\mathbb{E}(R_j)\theta_v q_{ij}(v)^{\frac{-1}{2}}\Psi_j^{-1} - \frac{w_i \tau_{ij}}{\varphi} - \rho_v \mathbf{V}(R_j)\theta_v^2 \Psi_j^{-2} = 0, \tag{12}$$

and it is readily to check that $\partial^2 \Pi_v / \partial q_{ij}^2 < 0$. As a result, *Payoff*-maximizing quantity is given by

$$q_{ij}(v)^{\frac{1}{2}} = \frac{\mathbb{E}(R_j)\theta_v \varphi}{2 w_i \tau_{ij}} \Psi_j^{-1} \left[1 + \rho_v \mathbf{V}(R_j)\Psi_j^{-2} \frac{\theta_v^2 \varphi}{w_i \tau_{ij}}\right]^{-1}. \tag{13}$$

In accordance with the standard literature related to producer theory under uncertainty, the risk averse firms produce less than they would under certainty (because $\rho_v > 0$ so that $\partial q_{ij} / \partial \mathbf{V}(R_j) < 0$), for a given mass of exporters. Further, we can readily check that quantities are concave in productivity ($\partial q_{ij} / \partial \varphi > 0$ and $\partial^2 q_{ij} / \partial \varphi^2 < 0$). Thus, the most productive firms are the largest in terms of labor and quantity produced. Another result standard in the trade theory literature is that quantities are convex in trade costs, such that $\partial q_{ij} / \partial \tau_{ij} < 0$ and $\partial^2 q_{ij} / \partial \tau_{ij}^2 > 0$). Hence, export sales decrease with trade costs, while they increase with productivity. New and more original is the following proposition:

Proposition 3.1 *For a given positive degree of the firm's risk aversion ($\rho_v > 0$) and industry supply (Ψ), the negative effect of demand volatility on export quantities is strength-*

ened when firm productivity increases and trade cost decreases.

A simple proof is that from equation (13) we can establish that

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

when $\rho_v > 0$. Remember that the variance of profits in a given foreign market is equal to the variance of foreign demand times the output size dedicated to that foreign country (see equation 11). Stated differently, the variance of profits of a firm increases with its productivity and decreases with trade costs for a given mass of firms.

Using (8) and (13), we can now determine the *ex post* equilibrium price of variety v prevailing in country j:

$$p_{ij}(v) = \frac{w_i \tau_{ij}}{\varphi} 2 \frac{R_j}{\mathbb{E}(R_j)} \left[1 + \rho_v \mathbf{V}(R_j) \frac{\theta_v^2 \varphi}{w_i \tau_{ij}} \Psi_j^{-2}\right] \tag{14}$$

The equilibrium price is equal to the marginal cost ($w_i \tau_{ij}/\varphi$) times a markup. Remember that, under demand certainty, the markup is equal to 2 (because of $\mathbb{E}[R_j/\mathbb{E}(R_j)] = 1$ and $\mathbf{V}(R_j) = 0$). With uncertain demand and risk-averse firms, the markup is higher on average than the markup prevailing under certain demand due to the fluctuations of income. Hence, uncertain demand curve tends to increase prices through a higher markup.

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

In addition, under demand uncertainty, the markup captures two opposite effects associated with the destination income (R_j). On the one side, higher income raises the markup and, in turn, prices (demand effect). On the other side, higher expected foreign demand increases the competition across firms (which have an incentive to reduce their level of production) and, in turn, decreases the markup. However, on average, both effects cancel each other out ($\mathbb{E}[R_j/\mathbb{E}(R_j)] = 1$).

The next proposition sums up our results on destination prices:

Proposition 3.2 *For a given positive degree of the firm's risk aversion ($\rho_v > 0$) and industry supply (Ψ), the markup increases more with foreign demand uncertainty, the higher the firm productivity and the lower the trade cost.*

Propositions (3.1) and (3.2) are related to the intensive margin of trade, i.e., variation in trade of existing trade relationships. They are established without accounting for the adjustment in the industry supply (Ψ). However, uncertainty leads to an adjustment in the quantities produced by the competitors. This adjustment reinforces proposition (3.2) on export prices but renders proposition (3.1) on exported quantities more ambiguous. Before presenting the effect of the industry adjustment, we study the role of uncertainty on the extensive margin of trade, i.e., new trade relationships.

Extensive margin of exports with uncertainty

The mass of domestic firms in each country is exogenously given,[5] while the mass of exporting firms is treated as endogenous. There is a large supply of potential entrants in the international market. However, firms located in country i serving destination country j have to pay a fixed cost f_{ij} to serve foreign markets (see equation 1). The decision to exit or enter a foreign market is taken on the basis of the expected payoff. A firm exports to destination j if and only if *ex ante* payoff Π_v is positive, i.e., $\mathbb{E}(\pi_{ij}) - \rho_v \mathbf{V}(\pi_{ij}) > w_i f_{ij}$.

[5] An endogenous mass of domestic firms can be incorporated in the analysis without qualitatively changing any of the main results.

It is straightforward to check that $\Pi_v = s_{ij}/2$ where $s_{ij} \equiv \mathbb{E}(p_{ij})q_{ij}$ with

$$s_{ij} = \frac{\mathbb{E}(R_j)^2}{2}\left[\frac{w_i\tau_{ij}}{\theta_v^2\varphi}\Psi_j^2 + \rho_v \mathbf{V}(R_j)\right]^{-1}. \tag{15}$$

As a result, $\Pi_v = 0$ when $\varphi = 0$ and $\partial\Pi_v/\partial\varphi > 0$. Hence, there exists a quality-adjusted productivity cutoff $\theta_v^2\varphi$ above which a firm serves country j. As expected, the probability of exporting decreases with $\mathbf{V}(R_j)$. In addition, we have $\partial^2\Pi_v/\partial\varphi\partial\mathbf{V}(R_j) < 0$ so the payoffs of large firms are more impacted by a rise in demand volatility than the small firms. Notice also that $\partial\Pi_v/\partial\Psi_j < 0$ and $\text{sign}\{\partial^2\Pi_v/\partial\varphi\partial\Psi_j\} = \text{sign}\left\{\rho_v\mathbf{V}(R_j)\frac{\theta_v^2\varphi}{w_i\tau_{ij}} - \Psi_j^2\right\}$ so that a higher total supply decreases the *ex ante* payoff of each incumbent firm. However, the high productivity firms are less affected by a rise in Ψ_j.

Until now, we have studied the impact of $\mathbf{V}(R_j)$ on exports and prices for a given Ψ_j. However, Ψ_j adjusts when $\mathbf{V}(R_j)$ changes. Therefore, we have to take into account the indirect effect of demand volatility on prices and quantity through Ψ_j. In what follows, we determine the relationship between Ψ_j and $\mathbf{V}(R_j)$ and the total effect of $\mathbf{V}(R_j)$. Let $\xi \equiv 1/(\theta_v^2\varphi) \geq 0$ be an inverse measure of quality-adjusted productivity and $\mu(\xi)$ is the distribution of ξ. The cutoff for exporting $\widehat{\xi}_{ij}$ is such that $\Pi_v(\widehat{\xi}_{ij}) = w_i f_{ij}$ or, equivalently,

$$\widehat{\xi}_{ij} \equiv \left[\frac{\mathbb{E}(R_j)^2}{4w_i f_{ij}} - \rho_v\mathbf{V}(R_j)\right]\frac{\Psi_j^{-2}}{w_i\tau_{ij}}. \tag{16}$$

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 conditions $\widehat{\xi}_{ij}$ can be non positive. No firm finds *a priori* profitable to serve country j if the expected income $\mathbb{E}(R_j)$ is not sufficiently high relatively to its variance $\mathbf{V}(R_j)$. Hence, we provide a rationale for the prevalence of zeros in bilateral trade without making an *ad hoc* assumption on the distribution of productivity across firms. Helpman *et al.* (2008) allow also for zero bilateral trade volumes as the authors assume that the most productive firms exhibit a level of productivity which is below than the exporting threshold.

Uncertainty and industry adjustment

Although our modeling strategy gives our framework a partial equilibrium flavor, it does not remove the interdependence among firms within industries. We can show that

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

or, equivalently, $\partial\Psi_j/\partial\mathbf{V}(R_j) < 0$ (see Appendix (B)). As expected, an increase in the variance of income reduces the aggregate supply for destination market j and, in turn, the equilibrium prices. Hence, equilibrium prices (14) increase with demand fluctuations through two effects: (i) a direct effect due to risk aversion (as explained above) and (ii) an indirect effect *via* the exit of firms relaxing competition among surviving firms. In contrast, the effect of demand volatility on the export sales (or profits) is ambiguous when Ψ_j adjusts to a change in $\mathbf{V}(R_j)$. Indeed, we have

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

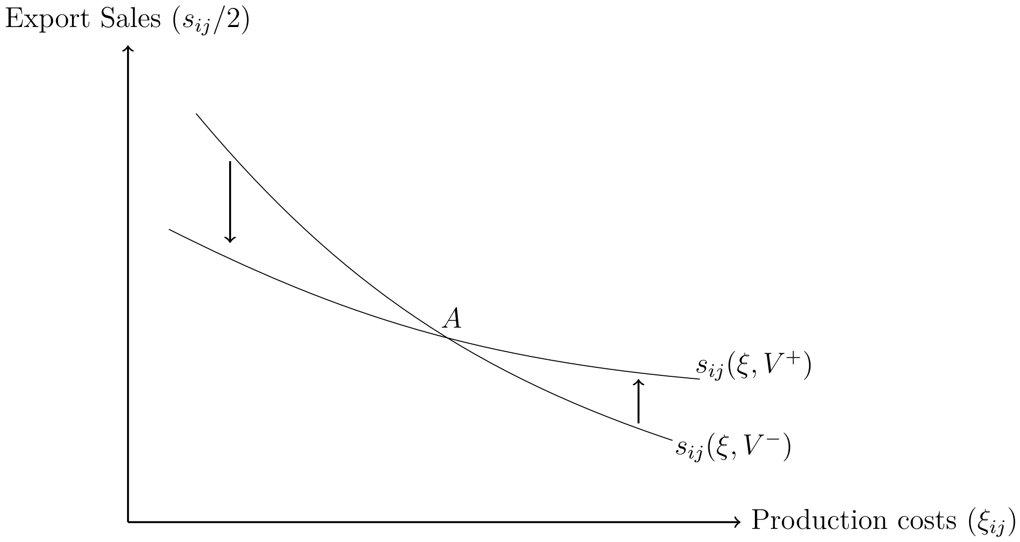
where $\partial s_{ij}(v)/\partial\mathbf{V}(R_j) < 0$ while $\partial s_{ij}/\partial\Psi_j < 0$ and $\partial\Psi_j/\partial\mathbf{V}(R_j) < 0$ (see above). It follows a rise in demand volatility induces a reallocation of market share from largest firms to smaller firms as $\mathrm{d}s_{ij}(v)/\mathrm{d}\mathbf{V}(R_j)$ increases with ξ. Hence, the aggregate productivity of exporters can decrease *ceteris paribus* with a higher uncertainty, in accordance with empirical facts (see Bloom, 2014). In addition, as the large firms reduce their export sales in high proportion when demand fluctuations increase, the export sales of smaller exporters may expand at the expense of largest firms (see Figure 3).

As a result, the effect of demand volatility on the probability of exporting is also ambiguous. Some standard calculations reveal that

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

where $\partial\widehat{\xi}_{ij}/\partial\mathbf{V}(R_j) < 0$ while $\partial\widehat{\xi}_{ij}/\partial\Psi_j < 0$ and $\partial\Psi_j/\partial\mathbf{V}(R_j) < 0$ (see above). Hence, the probability of serving a country decreases with the volatility of its demand provided

Figure 3: Productivity and reallocation of export sales when demand volatility increases



Note: V^{-} and V^{+} means low and high volatility, respectively.

that fixed trade costs or demand volatility are not too high. When fixed trade costs are low enough, more medium sized firms can export when demand fluctuations rise as the export sales of large firms decrease (see Figure 4).

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

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

so that the effects of $\mathbf{V}(R_j)$ on $q_{ij}(v)$ when Ψ_j reacts to a change in demand volatility are qualitatively similar to the effects on export sales. It 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).

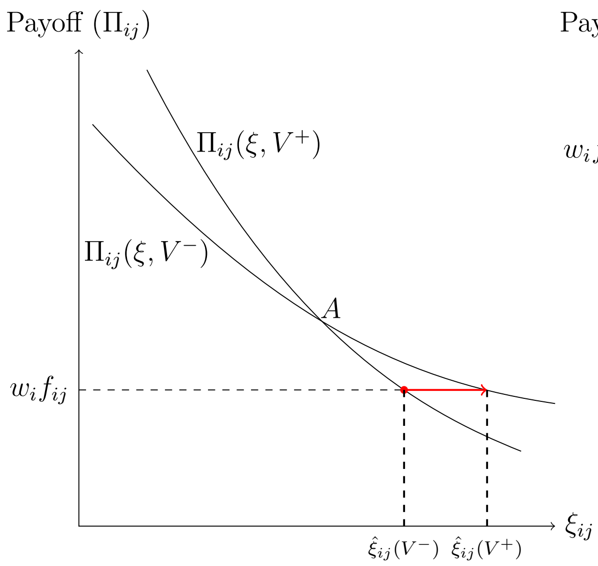
To summarize:

Proposition 3.3 *A rise in* industry-level *foreign demand uncertainty decreases industry export sales but*

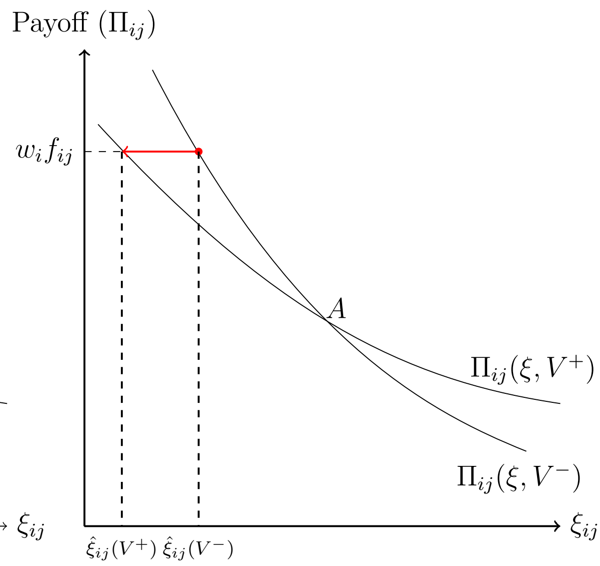
(i) decreases the export sales of large firms and increases the market share of medium sized firms;

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

Figure 4: The impact of higher demand 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^{+} means low and high volatility, respectively. ξ_{ij}: production costs.

The bad and the good variance: the role of skewness

We have considered a mean-variance analysis. The basic intuition is that the exporters prefer higher expected returns and lower risk. However, we should consider that, *ceteris paribus*, entrepreneurs prefer a high probability of an extreme event in the positive direction over a high probability of an extreme event in the negative direction. In order to take into account the fact that the marginal willingness of exporter to accept a risk increases when the distribution of the risk becomes more skewed to the right, we now consider the mean-variance-skewness utility function where $\eta_v > 0$. The payoff of each firm is given by (3). Given the inverse demand of consumers, we have

$$\mathbf{S}(\pi_{ij}) = \mathbf{S}(R_j)\theta_v^3 q_{ij}^{\frac{3}{2}}(v)\Psi_j^{-3}. \tag{17}$$

and the *Payoff*-maximizing quantity is implicitly given by $\partial\Pi_o/\partial q_{ij} = 0$, or, equivalently,

$$\frac{\mathbb{E}(R_j)}{2}\theta_v\Psi_j^{-1} - \left(w_i\frac{\tau_{ij}}{\varphi} + \rho_v\mathbf{V}(R_j)\theta_v^2\Psi_j^{-2}\right)q_{ij}(v)^{\frac{1}{2}} + \eta_v\frac{3\mathbf{S}(R_j)\theta_v^3\Psi_j^{-3}}{2}q_{ij}(v) = 0. \tag{18}$$

Clearly, if the income distribution is positively (resp., negatively) skewed, each exporter has an incentive to increase (resp., decrease) its level of output for a given $\mathbf{V}(R_j)$. The degree of skewness modifies the desirability of risk. It is readily to check that our predictions related to the impact of $\mathbf{V}(R_j)$ on quantity and prices according to the level of productivity and trade costs hold when $\mathbf{S}(R_j) \neq 0$. Using envelop theorem, it is straightforward to verify that $\partial q_{ij}/\partial \mathbf{S}(R_j) > 0$ whereas $\partial p_{ij}/\partial \mathbf{S}(R_j) < 0$ when the second order condition holds $(\mathbb{E}(R_j)\Psi_j^2 - \eta_v 3\mathbf{S}(R_j)\theta_v^2 q_{ij}(v) > 0)$. Regardless of the sign of $\mathbf{S}(R_j)$, an income distribution that is more skewed to the right induces higher level of output. More interesting, standard calculations show that

$$\frac{\partial^2 q_{ij}}{\partial \varphi \partial \mathbf{S}(R_j)} > 0 > \frac{\partial^2 q_{ij}}{\partial \tau \partial \mathbf{S}(R_j)} \quad \text{and} \quad \frac{\partial p_{ij}}{\partial \tau \partial \mathbf{S}(R_j)} > 0 > \frac{\partial p_{ij}(v)}{\partial \varphi \partial \mathbf{S}(R_j)}$$

as $\partial q_{ij}/\partial \varphi > 0$ and $\partial q_{ij}/\partial \tau > 0$. The magnitude of the positive impact of a higher $\mathbf{S}(R_j)$ on production is higher for firms exhibiting a higher productivity and for destination implying lower trade costs. The prices move in the opposite direction.

4 Empirical Analysis

This section is still incomplete by focusing only on the role of uncertainty on the intensive margin of trade.

4.1 Identification strategy

According to our theoretical predictions exporters react in response to volatility by decreasing volumes $\left(\frac{\partial q_{ij}}{\partial \mathbf{V}(R_j)} < 0\right)$ and increasing prices $\left(\frac{\partial p_{ij}}{\partial \mathbf{V}(R_j)} > 0\right)$, while in response to upside gains exporters increase volumes $\left(\frac{\partial q_{ij}}{\partial \mathbf{S}(R_j)} > 0\right)$ and reduce prices $\left(\frac{\partial p_{ij}}{\partial \mathbf{S}(R_j)} < 0\right)$.

The estimations of these predictions may be plagued by potential endogeneity at the aggregate level between trade openness and demand volatility. To mitigate this potential bias we exploit the following strategy of identification. We use French firm exports at the *4-digit* level k in a given year as our dependent variable. Then, we regress disaggregated French exports on three different moments of the distribution of demand R in destination j: the lagged expected value $\left(\mathbb{E}(R^K_{j,t-1})\right)$, the volatility $\left(\mathrm{V}(R^K_{jt})\right)$ and the skewness $\left(\mathrm{S}(R^K_{jt})\right)$ of demand at the *3-digit* sector level. We expect variation in French 4-digit exports to be explained by 3-digit demand shifters in destination countries. However, in turn, it is unlikely that a particular 4-digit export in a destination affects substantially a 3-digit sector demand in that destination. The 3-digit demand in a country is made of imports from all sources (including itself) and all 4-digit sub-sectors. To reinforce this strategy of identification, we remove French flows to compute countries' demand and its moments. Moreover, we exploit the different sources of variation of our panel and use various combinations of fixed effects to control for unobservables: firm f, destination j, 4-digit sector k and time (year) t fixed effects.

4.2 Data

Demand R in destination country j is proxied with apparent consumption such as: $a^K_{jt} = \text{Production}^K_{jt} + \text{Imports}^K_{jt} - \text{Exports}^K_{jt}$, where K is 3-digit sector and t year. Our sectoral data on production, exports and imports come from COMTRADE and UNIDO and covers the period 1995 to 2009. Using the absorption formula and the sector data, we construct three important regressors at the industry 3-digit level K in the destination country j. They correspond to three different moments of apparent consumption:

1. The mean demand or absorption $\left(\mathbb{E}(R^K_{j,t-1})\right)$ computed in year t as the log of the lagged value of mean absorption over the 5 previous years;

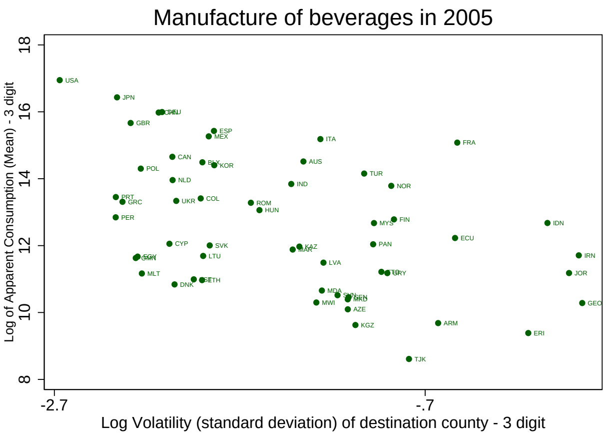
2. The volatility of demand $\left(\mathrm{V}(R^K_{jt})\right)$ computed as the standard deviation of the yearly growth rates of a^K_{jt} over 6 years and the sub-sectors k. As an example, consider the manufacture of beverages (K=155) in the United Kingdom in 2000. We first compute the yearly growth rates of the UK's apparent consumption over 1995 to 2000, and over the 4 sub-sectors of 155.[6] Then, we compute the standard deviation of the 20 growth rates. Figure (5) reports the volatility of demand in the manufacture

[6] The 4 sub-sectors are: 1551 - Distilling, rectifying and blending of spirits; ethyl alcohol production from fermented materials; 1552 - Manufacture of wines; 1553 - Manufacture of malt liquors and malt; 1554 - Manufacture of soft drinks; production of mineral waters.

of beverages in 2005. For a same level of mean demand for beverages in 2005, we observe different levels of demand volatility.

3. The unbiased skewness of demand $\left(\mathrm{S}(R_{jt}^{K})\right)$ computed as the skewness of the yearly growth rates of a_{jt}^{K} over 6 years and the sub-sectors k.

Figure 5: Demand level and demand volatility of a given 3-digit sector



To construct our dependent variable and test our theoretical predictions we use very rich firm-destination specific export data from the French customs over the period 2000 to 2009. We observe volume (in tons) and value (in euros) of exports for each product and destination, for each firm located on the French metropolitan territory. Unit values are computed as the ratio of export value to export volume. On average per year we have 60,000 firms, 70 destinations j and 117 4-digit sectors k.

4.3 Empirical results

Export volumes

The estimated equation for the *export volumes* comes directly from the theoretical model:

$$\ln q_{fjt}^{k} = \ln \mathbb{E}(R_{jt}^{K}) + \rho \mathrm{V}(R_{jt}^{K}) + \eta \mathrm{S}(R_{jt}^{K}) + \mathbf{FE} + \varepsilon_{fjt}^{k}, \tag{19}$$

where q_{fjt}^{k} is French firm f export volumes to j in 4-digit k in year t. This variable is regressed on different moments of demand defined in the data section (4.2). **FE** represents a vector of different combinations of fixed effects. The estimations of equation (19) is reported in Table (1). The sample covers the period 2000 to 2009.

Table 1: Firm level estimations: export volumes

Dep. Var.:	Firm export volumes: $\ln q_{fjt,k}$		
	(1)	(2)	(3)
Log Mean Demand$^{3K}_{j,t-1}$	0.211^a	0.079^a	0.063^a
	(0.031)	(0.014)	(0.010)
Ln Volatility$^{3K}_{jt}$	-0.021^a	-0.030^a	-0.025^a
	(0.008)	(0.009)	(0.007)
Skewness$^{3K}_{jt}$	0.009^a	0.015^a	0.013^a
	(0.003)	(0.004)	(0.003)
R^2	0.813	0.705	0.760
Fixed Effects:			
Firm.Destination.Sector$_{fjk}$	Yes	-	-
Time$_t$	Yes	-	-
Firm.Destination.Time$_{fjt}$	-	Yes	-
Sector (4-digit)$_k$	-	Yes	-
Firm.Sector.Time$_{fkt}$	-	-	Yes
Destination$_j$	-	-	Yes

Note: Robust and clustered standard errors in parentheses.
$^a: p < 0.01$, $^b: p < 0.05$, $^c: p < 0.1$. N=5,333,934.

The results are in line with our theoretical predictions. An increase in demand level and demand skewness in destination markets increases export volumes. In contrast, an increase in volatility reduces exports. How economically meaningful are the estimates of volatility and skewness? Based on the first column within estimates, we find that in 2005 a one standard deviation increase in the average of volatility of Belgium, reduces aggregate French exports to Belgium by 1.2%, while a one standard deviation increase in the average of volatility of China, reduces aggregate French exports to China by 1.3%. Moreover, if the United Kingdom market would be as volatile as Vietnam, French exports to the UK would decrease by 2.5%. On the other hand, if the UK would be as skewed as Vietnam, French exports to the UK would increase by 0.5%. This implies that both absolute and downside risk matter for exporters.

Export prices

The estimated equation for the *export prices* comes from the theoretical model as well:

$$\ln p_{fjt}^k = \ln\left(\frac{R_{j,t-1}^K}{\mathbb{E}(R_{j,t-1}^K)}\right) + \rho \mathrm{V}(R_{jt}^K) + \eta \mathrm{S}(R_{jt}^K) + \mathbf{FE} + \varepsilon_{fjt}^k, \tag{20}$$

where p_{fjt}^k is French firm f export unit values to destination j in 4-digit sector k in year t. Table (2) reports the estimates of equation (20) with the same sets of fixed effects as for the export volumes.

Table 2: Firm level estimations: export prices

Dep. Var.:	Firm export unit values: $\ln uv_{fjt,k}$		
	(1)	(2)	(3)
Ln Demand$_{j,t-1}^{3K}$	0.017^a	0.010	0.010^c
	(0.007)	(0.014)	(0.005)
Ln Mean Demand$_{j,t-1}^{3K}$	-0.028^a	-0.016	-0.015^b
	(0.011)	(0.015)	(0.006)
Ln Volatility$_{jt}^{3K}$	0.014^a	0.007	0.005^b
	(0.005)	(0.005)	(0.002)
Skewness$_{jt}^{3K}$	-0.004^b	-0.003	-0.001
	(0.002)	(0.002)	(0.001)
R^2	0.843	0.834	0.872
Fixed Effects:			
Firm.Destination.Sector$_{fjk}$	Yes	-	-
Time$_t$	Yes	-	-
Firm.Destination.Time$_{fjt}$	-	Yes	-
Sector (4-digit)$_k$	-	Yes	-
Firm.Sector.Time$_{fkt}$	-	-	Yes
Destination$_j$	-	-	Yes

Note: Robust and clustered standard errors in parentheses.
$^a: p < 0.01$, $^b: p < 0.05$, $^c: p < 0.1$. N=5,333,934.

Results on export prices are in line with our predictions but are not robust across all specifications. The within estimates, reported in column (1), highlight the two opposite effects associated with the destination demand. On the one side, higher lagged demand raises export prices (demand effect). On the other side, higher expected foreign demand, captured by the mean demand variable, increases the competition across firms (which have an incentive to reduce their level of production) and, in turn, decreases prices. As expected, the volatility and skewness estimates have an opposite effect compared with their influence on export volumes.

Interaction effects of uncertainty

Proposition (3.1) establishes that the negative effect of demand volatility on export quantities is strengthened when firm productivity increases and trade cost decreases. Remember that the variance of profits in a given foreign market is equal to the variance of foreign demand times the output size dedicated to that foreign country. Stated differently, the variance of profits of a firm increases with its productivity and decreases with trade costs for a given mass of firms.

To capture the non-linearity related to trade costs, we first interact the volatility of demand with the distance variable, which is a usual proxy for trade costs. Results are presented in Table (3). They report that the estimate of the interaction term is positive, which is line with our theoretical prediction: $\partial^2 q_{ij}/\partial\tau_{ij}\partial \mathrm{V}(R_j) > 0$.

Table 3: Interaction of volatility with distance: export volumes

Dep. Var.:	Exports volumes: $\ln q_{fjt,k}$		
Ln Mean Demand$^{3K}_{j,t-1}$	0.203^a	0.080^a	0.064^a
	(0.030)	(0.014)	(0.010)
Ln Volatility$^{3K}_{jt}$	-0.091^b	-0.282^a	-0.164^a
	(0.046)	(0.058)	(0.040)
Ln **Volatility**$^{3K}_{jt}$ × Ln **Distance**$_j$	**0.010**^{c}	**0.036**^{a}	**0.019**^{a}
	(0.006)	(0.007)	(0.005)
Skewness$^{3K}_{jt}$	0.008^a	0.015^a	0.013^a
	(0.003)	(0.004)	(0.003)
R^2	0.813	0.699	0.755
Fixed Effects:			
Firm.Destination.Sector$_{fjk}$	Yes	-	-
Time$_t$	Yes	-	-
Firm.Destination.Time$_{fjt}$	-	Yes	-
Sector$_k$	-	Yes	-
Firm.Sector.Time$_{fkt}$	-	-	Yes
Destination$_j$	-	-	Yes

Note: Robust and clustered standard errors in parentheses.
^{a} : $p < 0.01$, ^{b} : $p < 0.05$, ^{c} : $p < 0.1$. N=5,333,934.

Before presenting the results on the non-linearity of productivity, we reproduce the estimations of Table (3) with export prices as the dependent variable. Proposition (3.2) states that the price increases more with foreign demand uncertainty, the lower the trade cost. The results, reported in Table (4), confirm this prediction: the estimate of the interaction term between distance and volatility is negative, in line with our prediction: $\partial^2 p_{ij}/\partial\tau_{ij}\partial \mathrm{V}(R_j) < 0$.

To capture the non-linear effect of firm productivity and volatility on export volumes

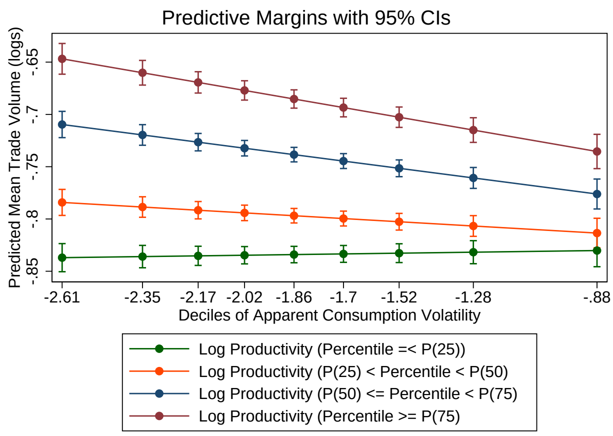
Table 4: Interaction of volatility with distance: export prices

Dep. Var. Firm exports in:	Unit values: $\ln uv_{fjt,k}$		
Ln Demand$^{3K}_{j,t-1}$	0.017^a	0.012	0.010^c
	(0.007)	(0.014)	(0.005)
Ln Mean Demand$^{3K}_{j,t-1}$	-0.029^b	-0.019	-0.015^b
	(0.011)	(0.015)	(0.006)
Ln Volatility$^{3K}_{jt}$	0.083^a	0.181^a	0.047^a
	(0.029)	(0.032)	(0.015)
Ln **Volatility**$^{3K}_{jt}$ $\times$ Ln **Distance**$_j$	**-0.010**^{a}	**-0.024**^{a}	**-0.006**^{a}
	(0.004)	(0.004)	(0.002)
Skewness$^{3K}_{jt}$	-0.004^b	-0.003	-0.001
	(0.002)	(0.002)	(0.001)
R^2	0.843	0.834	0.873
Fixed Effects:			
Firm.Destination.Sector$_{fjk}$	Yes	-	-
Time$_t$	Yes	-	-
Firm.Destination.Time$_{fjt}$	-	Yes	-
Sector$_k$	-	Yes	-
Firm.Sector.Time$_{fkt}$	-	-	Yes
Destination$_j$	-	-	Yes

Note: Robust and clustered standard errors in parentheses.
^{a} : $p < 0.01$, ^{b} : $p < 0.05$, ^{c} : $p < 0.1$. N=5,333,934.

$(\partial^2 q_{ij}/\partial\varphi\partial \mathrm{V}(R_j) < 0)$, we use the following strategy: we split the log of productivity into quartiles and interact the four categories with the deciles of volatility. The different point estimates are plotted in Figure (6). This plot shows three interesting results: (1) the most productive firms export more than the others; (2) the larger the demand volatility, the lower the export volumes for all levels of productivity; and (3) the marginal decrease in exports is larger for the most productive firms as the volatility increases.

Figure 6: Volatility, productivity and export volumes



5 Preliminary conclusion

Does demand volatility matter for exports? Yes and skewness as well!

References

Baldwin, R., and P. Krugman (1989): "Persistent Trade Effects of Large Exchange Rate Shocks," *Quarterly Journal of Economics*, 104(4), 635–654.

Bloom, N. (2014): "Fluctuations in Uncertainty," *Journal of Economic Perspectives*, 28(2), 153–175.

Dixit, A. K., and R. S. Pindyck (1994): *Investment under Uncertainty*. Princeton University Press.

Dixit, A. K., and J. E. Stiglitz (1977): "Monopolistic Competition and Optimum Product Diversity," *American Economic Review*, 67(3), 297–308.

Eeckhoudt, L., C. Gollier, and H. Schlesinger (2005): *Economic and Financial Decisions under Risk*. Princeton University Press.

Gabaix, X. (2011): "The Granular Origins of Aggregate Fluctuations," *Econometrica*, 79(3), 733–772.

Giovanni, J. d., and A. A. Levchenko (2009): "Trade openness and volatility," *Review of Economics and Statistics*, 91(3), 558–585.

Handley, K., and N. Limao (2013): "Policy Uncertainty, Trade and Welfare: Theory and Evidence for China and the US," Discussion Paper 19376, National Bureau of Economic Research.

Helpman, E., and A. Razin (1978): "A theory of international trade under uncertainty," Discussion paper, Academic Press, Harcourt Brace Jovanovitch.

Klemperer, P., and M. Meyer (1986): "Price competition vs. quantity competition: the role of uncertainty," *RAND Journal of Economics*, 17(4), 618–638.

Krugman, P. R. (1979): “Increasing returns, monopolistic competition, and international trade,” *Journal of international Economics*, 9(4), 469–479.

Leland, H. E. (1972): “Theory of the firm facing uncertain demand,” *American Economic Review*, 62(3), 278–291.

Lewis, T. L. (2014): “Exports versus Multinational Production under Nominal Uncertainty,” *Journal of International Economics*, forthcoming.

Melitz, M. J. (2003): “The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity,” *Econometrica*, 71(6), 1695–1725.

Menezes, C., C. Geiss, and J. Tressler (1980): “Increasing Downside Risk,” *American Economic Review*, 70(5), 921–932.

Popov, A. A. (2011): “Output Growth and Fluctuations: The Role of Financial Openness,” Discussion paper, ECB Working Paper.

Ramondo, N., V. Rappoport, and K. J. Ruhl (2013): “The Proximity-Concentration Tradeoff under Uncertainty,” *Review of Economic Studies*, 80(4), 1582–1621.

Zhelobodko, E., S. Kokovin, M. Parenti, and J.-F. Thisse (2012): “Monopolistic competition: Beyond the constant elasticity of substitution,” *Econometrica*, 80(6), 2765–2784.

Appendices

A Price setting

The demand for a variety v is

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

so that

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

Summing this expression over each variety consumed in country j yields

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

implying the demand for a variety can be rewritten as follows

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

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:

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

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

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

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

The first order condition implies that the equilibrium price is implicitly given by

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

$$\Phi(p_{ij}) \equiv -\left(p_{ij} - 2c_{ij}\right)\mathbb{E}(R_j) + \rho_v\left(p_{ij}^2 - 2c_{ij}^2\right)2p_{ij}^{-2}P_j\theta_v^2\mathbf{V}(R_j) \tag{21}$$

while the second order condition implies

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

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

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

Without uncertainty, the equilibrium price would be $p_{ij} = 2c_{ij}$, which is identical to the price prevailing when firms determine strategically the level of quantity. However, under uncertainty, $p_{ij} = 2c_{ij}$ is not an equilibrium as long as $\rho_v > 0$. Introducing $p_{ij} = 2c_{ij}$ into (21) implies $\Phi(p_{ij}) > 0$ so that the equilibrium price under uncertainty is higher than $2c_{ij}$. Using the envelop theorem:

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

B Industry supply and income volatility

In this Appendix, we show that $\partial\Psi_j/\partial\mathbf{V}(R_j) < 0$. According to (7) and (13), we have $\Lambda[\Psi_j, \mathbf{V}(R_j)] = 0$ with

$$\Lambda \equiv \Psi_j - \sum_k M_k\int_0^{\widehat{\xi}_{kj}}\frac{\mathbb{E}(R_j)}{2}\Psi_j^{-1}\left[w_k\tau_{kj}\xi + \rho_v\mathbf{V}(R_j)\Psi_j^{-2}\right]^{-1}\mu(\xi)\mathrm{d}\xi,$$

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

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

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

$$\frac{\partial\Lambda}{\partial\Psi_j} = \begin{array}{c} 1 - \Psi_j^{-1}\sum_k M_k \int_0^{\widehat{\xi}_{kj}} \theta_v \left[q_{kj}(\xi)\right]^{\frac{1}{2}} \frac{\rho_v \mathbf{V}(R_j)\Psi_j^{-2} - w_k\tau_{kj}\xi}{\rho_v \mathbf{V}(R_j)\Psi_j^{-2} + w_k\tau_{kj}\xi} \mu(\xi)\mathrm{d}\xi \\ -\frac{\partial\widehat{\xi}_{kj}}{\partial\Psi_j}\theta_v \left[q_{kj}(\widehat{\xi}_{kj})\right]^{\frac{1}{2}}, \end{array} \tag{22}$$

where $\partial\Lambda/\partial\Psi_j > 0$ as the second term on the RHS of (22) is inferior to 1 and $\partial\widehat{\xi}_{kj}/\partial\Psi_j < 0$. As a result,

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