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Volatility, financial Constraints, and trade

by

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Abstract

We construct a dynamic monopolistic competition model with heterogeneous firms to study the links between firms' earnings volatility, the degree of financial constraints that they face, their survival probabilities, and their export market participation decisions. Our model predicts that more volatile firms are more likely to face financial constraints and to go bankrupt, need to be more productive to stay in the market, and are more likely to enter export markets. A further implication is that through market diversification, exports tend to stabilize firms' total sales. We test these predictions, using a panel of 9292 UK manufacturing firms over the period 1993-2003. The data provide strong support to our model.

JEL Classification: D21; F12; G33; L11

Keywords: Firm-level volatility; Financial constraints; Firm survival; Exports

Outline

Non-technical summary

A rise in firm-level income volatility has been documented in the US and Europe in recent years. A number of studies have focused on the causes of this rise; fewer on its consequences. We construct a dynamic model of monopolistic competition aimed at studying the impact of firms' income volatility on the degree of financial constraints that they face, and on their probabilities of survival, and of entering export markets.

Our model assumes that each firm has to borrow a certain fixed amount to operate in the market, and that it faces a normally distributed income shock, which determines its income volatility. We derive a function relating a firm's productivity and volatility with its access to credit, whereby more productive and less volatile firms can obtain cheaper loans. As volatility increases, the cost of obtaining external funds grows, since lenders expect lower returns from highly volatile firms in the case of bankruptcy. Keeping other firm's characteristics constant, more volatile firms are more likely to go bankrupt and need to be more productive to stay in the market.

When the country opens up to trade, the model predicts that exporters can smooth their income. Entering export markets leads to two contrasting effects on the degree of financing constraints faced by firms. First, if the sunk cost that need to be paid to enter export markets are not too high, exporters experience a decrease in their financial constraints because, from the point of view of the bank, they have become less risky, due to their reduced volatility. Second, trade simultaneously increases competition, which decreases the expected profits of some incumbent firms. As competition rises, the probability of bankruptcy increases for some firms, limiting their access to external funds. We show that in the first case, trade can generate a reallocation of firms in the market, such that less productive and less volatile firms are replaced with highly productive and volatile ones. However, in the second case, trade does not necessarily raise average productivity in the market. Our analysis also shows that more volatile firms have more incentives to trade than their less volatile counterparts, as they take more advantage from the benefit of sales stabilization and associated lower financial costs. Volatility provides therefore a link between trade and the financial costs faced by the firms.

We test the predictions of the model using a panel of 9292 UK manufacturing firms over the period 1993-2003. We find empirical evidence showing that more volatile firms are more likely to go bankrupt, need to be more productive to stay in the market, and are more likely to enter export markets. A further result is that through market diversification, exports tend to stabilize firms' total sales.

1. Introduction

A rise in the volatility of firms' earnings streams has been documented throughout the world in recent years[1]. According to Comin and Philippon (2005), this may be due to increased competition in product markets, which might in turn follow from deregulation, increases in R&D investment, and higher use of debt and equity.

A vast literature has dealt with the adverse effects associated with high firm-level earnings volatility. For instance, Burgstahler and Dichev (1997) have shown that high volatility is costly for firms, as it implies high costs in transactions with stakeholders. Gibbins et al. (1990), Chaney and Lewis (1995), and Fudenberg and Tirole (1995) have insisted on the adverse reputation effects of high earnings volatility for firm managers. Other papers have shown that high volatility limits firms' access to external funds, and increases the cost of obtaining credit (Badrinath et al., 1989; Barnes, 2001; Minton and Schrand, 1999)[2]. Consequently, in order to avoid these adverse effects, managers should try to smooth their earnings. One possible way to achieve this goal is by exporting (Hirsch and Lev, 1971; Campa and Shaver, 2002). In this way, firms can diversify their incomes, leading to more stable cash flow and earnings streams (Buch et al. 2006), and, in turn, to a lower degree of financial constraints (Greenaway et al., 2007). To the best of our knowledge, no paper in the literature has analyzed the extent to which firm-level earnings volatility affects firms' survival probabilities and their decisions to enter export markets. Our paper bridges this gap.

We construct a dynamic model of monopolistic competition aimed at studying the impact of firms' income volatility on the degree of financial constraints that they face[3], which in turn affects their probabilities of survival, and of entering export markets. Specifically, our model assumes that each firm has to borrow a certain fixed amount to operate in the market, and that it faces a normally distributed income shock, which determines its income volatility. We derive a function relating a firm's productivity and income volatility with its access to credit, whereby more productive and less volatile firms can obtain cheaper loans. As volatility increases, the cost of obtaining external funds grows, since lenders expect lower returns from highly volatile firms in case of bankruptcy. Keeping other firm's characteristics constant, more volatile firms are therefore more likely to go bankrupt and need to be more productive to stay in the market.

When the country opens up to trade, our model predicts that exporters can smooth their income. Entering export markets leads to two contrasting effects on the degree of financing constraints faced by

[1] See Chaney et al. (2002) and Comin and Mulani (2004), who document this trend focusing on US firms; Comin and Philippon (2005), who analyze firms in 80 OECD countries; Thesmar and Thoenig (2004), who look at French firms; and Angelidis and Tessaromatis (2005), whose study is based on the UK.
[2] Focusing on a different perspective, Comin et al. (2006) show that increased firm-level earnings volatility in the US explains about 60 percent of the observed increase in the high frequency volatility of wages.
[3] We will hereafter use the terms income volatility and earnings volatility interchangeably.

firms. First, if the sunk cost that needs to be paid to enter export markets is not too high, exporters experience a decrease in their financial constraints because, from the point of view of the bank, they have become less risky, due to their reduced volatility. Second, trade simultaneously increases competition, which decreases the expected profits of some incumbent firms. As competition rises, the probability of bankruptcy increases for some companies, limiting their access to external funds. We show that in the first case, trade can generate a reallocation of firms in the market, such that less productive and less volatile firms are replaced with highly productive and volatile ones. However, in the second case, trade does not necessarily raise average productivity in the market. Our analysis also shows that more volatile firms generally have more incentives to trade than their less volatile counterparts, as they take more advantage from the benefit of sales stabilization and associated lower financial costs. Volatility provides therefore a link between trade and the financial costs faced by firms.

Our model can be seen as an extension of Melitz's (2003) framework, in which firms' earnings volatility, and, consequently, their ability to obtain external credit are included as new elements of firm heterogeneity, in addition to productivity. We test the predictions of the model using a panel of 9292 UK manufacturing firms over the period 1993-2003. Our choice of the UK in our empirical testing of the model stems from the fact that the UK is the fifth largest exporter of manufactures globally, and within our sample, almost 70 percent of all firms exported in at least one year. Moreover, on average, 30 percent of the total sales of UK exporters are directed abroad. We find empirical evidence showing that more volatile firms are more likely to go bankrupt, need to be more productive to stay in the market, and are more likely to enter export markets. A further result is that through market diversification, exports tend to stabilize firms' total sales.

The rest of the paper is laid out as follows. In Section 2, we outline our model, in the closed economy case. Section 3 focuses on the open economy case. In Section 4, we summarize the main testable implications that can be derived from our model. Section 5 describes our data. Section 6 tests the main implications of the model, and Section 7 concludes.

2. Closed economy model

2.1 Demand

We assume that the economy has two sectors: one is characterized by a numeraire good, and the other by differentiated products. The preferences of a representative consumer are given by the following intertemporal utility function:

$$U = \int_0^\infty (x_0 + \log Y)\, e^{-\hat{r}t} dt \,, \tag{1}$$

where $\hat{r}$ is the discount factor, x_0 is the consumption of the numeraire good, and Y is an index of consumption of the differentiated products that reflects the consumer's taste for varieties. Y can be expressed as: $Y = \left[\int_0^M y_z^{\rho} dz \right]^{\frac{1}{\rho}}$, where $0 < \rho < 1$; y_z is the quantity of variety z of the differentiated product demanded by the consumer; M is the mass of firms in the stationary competitive equilibrium; and $\alpha = 1/(1-\rho)$ is the elasticity of substitution among varieties. As shown by Dixit and Stiglitz (1977), the consumer's behavior can be modeled considering the set of varieties of the aggregate good Y consumed, with aggregate price $P_Y = \left[\int_0^M p_z^{1-\alpha} dz \right]^{\frac{1}{1-\alpha}}$. In this set-up, the aggregate demand for any of the varieties of the differentiated product is given by $y_z = \frac{p_z^{-\alpha}}{P_Y^{1-\alpha}} E$, where E is aggregate expenditure that we normalize to one, and p_z is the price of the good (see Grossman and Helpman, 1991, for a similar approach).

2.2 *Production*

We assume that firms are heterogeneous. The first element of heterogeneity among firms is their level of productivity, denoted by $\varphi \in [\hat{\varphi}, \infty)$, where $\hat{\varphi} > 0$ is the minimum level of productivity in the market equilibrium. In monopolistic competitive markets, productivity affects the firms' variable cost. More productive firms have lower marginal costs than their less productive counterparts. Firms' revenues depend on the average productivity in the market $\overline{\varphi}(\hat{\varphi}) > \hat{\varphi}$, which is a function of the threshold productivity[4]. Each of the differentiated goods is produced only with labor. The technology used to produce each good is given by: $l(\varphi, \overline{\varphi}) = I + y(\varphi, \overline{\varphi})/\varphi$, where l is labor, and I is a fixed cost. This leads to the standard pricing rule $p(\varphi) = 1/(\rho\varphi)$, where the numerator represents the common wage rate, normalized to one. Firms with high levels of productivity charge lower prices and obtain higher revenues[5].

We introduce a second and new element of heterogeneity among firms: their idiosyncratic income volatility, denoted by $\sigma \in [0, \infty)$. Volatility affects firms' output through an exogenous firm-specific demand shock which occurs in each period, immediately after they have chosen prices and

[4] In the remaining part of the paper, we omit this dependence from our notation, except when needed in derivations.

[5] As in Melitz (2003), $P_Y = M^{\frac{1}{1-\alpha}} p(\overline{\varphi})$. Therefore, $y(\varphi, \overline{\varphi}) = \rho\, M^{-1} \varphi^{\alpha} (\overline{\varphi})^{1-\alpha}$.

quantities. Specifically, in each period, a firm's income is given by $z_t(\sigma)p(\varphi)y(\varphi,\overline{\varphi})$, where z_t is the demand shock, which is distributed normally with mean equal to one and standard deviation σ. Note that if $\sigma = 0$ for all firms, the model simplifies to Melitz's (2003) case. We consider that firms' productivity and income volatility are exogenous, independent, and constant parameters[6].

2.3 The firm's problem

Each firm faces a cash-in advance constraint: at the beginning of every period it needs to incur a fixed cost to enter the market, and requires the bank to finance it[7]. Both the bank and the borrower are assumed to be risk neutral. As in Cooley and Quadrini (2001), only one period debt contracts are signed with the bank. If the firm defaults, the bank liquidates it, and the firm immediately exits the industry. The profit of a firm of type (φ,σ), at period *t* after the realization of its shock z_t can be written as:

$$\Pi_t(\varphi,\overline{\varphi},\sigma,z_t) = z_t p(\varphi)y(\varphi,\overline{\varphi}) - \frac{y(\varphi,\overline{\varphi})}{\varphi} - \left[1+r(\varphi,\overline{\varphi},\sigma)\right]I \qquad (2)$$

We assume that the bank perfectly observes the firm's characteristics. It makes a take-it-or-leave-it offer to the firm at the beginning of every period[8], and issues funds at an interest rate *r*, that differs among firms. As in Cooley and Quadrini (2001), we assume that the bank chooses the interest rate in such a way that the expected repayment from the loan is equal to the repayment of a riskless loan. This is summarized in the following equation:

$$(1+r_0)I = [1+r(\varphi,\overline{\varphi},\sigma)]\ \mathrm{I}\ [1-\delta(\varphi,\overline{\varphi},\sigma,r)] + C(\sigma)\delta(\varphi,\overline{\varphi},\sigma,r),$$

$$\text{where } (1+r_0)I > C(\sigma). \qquad (3)$$

The left-hand side of Equation (3) gives the return of the loan at the riskless interest rate r_0. The right hand side says that with probability ($1-\delta$), the firm can repay its debts, and with probability δ, it goes bankrupt. In case of bankruptcy, the bank gets a collateral denoted by $C(\sigma)$. The bank does not observe the future value of the collateral. However, since the firm's earnings can be used as collateral, ex-ante, the bank considers the firm's collateral to be negatively dependent on its income

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6 In other papers, productivity and volatility are treated as endogenous variables. For instance, in Comin and Mulani (2005), firms choose how much to invest in R&D. Since R&D investments are risky, they can affect both productivity and its volatility. In contrast, we analyze income volatility, and not the volatility of productivity. Moreover, in our model, income volatility is a demand variable that the firm cannot control in the short/medium-run, while productivity is a cost variable, which, in order to simplify the model, is considered as exogenous.

7 In order to simplify the model, we consider that the level of debt is the same for all firms, and that firms do not choose their optimal amount of debt.

8 See Clementi and Hopenhayn (2006) for a similar approach. We consider that both the bank and the firm commit to the contract without possibility of renegotiation.

volatility. For this reason, we assume that the expected value of the collateral depends negatively on the firm's income volatility[9].

The firm's probability of bankruptcy is given by the following normal cumulative distribution:

$$\delta(\varphi,\overline{\varphi},\sigma,r)=\int_{-\infty}^{\underline{z}(\varphi,\overline{\varphi},r)} f(z,\sigma)\,dz=\int_{-\infty}^{\underline{z}(\varphi,\overline{\varphi},r)} \frac{1}{\sigma\sqrt{2\pi}}e^{\frac{-(z-1)^2}{2\sigma^2}}\,dz \text{ , with } \delta(\varphi,\overline{\varphi},\sigma,r)>0\,. \tag{4}$$

The probability of bankruptcy in Equation (4) involves a threshold shock, denoted by $\underline{z}(\varphi,\overline{\varphi},r)<1$. A firm will exit the market as soon as it experiences an income shock below the threshold. The threshold shock is the value of the shock for which the firm gets zero profits, and it solves the following Equation:

$$\underline{z}p(\varphi)y(\varphi,\overline{\varphi})-\frac{y(\varphi,\overline{\varphi})}{\varphi}-(1+r)I=0\,. \tag{5}$$

The next proposition, proved in Appendix 1A, gives the relationship between a firm's volatility and its probability of bankruptcy.

Proposition 1: *Consider two firms that only differ in their earnings volatility. The firm with higher volatility has a higher probability of bankruptcy than the firm with lower volatility. It is consequently more costly for the more volatile firm to obtain external finance.*

This prediction is in line with the literature that argues that earnings management can be motivated by a desire to decrease earnings volatility. For example, Badrinath et al. (1989) indicate that investors prefer firms with smooth incomes because firms with high volatility are perceived as more risky. It is also consistent with the empirical result of Minton and Schrand (1999), who show that high cash flow volatility is positively related with the costs of accessing external funds. Our finding also

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[9] A firm is assumed to default and go bankrupt if it is unable to completely repay its loan: a renegotiation of the loan is not allowed. Furthermore, as we will show in Proposition 1, more volatile firms are more likely to go bankrupt than their less volatile counterparts. This can be justified considering that firms with higher income volatility are likely to suffer from more extreme shocks, which lead to more extreme incomes. In case of default, they are therefore more likely not to achieve the minimum income needed to repay the loan. In contrast, the shocks of less volatile companies are more concentrated around the mean. For this reason, in case of bankruptcy, a more volatile firm is expected to pay back a lower collateral than a less volatile company (see Rajan and Winton, 1995, for a model with variable collateral). As we will see later, this is a necessary condition to obtain a function that relates firms' productivity and volatility, and to separate those firms that can obtain a loan from those that cannot in terms of firm's volatility. Later in the paper, we will analyze two additional cases: the case in which there is no collateral, and the case in which collateral is independent on the firm's volatility. Several articles have analyzed the effect of collateral uncertainty on firms' default probabilities (see for example Jokivuolle and Peura, 2003), and the role of endogenous collateral in triggering financial crises (see Shleifer and Vishny, 1992, among others).

provides some theoretical foundation to the empirical results of Barnes (2001), who find a negative relationship between the volatility of a firm's earnings and its market valuation.

In every period new firms enter the market. Market characteristics therefore change over time. We assume that within each period the timing of actions is as follows (see Figure 1). First, incumbent firms, new firms, and banks observe the average productivity and average volatility in the market. Given the average productivity and volatility, firms decide how much to produce. Each firm can perfectly determine the interest rate that it has to pay during this period. It will opt to stay in the market, to ask for a loan, and to produce, if its expected future value is positive. Firms with productivity and volatility levels such that their expected future value is negative exit the market. Firms that choose to stay in the market ask for a loan and produce. When the income shock is realized, firms with negative profits go bankrupt and exit the market, while firms with positive profits repay the loan to the bank and continue to the following period.

INSERT FIGURE 1

2.4 Existence of equilibrium interest rate and exit function

Before the realization of the shock, firms and banks observe market characteristics. The value of a firm of type (φ,σ) at period *t* before the realization of the shock is given by:

$$v_t(\varphi,\overline{\varphi},\sigma)=\sum_{s=t}^{\infty}(1-\delta((\varphi,\overline{\varphi},\sigma))^{s-t}\Pi_s(\varphi,\overline{\varphi},\sigma,1)=\frac{\Pi(\varphi,\overline{\varphi},\sigma,1)}{\delta(\varphi,\overline{\varphi},\sigma)}\,. \tag{6}$$

Firms with positive future value, i.e. such that their average expected profits are positive ($\Pi(\varphi,\overline{\varphi},\sigma,1)>0$), decide to ask for a loan[10]. In the absence of bankruptcy, these firms' average expected profit is given by the following expression: $\Pi(\varphi,\overline{\varphi},\sigma)=p(\varphi)y(\varphi,\overline{\varphi})-\dfrac{y(\varphi,\overline{\varphi})}{\varphi}-[1+r(\varphi,\sigma,\overline{\varphi})]I=d(\varphi,\overline{\varphi})-[1+r(\varphi,\sigma,\overline{\varphi})]I$, where $d(\varphi,\overline{\varphi})=\dfrac{1}{M\ \alpha}\left(\dfrac{\varphi}{\overline{\varphi}}\right)^{\alpha-1}$ represents the firm's income net of its variable costs. The equilibrium interest rate is $r\in[r_0,\tilde{r}]$. The maximum interest rate that the firm is willing to pay is the interest rate which leads to an expected future value equal to zero. We denote this interest rate by $\tilde{r}$. It satisfies: $1+\tilde{r}=d(\varphi,\overline{\varphi})/I$. When the firm is charged the interest rate $\tilde{r}$, the threshold shock is $\underline{z}(\tilde{r})=1$, and the probability of bankruptcy is $\delta(\tilde{r})=1/2$, independent on the firm's volatility. The minimum interest rate that the bank charges is the riskless interest rate r_0. We show that there exists a unique $r^* \in [r_0, \tilde{r}]$ such that Equations (3), (4), and (5) hold, i.e. such that:

$$I(r^* - r_0) - \delta(r^*, \varphi, \sigma, \overline{\varphi})[(1 + r^*)I - C(\sigma)] = 0 \qquad (7)$$

Let us to define $j_1(r) = I(r - r_0)$, and $j_2(r, \varphi, \sigma, \overline{\varphi}) = \delta(r, \varphi, \sigma, \overline{\varphi})[(1 + r)I - C(\sigma)]$. We show in Appendix 1B that, when $d(\varphi, \overline{\varphi}) + C(\sigma) \geq 2I(1 + r_0)$, these functions intersect at a unique point, as can be seen in Figure 2.

Two possible cases need to be highlighted. On the one hand, if the collateral is $C(\sigma) \geq (1 + r_0)I$, there is no risk, and the bank will set $r^* = r_0$. This case is not relevant for our analysis. On the other hand if $C(\sigma) < (1 + r_0)I$, the following three possibilities arise. First, for firms with $d(\varphi, \overline{\varphi}) + C(\sigma) > 2I(1 + r_0)$, the bank charges an interest rate $r^* \in (r_0, \tilde{r})$. Second, for firms with $d(\varphi, \overline{\varphi}) + C(\sigma) < 2I(1 + r_0)$, the bank only has incentives to give a loan at an interest rate $r > \tilde{r}$. Firms know that this interest rate leads to a negative expected future value, and therefore do not obtain credit. Finally, for firms with:

$$d(\varphi, \overline{\varphi}) + C(\sigma) = 2I(1 + r_0), \qquad (8)$$

the bank sets $r^* = \tilde{r}$. These firms can get credit and stay in the market in period *t* with expected zero profit. Assuming that the function $C(\sigma)$ is invertible, this implies that there exits a function $s(\varphi, \overline{\varphi}) = \sigma$ that solves Equation (8). Firms whose volatility and productivity lie on this function are charged the interest rate $\tilde{r}$, leading to zero expected future value. In the model, keeping the productivity constant, as volatility increases, the interest rate also increases, and profit decreases (see Figure 3). The exit function gives the maximum level of volatility such that, in a market with average productivity $\overline{\varphi}$, a firm with productivity φ can obtain external finance and stay in the market.

INSERT FIGURES 2 AND 3

The main results of this Section can be summarized as follows:

Exit function and zero profit condition: For $\varphi > 0$, there exits a function s satisfying $s(\varphi, \overline{\varphi}) = \sigma$, such that $\Pi(\varphi, s(\varphi, \overline{\varphi})) = 0$. Thus, if $\sigma > s(\varphi, \overline{\varphi})$, the firm cannot obtain a loan and exits the market,

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[10] In order to simplify the notation, from now on, we will write $\Pi(\varphi, \overline{\varphi}, \sigma)$ instead of $\Pi(\varphi, \overline{\varphi}, \sigma, 1)$, and we will refer to this expression as average expected profit or expected profit indistinctly.

while if $\sigma < s(\varphi,\overline{\varphi})$, the firm obtains credit and remains in the market. This leads to the following Proposition:

Proposition 2: *Firms characterized by high income volatility need to have a high level of productivity to stay in the market. However, there is no correlation between volatility and productivity for low levels of volatility: firms with low volatility can have either a high or a low productivity level (as long as their productivity is higher than the minimum threshold) and stay in the market.*

The intuition behind Proposition 2 is that volatility is costly. Only firms with high productivity levels can counterbalance the cost associated with high volatility and obtain credit.

Let us now give a functional form to the expected value of the collateral. In order to keep the model as tractable and as simple as possible, we assume that $C(\sigma) = C_0 - \sigma$, where C_0 is a constant. This gives us an explicit value for the exit function:

$$s(\varphi,\overline{\varphi}) = \left(\frac{\varphi}{\overline{\varphi}}\right)^{\alpha-1} \frac{1}{M\ \alpha} - 2I(1+r_0) + C_0 . \tag{9}$$

Graphically, the exit function can be depicted as in Figure 4.

INSERT FIGURE 4

In the model, we consider that, in case of bankruptcy, the expected value of collateral is a negative function of volatility. If either collateral is independent on firms' volatility or there is no collateral, then the probability of bankruptcy is the only term that depends on volatility in Equation (7). As we have seen, for any given level of productivity, the exit function is equivalent to finding the level of volatility such that $r = \tilde{r}$ (i.e. such that the firm's expected future value is zero). When $r = \tilde{r}$, the threshold shock is equal to one, and the probability of bankruptcy is $\delta(\tilde{r}) = 1/2$, independent on the firm's level of volatility. If collateral is independent on volatility, as volatility increases, firms with $d(\varphi,\overline{\varphi}) > 2I(1+r_0) - C$ have to pay a higher interest rate, but this interest rate is always lower than $\tilde{r}$. Firms with $d(\varphi,\overline{\varphi}) = 2I(1+r_0) - C$ obtain on average zero profits. This implies that the exit function is independent on volatility. There is therefore an extreme separation in the market between companies that get a loan (with productivity such that $d(\varphi,\overline{\varphi}) \geq 2I(1+r_0) - C$), and companies that do not obtain a loan (with productivity such that $d(\varphi,\overline{\varphi}) < 2I(1+r_0) - C$), independent on their volatility. This case, is similar to the one in which there is no collateral, whereby the bank finances a company if on average the expected return of the investment $d(\varphi,\overline{\varphi})/I$ is greater than $2I(1+r_0)$.

Figure 4 shows that firms that stay in the market have productivity and volatility below or on the function $s(\varphi,\overline{\varphi})$. In equilibrium, the interest rate charged to each firm depends negatively on the firm's productivity, and positively on both the firm's volatility and the average productivity in the market. The exit function provides a link between average productivity in the market and firms' financial constraints. As average productivity increases, the exit function shifts downward, and the earnings of a given firm decrease. The bank realizes that the probability of bankruptcy of this firm increases because its earnings are lower, and the interest rate increases up to the point that some firms cannot get credit anymore.

In order to completely characterize the firm's problem, our next step is to calculate the exit function in terms of the minimum level of productivity in the market. The minimum level of productivity in the market, denoted by $\hat{\varphi}$, corresponds to the productivity of a firm with zero volatility, whose productivity belongs to the exit function. This implies that $\hat{\varphi}$ solves $s(\hat{\varphi},\overline{\varphi})=0$. Equating Equation (9) to zero, and solving for $\hat{\varphi}$, we obtain a relationship between minimum and average productivity, i.e. $\hat{\varphi}=\overline{\varphi}\left[(2I(1+r_0)-C_0)M\alpha\right]^{\frac{1}{\alpha-1}}$. Solving for $\overline{\varphi}$ we find the opposite relationship:

$$\overline{\varphi}=a\ \hat{\varphi}\text{, where}\qquad a=\frac{1}{\left[(2I(1+r_0)-C_0)M\alpha\right]^{\frac{1}{\alpha-1}}}>0\,. \tag{10}$$

Substituting Equation (10) into Equation (9) we get the value of the exit function in terms of the minimum productivity level in equilibrium in the market:

$$s(\varphi,a\hat{\varphi})=\left[\left(\frac{\varphi}{\hat{\varphi}}\right)^{\alpha-1}-1\right]\left[2I(1+r_0)-C_0\right]. \tag{11}$$

2.5 Firm entry

An unbounded pool of identical prospective entrants draw their initial productivity $g(\varphi)$, and volatility $h(\sigma)$ from common distributions with continuous cumulative distributions given respectively by $G(\varphi)$ and $H(\sigma)$.

To enter the market, firms must pay an entry cost denoted by f_e. Firms enter the market if their expected ex-ante value equals the entry cost (free entry condition):

$$E_t^a[v_t]-f_e=0. \tag{12}$$

Let $E_t^a[v_t]$ represent the expected ex-ante firm value. Then, $E_t^a[v_t] = P_{in}\sum_{s=t}^{\infty}(1-\bar{\delta})^{s-t}\,\bar{\Pi}_s = \frac{P_{in}}{\bar{\delta}}\bar{\Pi}$, where P_{in} is the ex-ante probability of successful entry, $\bar{\delta}$ is the average probability of bankruptcy, and $\bar{\Pi}$ is the average ex-ante profit. The average probability of bankruptcy is given by $\bar{\delta} = \int_{-\infty}^{\underline{z}} f(z,\bar{\sigma})dz$, where the average threshold shock is $\underline{z} = (1+\bar{r})I\ M + \frac{\alpha-1}{\alpha}$, and $\bar{r}$ is the average interest rate. The threshold shock depends positively on the average volatility in the market and negatively on the average productivity. The ex-ante probability of successful entry is equal to:

$$P_{in}(\hat{\varphi}) = \text{Prob}(\varphi > \hat{\varphi})\text{Prob}(\sigma \in [0, s(\varphi, a\hat{\varphi})]) =$$

$$= \int_{\hat{\varphi}}^{\infty} g(\varphi) \int_{0}^{s(\varphi,a.\hat{\varphi})} h(\sigma)d\sigma\ d\varphi = \int_{\hat{\varphi}}^{\infty} g(\varphi)H(s(\varphi,a\hat{\varphi}))\ d\varphi.$$

We assume that average volatility and average productivity are weighted harmonic means. Therefore, the average volatility is given by:

$\bar{\sigma}^{\alpha-1} = \frac{1}{P_{in}(\hat{\varphi})}\int_0^{\infty}\sigma^{\alpha-1}h(\sigma)\int_{\tilde{\varphi}(\sigma,\hat{\varphi})}^{\infty} g(\varphi)d\varphi\ d\sigma = \frac{1}{P_{in}(\hat{\varphi})}\int_0^{\infty}\sigma^{\alpha-1}h(\sigma)\left[1-G(\tilde{\varphi}(\sigma,\hat{\varphi})\right]d\sigma$, where $\tilde{\varphi}$ is the inverse with respect to φ of the exit function $s(\varphi, a\hat{\varphi}) = \sigma$, and takes the following value:

$$\tilde{\varphi} = \bar{\varphi}\left[(\sigma + 2I(1+r_0) - C_0)M\alpha\right]^{1/\alpha-1} = \hat{\varphi}\left(\frac{\sigma}{2I(1+r_0)-C_0}+1\right)^{\frac{1}{\alpha-1}}.$$

The average productivity is equal to:

$$\bar{\varphi}^{\alpha-1} = \frac{1}{P_{in}(\hat{\varphi})}\int_{\hat{\varphi}}^{\infty}\varphi^{\alpha-1}g(\varphi)\int_0^{s(\varphi,a\hat{\varphi})} h(\sigma)d\sigma d\varphi = \frac{1}{P_{in}(\hat{\varphi})}\int_{\hat{\varphi}}^{\infty}\varphi^{\alpha-1}g(\varphi)H(s(\varphi,a\hat{\varphi}))d\varphi.$$

A stationary equilibrium is defined by constant aggregate variables over time and free entry for firms into the industry. In equilibrium, the distribution of firms can be represented as follows:

$$\mu(\varphi,\sigma) = \begin{cases} \dfrac{g(\varphi)H(s(\varphi,a\hat{\varphi}))}{P_{in}(\hat{\varphi})} & \text{if } \varphi \geq \hat{\varphi}, \text{ and } \sigma \leq s(\varphi,a\hat{\varphi}) \\ 0 & \text{otherwise.} \end{cases}$$

We show in Appendix 1C that there is a unique equilibrium that satisfies the exit function condition, zero cut-off profit condition, free entry condition, and two aggregate stability conditions. These require that the mass of successful entrants in each period exactly replaces the mass of incumbents who are hit by a bad shock and exit, and that the mass of firms with high volatility and productivity is not too high[11].

3. Open economy model

3.1 Effects of trade on the probability of bankruptcy

We now assume that there are two identical countries that trade the varieties of *Y*. Trade involves two types of costs. First, there is a sunk entry cost into the foreign market, f_{ex}. Every period, the firm pays the amortized per-period portion of this cost, denoted by I_x. As in the closed economy framework, every period, exporters borrow a fixed amount from the bank. Second, there is a variable per unit cost of product that is transported. This variable cost takes the form of an iceberg cost, so that for one unit of a good to arrive to the final destination, $\tau > 1$ units of the good need to be shipped. While prices in the domestic market are the same as before, i.e. $p_d(\varphi) = 1/(\rho\varphi)$, exporters set higher prices in the foreign market, due to the increase in the marginal cost. These are given by $p_x(\varphi) = \tau/(\rho\varphi)$. In the absence of bankruptcy, the profits of an exporter in the domestic and the foreign markets are respectively:

$\Pi_{dt} = z_{dt} p_d y_d - \frac{y_d}{\varphi} - (1+r_x)I$, and $\Pi_{xt} = z_{xt} p_x y_x - \frac{y_x}{\varphi} - (1+r_x)I_x$, where r_x is the interest rate paid by exporters, z_{xt} (z_{dt}) is the income shock in the foreign (domestic) market, and y_x (y_d) is the amount produced in the foreign (domestic) market. We assume that the income shock in the foreign market is normally distributed, with mean equal to one and variance σ_x^2. As in the closed economy model, the domestic shock, has mean one and variance σ_d^2. When firms start exporting, their probability of bankruptcy and their access to external finance change. If national and international shocks are correlated, we can aggregate both shocks and model them as a total income shock, normally distributed with variance σ_T^2 (given by the sum of the national and international income variances plus two times the covariance between the two shocks). The probability of bankruptcy of an exporter is the cumulative normal distribution shown in the following expression:

$$\delta_T(\varphi, \sigma_T, r_x) = \int_{-\infty}^{\underline{z}_T(\varphi, r_x)} f_T\, dz = \int_{-\infty}^{\underline{z}_T(\varphi, r_x)} \frac{1}{\sigma_T\sqrt{2\pi}} e^{\frac{-(z-2)^2}{2(\sigma_T)^2}} dz\,, \tag{13}$$

[11] This last condition is necessary to guarantee that as the minimum productivity increases, the ratio of average to minimum productivity decreases; and average volatility, increases, stays constant, or does not decrease too much. These are sufficient conditions for the existence of an equilibrium (see Appendix 1C for details). Several studies have shown that the distribution of firms' productivity has a positive skew. We find a similar feature for both the distribution of volatility and that of productivity in the panel of UK firms that we use in Sections 5 and 6 to test the main predictions of our model.

with a threshold shock that solves: $\underline{z}_T(p_d y_d + p_x y_x) - (y_d + y_x)/\varphi \; - (I + I_x)(1 + r_x) = 0$

If the covariance between national and international shocks is negative, and larger in absolute value than $\sigma_x^2/2$, then total earnings volatility decreases with trade[12]. Furthermore, when the fixed cost of exporting is zero, the threshold shock of an exporter is always lower than that of a non-exporter. To ensure that the threshold shock of an exporter is always lower than that of a non-exporter, the fixed export cost should not be too high. In particular, the following inequality needs to hold: $I_x(1+r_x) < I\left[(r - r_x) + (1+r)\tau^{1-\alpha}\right] + (\tau - 1)y_d\tau^{-\alpha}\big/\varphi$. Consequently, if the covariance between national and international shocks is negative, and larger in absolute value than $\sigma_x^2/2$, and if the fixed cost of exporting is not too high, then the probability of bankruptcy decreases with trade. The bank charges an interest rate r_x to exporters, such that the expected repayment of the loan equals the repayment of a riskless loan, solving the following equation:

$$(I + I_x)(r_x - r_0) = \delta_x(r_x)\left[(1 + r_x)(I + I_x) - C_0 + \sigma_T\right]. \qquad (14)$$

As long the conditions outlined above are satisfied, trade also reduces the exporters' cost of external financing[13]. The following Proposition summarizes the impact of trade on firms' volatility and their probability of bankruptcy.

Proposition 3: *If demand shocks in the national and international markets are negatively correlated, trade can lead to a reduction of total earnings volatility, through market diversification. If the fixed cost of exporting is not too high, trade can also reduce the firm's probability of bankruptcy.*

The intuition behind this Proposition is that if trade smoothes firms' earnings and, if it is not too costly to export compared with selling only domestically, it can reduce firms' financial constraints. The income diversification associated with trade can in fact decrease the exporters' probability of bankruptcy, and, consequently, reduce their costs of accessing external finance, improving their financial health. This result is consistent with an early study of Hirsch and Lev (1971) based on data from Denmark, the Netherland, and Israel, which finds that exports tend to stabilize firms' sales through market diversification. It is also in line with the work of Campa and Shaver (2002), who, using a panel of Spanish firms, show that exporters have more stable cash flows than non-exporters, and are consequently less financially constrained; and with a recent empirical article by Buch et al. (2006), who

[12] Note that this result does not imply that trade leads to a decrease in macroeconomic volatility, as firm volatility and macroeconomic volatility are not necessarily positively related. In fact, Comin and Mulani (2005) document a negative linkage between firm-level and aggregate volatility.

find that trade decreases German firms' output volatility. Finally, Proposition 3 could provide a theoretical foundation for the outcome described in Greenaway et al. (2007), who have empirically shown that trade improves the financial health of UK firms.

3.2 Exit functions under free trade and incentives to trade

As in the autarky case, the exit function for non-exporters is given by the following expression:

$$s(\varphi, a\hat{\varphi}) = \left[\left(\frac{\varphi}{\hat{\varphi}}\right)^{\alpha-1} - 1\right]\left[2I(1+r_0) - C_0\right].$$

In order to obtain the exit function for exporters, we need to determine the interest rate that leads to zero expected future value. This interest rate is equal to[14]:

$$1+\tilde{r}_x = \left[p_d y_d + p_x y_x - (y_d/\varphi) - (y_x/\varphi)\right]/(I+I_x) = \left(\frac{\varphi}{\overline{\varphi}_T}\right)^{\alpha-1}\frac{1}{(I+I_x)M_T\alpha}\left[1+\frac{\tau\alpha-(\alpha-1)}{\tau^{\alpha}}\right],$$

where $\overline{\varphi}_T$ is the average productivity in the market under free trade. Substituting this expression into Equation (14), and solving for volatility, we determine the exit function for exporters as follows:

$$s_X(\varphi, \overline{\varphi}_T) = \left(\frac{\varphi}{\overline{\varphi}_T}\right)^{\alpha-1}\frac{1}{M_T\alpha}\left[1+\frac{\tau\alpha-(\alpha-1)}{\tau^{\alpha}}\right] - 2(I+I_x)(1+r_0) + C_0. \tag{15}$$

Let us define $\hat{\hat{\varphi}}$ as the level of productivity such that $s_X(\hat{\hat{\varphi}}, \overline{\varphi}_T) = 0$. Substituting it into the exit function for exporters, and solving for $\hat{\hat{\varphi}}$, we obtain:

$$\hat{\hat{\varphi}}^{\alpha-1} = \overline{\varphi}^{\alpha-1}\left[2(I+I_x)(1+r_0) - C_0\right]M_T\alpha\left(\frac{\tau^{\alpha}}{\tau\alpha-(\alpha-1)+\tau^{\alpha}}\right).$$

We show, in Appendix 1D, that the exit function of exporters can be expressed in terms of the minimum productivity level in the market as follows:

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[13] This obviously holds under the assumption that the collateral of exporters is greater than or equal to that of non-exporters, which is a reasonable assumption considering that exporters are typically larger than non-exporters (Clerides et al., 1998; Bernard and Jensen, 1999; Aw et al., 2000).

[14] The aggregate price in the open economy model is $P = M_T^{1/(\alpha-1)}\dfrac{1}{\rho\overline{\varphi}_T}$, where $\overline{\varphi}_T$ is the average productivity in the market, and M_T is the number of firms in the market with free trade.

$s_X(\varphi, c\hat{\varphi}) = \left[\left(\frac{\varphi}{\hat{\varphi}} \right)^{\alpha-1} \left(1 + \frac{\tau\alpha - (\alpha-1)}{\tau^{\alpha}} \right) - 1 \right] \left[2I(1+r_0) - C_0 \right] - 2I_x(1+r_0)$, where c is the constant that relates $\hat{\varphi}$ with $\overline{\varphi}_T$. An equilibrium with exporters and non-exporters requires that $\hat{\hat{\varphi}} > \hat{\varphi}$. This condition holds if the fixed cost for exporting is not too low, i.e. if:

$$\frac{2I_x(1+r_0)}{2I(1+r_0) - C_0} > \frac{\tau\alpha - (\alpha-1)}{\tau^{\alpha}}. \tag{16}$$

If $\tau > (\alpha - 1)/\alpha$, (17)

the slope of the exit function of exporters is higher than that of non-exporters. Let us assume that conditions (16) and (17) hold[15]. In this case, the exit functions for exporters and non-exporters intersect at a unique point, which determines the minimum level of productivity required to acquire a loan and to become an exporter. Let us denote this level of productivity with $\hat{\varphi}_x$. Figure 5 shows that the economy can be divided into four types of firms. The first type consists of firms with productivity lower than $\hat{\varphi}$, which cannot obtain any loan and cannot produce. The second type consists of firms with productivity between $\hat{\varphi}$ and $\hat{\hat{\varphi}}$, and volatility below $s(\varphi, a\hat{\varphi})$, which can obtain a loan to sell their products domestically. The third type of firms are firms with productivity between $\hat{\hat{\varphi}}$ and $\hat{\varphi}_x$, and volatility below $s(\varphi, a\hat{\varphi})$, which can obtain a loan to export, but find it more profitable to sell only in the domestic market. Finally, firms with productivity higher than $\hat{\varphi}_x$ and volatility below $s_X(\varphi, c\hat{\varphi})$ obtain a loan to export, and decide to export. In Appendix 1E, we illustrate the conditions for the existence of a unique stationary equilibrium in the open economy, in which the minimum productivity level is higher than in autarky.

INSERT FIGURE 5

3.3 *Effects of opening up to trade*

We now analyze the effect of opening up to trade on the distribution of firms in the market and their access to external finance. Trade increases the minimum productivity in the market, leading to different responses of the exit functions of exporters and non-exporters. The exit function for non-exporters is shifted to the right, and becomes flatter than in autarky. This implies that non-exporters with low

[15] There are, in fact, three alternative scenarios. First, neither condition (16) nor condition (17) holds. In this case, there is no trade. Second, if condition (16) holds, but condition (17) does not hold, there is again no trade. Third, if condition (16) does not hold, but condition (17) holds, then only firms with low productivity and low volatility trade, which is not a realistic scenario.

productivity and low volatility exit the market. Due to the increased competition, these firms cannot obtain a loan anymore.

For exporters, there are two possible cases. The first occurs if the slope of the exit function is higher than the slope of the exit function in autarky, i.e. if:

$\left(1+\frac{\tau\alpha-(\alpha-1)}{\tau^{\alpha}}\right)^{\frac{1}{\alpha-1}} > \frac{\hat{\varphi}_{FT}}{\hat{\varphi}_{A}}$, where $\hat{\varphi}_{FT}$, and $\hat{\varphi}_{A}$ represent the minimum level of productivity in the market under free trade and autarky respectively (Figure 6a). In this case, firms with high volatility and high productivity can operate in the new stationary equilibrium. These companies were unable to obtain credit before the trade liberalization, due to their high volatility. Following the liberalization, they can smooth their earnings as they trade, becoming less volatile. Trade liberalization produces therefore a reallocation of firms in the market, whereby firms with low/medium productivity and volatility are replaced with firms with high productivity and volatility, increasing therefore average productivity in the market.

INSERT FIGURE 6a

The second case occurs if the slope of the exit function for exporters is lower than or equal to that of the exit function in autarky (Figure 6b). Here, due to the large increase in competition, the increase in the minimum level of productivity under free trade is much higher than in autarky. This leads to a reduction of external funds for all firms that were close to the autarky exit function. These firms are now forced to exit the market, and there is no reallocation of companies. Due to increased competition, opening up to trade induces such a decrease in earnings for the local firms, that not even exporters become less financially constrained than in autarky. Thus, in this situation, there is no gain from trade for the domestic firms. Consequently, contrary to Melitz (2003), in this case, trade does not necessarily increase average productivity.

INSERT FIGURE 6b

In sum, the effect of a trade liberalization on the distribution of firms in the market is ambiguous, and depends on its effect on firms' access to external finance.

3.4 Volatility and the incentive to trade

We now turn to a related question: do firms with high national income volatility have more incentives to trade than firms with low national income volatility? In our model, this can happen if firms are able to diversify their income shocks by exporting.

Let us denote with $\Pi_x(\varphi, \sigma_T)$ and $\Pi(\varphi, \sigma_d)$, the average expected profits for exporters and non-exporters respectively, in the absence of bankruptcy; with r_x, the interest rate charged to exporters; and with r_{nx} the interest rate charged to non-exporters. The differential in firm value for exporters and non-exporters (for positive expected profits) is given by $\Pi_x(\varphi, \sigma_T)/\delta_x - \Pi(\varphi, \sigma_d)/\delta.$

Firms with high national income volatility have more incentives to trade than firms with low volatility if this value differential increases with domestic income volatility. As shown in Proposition 1, in the absence of trade, an increase in volatility leads to an increase in the interest rate (i.e. $\frac{\partial r_{nx}}{\partial \sigma_d} > 0$). However, this is not necessarily the case with trade if there is diversification. If a firm sells to markets characterized by negatively correlated income shocks, we can observe two scenarios in which the differential in firm value for exporters and non-exporters can increase with domestic income volatility. The first occurs if the interest rate of exporters does not change for different degrees of national income volatility (i.e. if $\frac{\partial r_x}{\partial \sigma_d} = 0$). This may happen if exporters with high domestic volatility do not have higher total volatility, due to diversification. In this situation, firms with high domestic income volatility have more incentives to trade than firms with low domestic income volatility, as they are able to diversify their income shocks relatively more than low volatility firms. Exporters and non-exporters end up having a similar total volatility, independently of their domestic income volatility. For this reason more volatile firms have more incentives to trade.

The second scenario occurs if exporters with high domestic volatility are charged a higher interest rate than exporters with lower domestic volatility (i.e. if $\frac{\partial r_x}{\partial \sigma_d} > 0$). In this situation, if the increase in interest rate associated with higher domestic volatility is lower for exporters than for non-exporters (i.e. if $\frac{\partial r_{nx}}{\partial \sigma_d} > \frac{\partial r_x}{\partial \sigma_d}$, which would occur if following a rise in domestic volatility, the total volatility of exporters remained constant or increased little, thanks to diversification), and if this advantage in terms of interest rates is sufficiently large as to counter balance the rise in the fixed cost necessary to export, then firms with high domestic income volatility have, once again, more incentives to export than firms with low domestic income volatility. This occurs because, in this case, the differential in the firm's value for exporters and non-exporters increases with domestic volatility. Proposition 4 summarizes the relationship between national income volatility and incentives to trade.

Proposition 4: *Firms with high national income volatility have more incentives to trade than firms with low national income volatility, provided that the increase in the interest rate associated with a higher domestic volatility is lower for exporters than for non-exporters, and provided that this advantage in terms of interest rate counterbalances the increase in the amortized per-period portion of the fixed cost that exporters have to face.*

Intuitively, before starting to export, firms with low domestic income volatility can obtain a loan at a lower cost than firms with high domestic income volatility. This generates incentives for firms with low volatility to start exporting. However, for highly volatile firms, the prospective reduction in the total volatility is larger than for firms with low volatility, which in turn reduces their interest rates and encourages them to trade.

4. Testable implications

From the analysis of our theoretical model, several testable implications emerge. First, the model suggests that controlling for productivity and collateral, firms with higher volatility have a higher probability of bankruptcy. It is consequently more costly for them to obtain external finance. Second, the model implies that there is a positive correlation between volatility and productivity for high levels of volatility, while there is no correlation for low levels: highly volatile firms need to be more productive to stay in the market. Third, the open economy model suggests that, through market diversification, exports tend to stabilize firms' total sales. Exporters' total income volatility will therefore be lower than their national income volatility. Finally, firms characterized by high national income volatility will have more incentives to start exporting than firms with low volatility. In the Sections that follow, we will test these implications using a panel of 9292 UK firms over the period 1993-2003. Our choice of the UK in our empirical testing of the model stems from the fact that the UK is the fifth largest exporter of manufactures globally, and within our sample, almost 70 percent of all firms exported in at least one year. Moreover, on average, 30 percent of the total sales of UK exporters are directed abroad.

5. Data and summary statistics

5.1 The dataset

We construct our dataset from profit and loss and balance sheet data gathered by Bureau Van Dijk in the *Financial Analysis Made Easy* (*FAME*) database. This provides information on firms for the period 1993-2003. It includes a majority of firms which are not traded on the stock market, or are quoted on other exchanges such as the Alternative Investment Market (*AIM*) and the Off-Exchange (*OFEX*) market[16]. Unquoted firms are more likely to be characterized by adverse financial attributes such as a short track record, poor solvency, and low real assets compared to quoted firms, which are typically large, financially healthy, long-established firms with good credit ratings.

The firms in our dataset operate in the manufacturing sector. We excluded firms that changed the date of their accounting year-end by more than a few weeks, so that data refer to 12 month accounting periods. Firms that did not have complete records on the variables used in our regressions were also dropped. Finally, to control for outliers, we excluded observations in the one percent tails for each variable[17]. Our panel therefore comprises a total of 51668 annual observations on 9292 firms, covering the years 1993-2003. It has an unbalanced structure, with an average of 7 observations per firm. By allowing for both entry and exit, the use of an unbalanced panel partially mitigates potential selection and survivor bias.

5.2 Summary statistics

Summary statistics of the main variables used in our empirical analysis are presented in Table 1. Column 1 refers to the entire sample; column 2 and 3, to surviving and failed firms, respectively. As in Bunn and Redwood (2003), we define a firm as failed (bankrupt) in a given year if its status is in receivership, liquidation, or dissolved[18]. Columns 4 and 5 of Table 1 refer respectively to low and high volatility firms. Firm *i* is classified as a low (high) volatility firm in year *t* if its total volatility in year *t* is in the lowest (highest) 50 percent of the distribution of the volatilities of all firms operating in its same industry in year *t*. Columns 6 and 7 respectively refer to non-exporters at time *t*-1 that did not enter (non-starters), and entered (starters) export markets at *t*.

As in Comin and Mulani (2004) and Comin and Philippon (2005), our main volatility measure is calculated as the standard deviation of the firm's total real sales growth, measured over a rolling window of 5 years. Specifically, denoting with $Totalvol_{it}$ this standard deviation for firm *i* at time *t*; with $srgr_{it}$, the growth rate of the real sales of firm *i* at time *t*, and with μ_{it}, its average sales growth rate between *t*-2 and *t*+2, we have:

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[16] We only selected firms that have unconsolidated accounts: this ensures the majority of firms in our dataset are relatively small. Moreover, it avoids the double counting of firms belonging to groups, which would be included in the dataset if firms with consolidated accounts were also part of it.

[17] These cut-offs are aimed at eliminating observations reflecting particularly large mergers, extraordinary firm shocks, or coding errors. See Appendix 2 for more information on the structure of our panel and complete definitions of all variables used.

[18] Liquidation and receivership are two types of reorganization procedures, which can take place when a firm becomes insolvent. In liquidation, the assets of the firm are sold so as to meet the claims of creditors. In receivership, the receiver can decide whether it is in the creditors' interests to sell the firm's assets. Generally, it is in the creditors' interests to liquidate if the liquidation value of the firm exceeds its going concern value (Lennox, 1999b).

$$Totalvol_{it} = \left[\frac{1}{5} \sum_{\tau=-2}^{2} \left(srgr_{i(t+\tau)} - \mu_{it} \right)^2 \right]^{1/2}$$

We also provide measures of volatility only based on national sales growth and overseas sales growth, which we denote respectively with $Nationalvol_{it}$ and with $Overseasvol_{it}$[19].

Comparing total sales growth volatility at failed and surviving firms (columns 2 and 3), we can see that the former display a higher volatility (0.207) than the latter (0.199). The difference between the two figures is marginally statistically significant (*t*-statistic: 1.69). In accordance with the first testable implication of our model, there is some evidence that failed firms are more volatile than their surviving counterparts. More formal tests of this hypothesis will be provided in the Section that follows.

Focusing now on columns 4 and 5, with emphasis on productivity (*TFP*), which is calculated using the Levinsohn and Petrin (2003) method[20], it appears that both high and low volatility firms display very similar levels of productivity (5.820 and 5.826, respectively). Yet the correlation between *TFP* and volatility is positive for high-volatility firms (0.0650) and negative for low-volatility firms (-0.0655). This seems to support our model's second prediction, according to which one should observe a positive correlation between idiosyncratic volatility and productivity for high levels of volatility only.

Next, in relation to our open economy model's predictions, we compare the firm's total, national, and overseas sales growth volatility, based on the entire sample (column 1). We can see that, as suggested by our model, the volatility of total sales growth (0.197) is lower than that of national sales growth (0.238). The difference between the two means is strongly significant (*t*-statistic = 29.86). Also considering that overseas sales display the highest volatility (0.482), this provides some preliminary support for the hypothesis that, through market diversification, exports tend to stabilize total sales[21].

Finally, focusing on columns 6 and 7 of Table 1, we can see that starters display a much higher national sales volatility compared to non-starters (0.309 versus 0.193). The difference between the two means is statistically significant (*t*-statistic = 7.63). Although this comparison is simply based on

[19] It should be noted that given the way in which we calculate volatility, this variable is not available for the years 1993, 1994, 2002, and 2003. For this reason, all regressions which contain our main measure of volatility are based on the sample 1995-2001. This explains why the number of observations reported in Tables 2 to 4 is lower than that reported in Table 1, which refers to the full sample.

[20] A key issue in the estimation of production functions is the correlation between unobservable productivity shocks and input levels. Profit-maximizing firms respond to positive productivity shocks by expanding output, which requires additional inputs; and to negative shocks, by decreasing output and input usage. Olley and Pakes' (1996) estimator uses investment as a proxy for these unobservable shocks. This could cause problems as any observation with zero investment would have to be dropped from the data. Levinsohn and Petrin (2003), by contrast, introduce an estimator which uses intermediate inputs as proxies, arguing that these (which are generally non-zero) are likely to respond more smoothly to productivity shocks.

[21] If we limit the sample to exporters, the volatility of total sales growth is given by 0.198; that of national sales growth, by 0.248; and that of overseas sales growth, by 0.479.

unconditional means, it provides some strong support for our model's last testable implication. More formal tests of all the implications of our model are provided in the next Section.

INSERT TABLE 1

6. Specifications and results

6.1 Are more volatile firms more likely to go bankrupt?

In order to test the first implication of our model, namely that more volatile firms are more likely to fail, we will estimate a random-effects Probit specification of the following type:

$$Pr(FAIL_{it}=1) = \Phi(\, \mathrm{a}_0 + \mathrm{a}_1\, size_{it} + \mathrm{a}_2\, age_{it} + \mathrm{a}_3\, group_i + \mathrm{a}_4\, TFP_{it} + \\ + \mathrm{a}_5\, Collateral_{it}/Debt_{it}{*} + \mathrm{a}_6\, Totalvol + u_i + u_j + u_t\,) \tag{18}$$

$FAIL_{it}$ is a dummy variable equal to 1 if firm i failed in year t, and 0 otherwise. $\Phi(.)$ denotes the standard normal distribution function. As typically done in the literature (see for instance Bunn and Redwood, 2003; and Disney et al., 2003), our equation controls for firm's size, age, productivity, and for whether the firm is part of a group. In accordance with our model, we also include the firm's collateral to debt ratio and the volatility of its total sales growth among the regressors[22]. Since the average length of time between the final annual report of a failing firm and its entry into bankruptcy is usually 14 months (Lennox, 1999a), our specification includes regressors evaluated at time t. Yet, all our results were robust to using lagged regressors. The error term is made up of three components: u_i, u_t, *and* u_j. u_i represents a firm-specific effect, and is controlled for by our random-effects estimator. u_t represents a time-specific effect accounting for business cycle conditions, and is taken into account by including a full set of time dummies. u_j represents a sector-specific effect, and is controlled for by including a full set of industry dummies[23].

The estimates of Equation (18) are presented in column 1 of Table 2. As typically found in the literature, size and *TFP* have a negative effect on the firm's probability of failure. The coefficient associated with the ratio of the firm's collateral to total debt is poorly determined suggesting that this variable does not play a statistically significant effect on firm survival. In accordance with Proposition 1

[22] In the model, we assumed that firms have the same level of debt, but different levels of collateral. In reality, however, different firms have different levels of debt. For this reason, we control for the ratio of collateral over debt. All our results were robust to including collateral and total debt separately in the regressions.
[23] Firms are allocated to the following industrial groups: metals and metal goods; other minerals, and mineral products; chemicals and man made fibres; mechanical engineering; electrical and instrument engineering; motor vehicles and parts, other transport equipment; food, drink, and tobacco; textiles, clothing, leather, and footwear; and others (Blundell et al., 1992).

in our model, the volatility of the firm's total sales growth is positively associated with the chances that the firm will go bankrupt: more volatile firms are therefore more likely to fail.

As an alternative test of this first implication of the model, we make use of the *Quiscore* measure produced by Qui Credit Assessment Ltd., which assesses the likelihood of firm failure in the 12 months following the date of calculation. The lower its *Quiscore*, the more risky the firm, and the higher its chances of failure. We estimate the following fixed-effects regression:

$$QUISCORE_{it} = a_0 + a_1\, size_{it} + a_2\, age_{it} + a_3\, TFP_{it} + \\ + a_4\, Collateral_{it}/Debt_{it} + a_5\, Totalvol + u_i + u_t \qquad (19)$$

The results are presented in column 2 of Table 2. *TFP* is positively associated with *Quiscore*, suggesting that more productive firms are less risky, and less likely to fail[24]. Our collateral to debt ratio is also positively associated with *Quiscore*, indicating that the more collateral a firm has relative to its total debt, the less risky it is. Surprisingly, our size variable is negatively associated with *Quiscore*, suggesting that larger firms are more risky. Finally, our volatility measure displays a negative coefficient: more volatile firms are more risky, and therefore more likely to fail, which is in accordance with our Proposition 1.

As banks generally look at firms' credit ratings such as *Quiscore* when deciding the terms of the loans they make to firms, it is likely that they will charge higher interest rates to the riskiest firms. Thus, as predicted by our model, more volatile firms are more likely to fail, and to be charged higher interest rates by their lenders.

INSERT TABLE 2

6.2 Is there a positive correlation between productivity and volatility for highly volatile firms only?

The second main implication of our model is that there should be a positive correlation between productivity and volatility for highly volatile firms only. In order to test this implication, we construct the following two dummies: $LOWVOL_{it}$, which is equal to one if firm *i*'s total real sales growth volatility in year *t* is in the lowest half of the distribution of the volatilities of all firms operating in the same industry as firm *i*'s in year *t*, and 0 otherwise; and $HIGHVOL_{it}$, which is equal to one if firm *i*'s volatility in year *t* is in the highest half of the distribution, and 0 otherwise. We then interact our

[24] Industry dummies are not included in this regression, as they are automatically wiped out in the differencing process undertaken by the fixed-effects estimator.

volatility measure with the two dummies and estimate the following equation, using a fixed-effects specification[25]:

$$TFP_{it} = \mathrm{a}_0 + \mathrm{a}_1 totalvol_{it}*LOWVOl_{it} + \mathrm{a}_2 totalvol_{it}*HIGHVOl_{it} + u_i + u_t + e_{it} \qquad (20)$$

The coefficient a_1 can be interpreted as the effect of volatility on *TFP* for firms with low volatility; and a_2, as the effect for firms with high volatility. The estimates are reported in column 1 of Table 3. We can see that only a_2 is statistically significant. This suggests that volatility only affects the productivity of those firms characterized by a high volatility. This is consistent with our model's second prediction. Column 2 reports the results when firms are divided in three categories based on their volatility: there are three interaction terms: one for low-volatility firms, one for medium-volatility firms, and one for high-volatility firms[26]. Once again, there is a positive association between volatility and *TFP* only for high-volatility firms, which supports our model's second prediction.

INSERT TABLE 3

6.3 Are more volatile firms more likely to start exporting?

Lastly, our model predicts that it is those firms that display highest volatility of national sales growth that should have more incentives to start exporting. In order to test this prediction, we estimate the following random-effects Probit equation for the probability that a non-exporter at time *t*-1 becomes an exporter at *t*:

$$\begin{aligned} START_{it} = {} & \mathrm{a}_0 + \mathrm{a}_1\, size_{it} + \mathrm{a}_2\, age_{it} + \mathrm{a}_3\, TFP_{it} + \mathrm{a}_4\, group_i + \\ & + \mathrm{a}_5\, nationalvol_{it} + u_j + u_t + e_{it} \end{aligned} \qquad (21)$$

The dependent variable, $START_{it}$, is equal to one for those firms that exported at *t*, but not at *t*-1, and 0 otherwise. As in the regression for firm failure, our right-hand side variables include the firm's size, its age, its *TFP*, and the dummy indicating whether it is part of a group. To test our model's prediction, we have added the volatility of the firm's national sales growth among our regressors. The results are presented in column 1 of Table 4[27]. We can see that larger firms are more likely to enter

[25] Once again, industry dummies are not included in this specification.
[26] In this case the interaction dummies are defined as follows: $LOWVOL_{it}$ is equal to one if firm *i*'s total real sales growth volatility in year *t* is in the lowest 33 percent of the distribution of the volatilities of all firms operating in the same industry as firm *i*'s in year *t*, and 0 otherwise; $MIDDLEVOL_{it}$ is equal to one if firm *i*'s volatility in year *t* is in the middle 33 percent of the distribution, and 0 otherwise; and $HIGHVOL_{it}$ is equal to one if firm *i*'s volatility in year *t* is in the highest 33 percent of the distribution, and 0 otherwise.
[27] The sample used in this regression is therefore only made up of firms that did not export at time *t*-1. This explains the low number of observations reported in this Table.

export markets, and that the volatility of national sales growth is also positively associated with the probability that the firm starts exporting. Yet, it should be noted that our previous measure of volatility, calculated over a rolling window of five years is based on the firm's national sales before and after entry in the foreign market. This could introduce bias in the regression. We therefore verify whether our results are robust to using two different measures of national sales volatility: the first is the standard deviation of the firm's real sales growth calculated over the five years preceding and including year *t*. The second one is calculated in a similar way but using all years preceding and including year *t*. The results based on these two alternative measures of volatility are presented in columns 2 and 3 of Table 4. We can see that in both cases, a higher volatility is still positively associated with a higher probability to start exporting. Thus, as predicted by the model, those firms displaying high volatility in their national real sales are also more likely to start exporting. In summary, the data seem to lend strong support our model.

INSERT TABLE 4

7. Conclusion

We have constructed a dynamic model of monopolistic competition, aimed at studying the impact of firms' earnings volatility on the degree of financial constraints that they face, and on their probabilities of survival, and of entering export markets. Our model predicts that high earnings volatility may prevent some firms from obtaining loans, and that more volatile firms are more likely to go bankrupt, need to be more productive to stay in the market, and have more incentives to enter export markets. We show that trade allows exporters to smooth their income, leading to a decrease in the degree of financial constraints that they face, and in their expected average probability of bankruptcy. Yet, since trade also increases competition, there can be two possible equilibria. If competition is not too high, there is a reallocation of firms in the market, whereby firms with low productivity and low volatility are substituted by exporters with high productivity and high volatility. However, if competition is very high, it is possible that all firms become more financially constrained than in autarky. In this circumstance, trade does not necessary increase the average productivity in the industry. We have tested our model's predictions, using a panel of 9292 UK manufacturing firms over the period 1993-2003. In line with the model's predictions, we found empirical evidence showing that more volatile firms are more likely to go bankrupt, need to be more productive to stay in the market, and are more likely to enter export markets, and that exports tend to stabilize firms' total sales, through market diversification.

Our analysis has some limitations. We found that when firms export, their earnings volatility can decrease, improving their financial situation. Yet, we considered the decrease in volatility as the only channel through which exporters can improve their financial situation, leaving aside other possible factors that may shield exporters from liquidity constraints such as improvements in their reputation, enhancement in the quality of their products through the adoption of international standards, and access not only to domestic, but also to foreign credit markets[28]. The latter channel is particularly important, especially in the absence of perfect competition in the domestic market for loans, as we have implicitly assumed. Furthermore, in our model, all firms are assumed to borrow the same quantity, and they cannot use their own previous resources to finance their production fixed costs. We abstract therefore from the role of firms' age and of their current capital structure (with the exception of their collateral). Finally, we do not analyze how trade might increase firms' earnings volatility, for example through a rise in the exchange rate volatility. This effect is particularly important in developing countries that open up to trade (Chaney, 2005; Razin et al., 2003). More research, both empirical and theoretical, is necessary to fully understand the interactions between volatility, financial constraints, and trade.

APPENDIX 1: Proofs

A. Proof of Proposition 1

We wish to show that given two firms (*i* and *j*), which only differ in their volatilities (for example $\sigma_i > \sigma_j$), the more volatile firm has a higher probability of bankruptcy than the less volatile one (i.e. $\delta_i > \delta_j$). To this end, we construct the proof in two parts.

We initially show that if the threshold shock $\underline{z}$ is the same for both firms, then the firm with higher volatility has a higher probability of bankruptcy. Let us denote with $f(dz)$ the distribution of shocks of firm *i*, and with $g(dz)$ the distribution of shocks of firm *j*. By assumption, the firms have the same productivity level. Let $\hat{z}$ be the point where both distributions intersect. If $\hat{z} > \underline{z}$, Figure A1 shows that A>B, meaning that $\int_{-\infty}^{\underline{z}} f dz > \int_{-\infty}^{\underline{z}} g dz$, and therefore $\delta_i > \delta_j$.

INSERT FIGURE A1

If, on the other hand, $\hat{z} < \underline{z}$, focusing on Figure A2, we can see that the probability of bankruptcy can be expressed as $\delta_i = A + B + C$ for firm *i*, and as $\delta_j = B + C + D$ for firm *j*. If

[28] See, for example, Bridges and Guariglia (2006), for a summary of the literature on the reduced effects of liquidity constraints on the behavior of exporters, relative to purely domestic firms.

$A > D$, then $\delta_i > \delta_j$. The properties of the normal distribution imply that $A+B+C+F=B+D+C+E+F=1/2$, therefore $A=D+E$. Since we have assumed that $\underline{z} < 1$, this leads to $E > 0$, and therefore to $A > D$, which, provided that the threshold shock is the same for both firms, implies again that the firm with higher volatility has a higher probability of bankruptcy. (Note that this result also holds if the threshold shock is higher for the more volatile company).

INSERT FIGURE A2

Next, we wish to show that the threshold shock cannot be lower for the more volatile firm. To this end, considering that the interest rate is higher for the more volatile firm, we only need to show that it is more costly for the latter to obtain external funding. Let us prove this by contradiction. Suppose that it were not more costly for the more volatile firm to obtain financial resources. In this case, assuming that they borrow the same amount, two firms with the same productivity and different volatilities would be charged the same interest rate. The threshold shock would consequently be the same for both firms. If the threshold shock is the same, then we have shown that the probability of bankruptcy is higher for the more volatile firm. Additionally, we know that the collateral is lower for the more volatile firm. Yet, if the probability of bankruptcy is higher, and the collateral is lower for the more volatile firm, it cannot be true that the two firms are charged the same interest rate. Therefore, the threshold shock has to be higher for the more volatile firm than for the less volatile one, and consequently, the former firm has a higher probability of bankruptcy than the latter. Q.E.D.

B. Proof that the functions that determine the equilibrium interest rates intersect at a unique point

The equilibrium interest rate is given by the following equation:

$$I(r^* - r_0) - \delta(r^*, \varphi, \sigma, \overline{\varphi})[(1+r^*)I - C(\sigma)] = 0 \tag{A1}$$

We have defined $j_1(r) = I(r - r_0)$, and $j_2(r, \varphi, \sigma, \overline{\varphi}) = \delta(r, \varphi, \sigma, \overline{\varphi})[(1+r)I - C(\sigma)]$. We wish to show that these two functions intersect at a unique point.

First of all, we show that both $j_1(r)$ and $j_2(r, \varphi, \sigma, \overline{\varphi})$ are increasing functions of *r* in the interval $[r_0, \tilde{r}]$. The first derivatives with respect to the interest rate are:

$\dfrac{\partial j_1(r)}{\partial r} = I > 0$ and $\dfrac{\partial j_2(r, \varphi, \sigma, \overline{\varphi})}{\partial r} = \dfrac{\partial \delta(r, \varphi, \sigma, \overline{\varphi})}{\partial r}[(1+r)I - C(\sigma)] + I\delta(r, \varphi, \sigma, \overline{\varphi}) > 0$ since

$$\frac{\partial \delta(r, \varphi, \sigma, \overline{\varphi})}{\partial r} = \left(\frac{I}{p.y}\right)\frac{1}{\sqrt{2\pi}\sigma} e^{-(\underline{z}-1)^2/2\sigma^2} > 0.$$

We then show that the second derivate of $j_2(r,\varphi,\sigma,\overline{\varphi})$ with respect to *r* is positive for $\underline{z}<1$, i.e.:

$$\frac{\partial^2 j_2(r,\varphi,\sigma,\overline{\varphi})}{\partial r^2}=\frac{\partial^2\delta(r,\varphi,\sigma,\overline{\varphi})}{\partial r^2}[(1+r)I-C(\sigma)]+2I\frac{\partial\delta(r,\varphi,\sigma,\overline{\varphi})}{\partial r}\delta(r,\varphi,\sigma,\overline{\varphi})>0,$$ where

$$\frac{\partial^2\delta(r,\varphi,\sigma,\overline{\varphi})}{\partial r^2}=\left(\frac{I}{p.y}\right)^2\frac{1}{\sqrt{2\pi}\sigma}e^{-(\underline{z}-1)^2/2\sigma^2}\left(\frac{-\underline{z}+1}{\sigma^2}\right).$$

We know that when $(1+r_0)I>C(\sigma)$, at r_0, $j_1(r_0)=0<j_2(r_0,\varphi,\sigma,\overline{\varphi})=\delta(r_0,\varphi,\sigma,\overline{\varphi})[(1+r_0)I-C(\sigma)]$. At $\tilde{r}$, $j_1(\tilde{r})=I(\tilde{r}-r_0)$ and $j_2(\tilde{r},\varphi,\sigma,\overline{\varphi})=\delta(\tilde{r},\varphi,\sigma,\overline{\varphi})[(1+\tilde{r})I-C(\sigma)]=\frac{1}{2}[d(\varphi,\overline{\varphi})-C(\sigma)]$. It follows that, if $d(\varphi,\overline{\varphi})>2I(1+r_0)-C(\sigma)$, at $\tilde{r}$, $j_1(\tilde{r})>j_2(\tilde{r},\varphi,\sigma,\overline{\varphi})$. Therefore, by the intermediate value theorem, when $d(\varphi,\overline{\varphi})+C(\sigma)>2I(1+r_0)$, there exists a unique $r^*\in[r_0,\tilde{r}]$ in which both functions intersect and Equation (A1) holds (see Figure 2).

It is important to note that the function $j_2(r,\varphi,\sigma,\overline{\varphi})$ is continuous with respect to φ and σ. As productivity decreases, the threshold shock that leads to zero profit increases, which implies an increase of the probability of bankruptcy. A decrease in the firm's productivity shifts therefore the function $j_2(r,\varphi,\sigma,\overline{\varphi})$ upward, while the function $j_1(r)$ remains constant. Therefore, firms with lower productivity are charged a higher interest rate than those with higher productivity.

Furthermore, as volatility increases, there is an increase in the probability of bankruptcy (as shown in Proposition 1), and a decrease in the expected collateral. These two effects also cause an upward shift in the function $j_2(r,\varphi,\sigma,\overline{\varphi})$, and an increase in the interest rate.

Thus, a decrease in productivity or an increase in volatility increases the interest rate, and at the same time, decreases $d(\varphi,\overline{\varphi})+C(\sigma)$, until the maximum possible interest rate for a firm $\tilde{r}$ is reached when $d(\varphi,\overline{\varphi})+C(\sigma)=2I(1+r_0)$. This guarantees that the function j_2 does not intersect j_1 twice in the interval $[r_0,\tilde{r}]$, and avoids therefore the possibility that a firm gets charged two interest rates in this interval. Q.E.D.

C. Proof of the existence and uniqueness of a stationary equilibrium in the closed economy

From the free entry condition, we know that the average profits can be expressed as:

$$\overline{\Pi}=\frac{\overline{\delta}(\hat{\varphi})f_e}{P_{in}(\hat{\varphi})}. \qquad \text{(A2)}$$

Average profits can also be expressed in terms of the profits of a firm with minimum productivity in the market as:

$$\bar{\Pi} = \left\{ \left(\frac{\bar{\varphi}}{\hat{\varphi}} \right)^{\alpha-1} (1+r_0) - [1+\bar{r}(\hat{\varphi})] \right\} I \,. \tag{A3}$$

We wish to find a unique $\hat{\varphi}$ such that Equations (A2) and (A3) hold. We know that the average interest rate is an increasing function of the average probability of bankruptcy and average volatility. The average probability of bankruptcy depends negatively on $\left(\frac{\bar{\varphi}}{\hat{\varphi}} \right)^{\alpha-1}$, and positively on the average volatility. There is an equilibrium if, as $\hat{\varphi}$ goes from 0 to infinity, Equation (A3) decreases monotonically from infinity to zero, and Equation (A2) increases from a positive value to infinity.

First, as $\hat{\varphi}$ goes to infinity, $\lim_{\hat{\varphi}\to\infty} P_{in}(\hat{\varphi}) \to 0$. Since the probability of bankruptcy is larger than zero, and the average interest rate is bounded (note that the maximum interest rate is the rate leading to an expected profit which goes to zero as $\hat{\varphi}$ goes to infinity), then Equation (A3) goes to zero and Equation (A2) to infinity.

Second, as $\hat{\varphi}$ goes to zero, $\lim_{\hat{\varphi}\to 0} P_{in}(\hat{\varphi}) \to 1$ and $\lim_{\hat{\varphi}\to 0} \bar{\sigma}(\hat{\varphi})^{\alpha-1} = \int_0^\infty \sigma^{\alpha-1} h(\sigma) d\sigma = \tilde{\sigma}$, where $\tilde{\sigma}$ is a constant. This implies that both the average probability of bankruptcy, and the average interest rates are also constants. Therefore, as $\hat{\varphi}$ goes to zero, Equation (A3) goes to infinity and Equation (A2) tends to a constant positive value.

Sufficient conditions for the existence of an equilibrium are that $\left(\frac{\bar{\varphi}}{\hat{\varphi}} \right)^{\alpha-1}$ is a decreasing function of $\hat{\varphi}$, and that the average volatility is increasing, constant, or does not decrease too much with respect to $\hat{\varphi}$. We will show that the first condition holds if the distribution of volatilities is such that the majority of firms do not have very high volatility. The second condition holds if the distribution of productivities is such that the majority of the firms do not have too high productivity. As discussed in footnote 11 in the paper, our data show that these conditions hold.

Let us now determine the conditions under which $\left(\frac{\bar{\varphi}(\hat{\varphi},h)}{\hat{\varphi}} \right)^{\alpha-1}$ is a decreasing function of $\hat{\varphi}$ for any density function of volatility h. The density function can be expressed as a normalized weighted average of the different values of a random variable. Let us consider the case in which the volatility distribution is concentrated around the value $h_0 > 0$ (see Figure A3).

INSERT FIGURE A3

The condition under which $\left(\frac{\overline{\varphi}(\hat{\varphi},h_0)}{\hat{\varphi}}\right)^{\alpha-1}$ is decreasing with respect to $\hat{\varphi}$ can be expressed as

$$\frac{\partial\left(\frac{\overline{\varphi}(\hat{\varphi},h_0)^{\alpha-1}}{\hat{\varphi}^{\alpha-1}}\right)}{\partial\hat{\varphi}} = \frac{\partial\overline{\varphi}(\hat{\varphi},h_0)^{\alpha-1}}{\partial\hat{\varphi}}\hat{\varphi}^{1-\alpha} - (\alpha-1)\overline{\varphi}(\hat{\varphi},h_0)^{\alpha-1}\hat{\varphi}^{-\alpha},$$

where $\frac{\partial\overline{\varphi}(\hat{\varphi},h_0)^{\alpha-1}}{\partial\hat{\varphi}} = \frac{g(\varphi_0)}{1-G(\varphi_0)}\frac{\partial\varphi_0}{\partial\hat{\varphi}}\left(\overline{\varphi}(\hat{\varphi},h_0)^{\alpha-1} - \varphi_0^{\alpha-1}\right)$, and φ_0 is the minimum productivity level such that a firm with volatility h_0 can stay in the market, and is equal to $\left(\frac{h_0}{I(1+r_0)}+1\right)^{1/(\alpha-1)}\hat{\varphi}$. An increase in the minimum productivity level from $\hat{\varphi}^0$ to $\hat{\varphi}^1$ makes that firms with productivity levels between $\varphi_0(\hat{\varphi}^0,h_0)$ and $\varphi_0(\hat{\varphi}^1,h_0)$ exit the market. As volatility increases (i.e. as h_0 increases), a larger number of firms with high productivity have to exit the market. If the productivity were distributed uniformly, this would lead to an increase in the average productivity in the market. Note that the increase in the average productivity is higher if the distribution of the volatilities is such that there are many firms in the market with high volatility. Our necessary condition for $\left(\frac{\overline{\varphi}(\hat{\varphi},h)}{\hat{\varphi}}\right)^{\alpha-1}$ to be a decreasing function of $\hat{\varphi}$ is that the proportion of firms in the market, characterized by high volatility is not too high. Analytically, this condition can be expressed as:

$$\frac{\partial\left(\frac{\overline{\varphi}(\hat{\varphi})}{\hat{\varphi}}\right)^{\alpha-1}}{\partial\hat{\varphi}} = (\alpha-1)\hat{\varphi}^{-\alpha}\left\{\frac{\left[2I(1+r_0)-C_0\right]\hat{\varphi}^{1-\alpha}}{P_{in}(\hat{\varphi})}\left[\overline{\varphi}^{\alpha-1}\int_{\hat{\varphi}}^{\infty}\varphi^{\alpha-1}g(\varphi)h(s(\varphi,a\hat{\varphi}))d\varphi\right.\right.$$

$$\left.\left.-\int_{\hat{\varphi}}^{\infty}\varphi^{\alpha-1}g(\varphi)h(s(\varphi,a\hat{\varphi}))d\varphi\right] - \overline{\varphi}^{\alpha-1}\right\} < 0.$$

We now determine the conditions under which the average volatility increases, remains constant, or does not decrease too much with respect to $\hat{\varphi}$. The effect of $\hat{\varphi}$ on the average volatility,

$\frac{\partial \bar{\sigma}(\hat{\varphi})^{\alpha-1}}{\partial \hat{\varphi}}$, is ambiguous: it depends on the specific distribution functions of productivity and volatility.

An increase in $\hat{\varphi}$ causes the exit function $s(\varphi, a\hat{\varphi})$ to shift downwards. This implies that some firms in the market cannot obtain a loan anymore, and therefore have to exit the market. Consider the example illustrated in Figure A4. If, initially (when $\hat{\varphi} = \hat{\varphi}^0$), the distribution of firms in the market is formed by firms with low productivity and low volatility (firms in the circle labelled 1), and firms with high productivity and medium volatility (firms in the circle labelled 2), as $\hat{\varphi}$ increases (from $\hat{\varphi}^0$ to $\hat{\varphi}^1$), the average volatility increases, as the firms in the circle labelled 1 have to exit the market. In this case, both the average interest rate and the average probability of bankruptcy increase, the entrance of new firms is bounded, and there is an equilibrium.

INSERT FIGURE A4

Let us now focus on Figure A5.

INSERT FIGURE A5

Let us suppose that there are two types of firms in the market when productivity is given by $\hat{\varphi}^0$: firms with low volatility and low productivity (in circle 1), and firms with high volatility and high productivity (in circle 2). As $\hat{\varphi}$ increases to $\hat{\varphi}^1$, all firms in circle 2, as well as some of the firms in circle 1 will be forced to exit the market. Therefore, the average volatility in the market decreases, and both the average probability of bankruptcy and the average interest rate decrease as well. This effect is stronger if the proportion of firms with high productivity levels is very high. To see this, consider the case in which productivity is concentrated at the value φ', the maximum volatility in the market is σ', and the average volatility is $\bar{\sigma}(\hat{\varphi}, \sigma'(\hat{\varphi}))^{\alpha-1} = \frac{\int_0^{\sigma'} \sigma^{\alpha-1} h(\sigma) d\sigma}{H(\sigma')}$. In this case, the derivative of $\bar{\sigma}$ with respect to $\hat{\varphi}$ is always negative, and higher in absolute value, the higher the value of φ' (i.e. the higher the concentration of firms with high productivity in the market). Therefore, a necessary condition for average volatility to increase, remain constant, or not decrease too much, as $\hat{\varphi}$ rises, which itself is a sufficient condition to ensure that Equation (A3) is decreasing, and Equation (A2) increasing with respect to $\hat{\varphi}$, is that the proportion of firms in the market with high productivity levels is not too high. Analytically, the derivative of average volatility with respect to $\hat{\varphi}$ can be expressed as:

$$\frac{\partial \bar{\sigma}(\hat{\varphi})^{\alpha-1}}{\partial \hat{\varphi}} = \frac{1}{P_{in}(\hat{\varphi})}\left[\bar{\sigma}^{\alpha-1}\int_0^\infty h(\sigma)g(\tilde{\varphi}(\sigma))\frac{\partial \tilde{\varphi}(\sigma)}{\partial \hat{\varphi}}d\sigma - \int_0^\infty \sigma^{\alpha-1}h(\sigma)g(\tilde{\varphi}(\sigma))\frac{\partial \tilde{\varphi}(\sigma)}{\partial \hat{\varphi}}d\sigma\right].$$

To ensure the existence of an equilibrium, this derivative has to be positive, equal to 0, or negative, but small in absolute value. Q.E.D.

D. Proof that the exit function of exporters can be expressed in terms of the minimum productivity in the market.

Solving $s_X(\hat{\varphi}_x, \bar{\varphi}_T) = s(\hat{\varphi}_x, \bar{\varphi}_T)$, we obtain: $\hat{\varphi}_x^{\ \alpha-1} = \bar{\varphi}_T^{\ \alpha-1}\dfrac{2I_x(1+r_0)M_T\alpha\tau^\alpha}{\tau\alpha-(\alpha-1)}$. Rewriting this expression in terms of $\bar{\varphi}_T^{\ \alpha-1}$ and substituting its value into Equation (15), we obtain the exit function of exporters, in terms of their minimum level of productivity, i.e. $s_X(\varphi, b\hat{\varphi}_x) = \left[\left(\dfrac{\varphi}{\hat{\varphi}_x}\right)^{\alpha-1}\left(1+\dfrac{\tau^\alpha}{\tau\alpha-(\alpha-1)}\right)-1\right]2I_x(1+r_0) - 2I(1+r_0) + C_0$, where b is the constant that relates $\hat{\varphi}_x$ with $\bar{\varphi}_T$. Equation (10) gives us the relationship between $\hat{\varphi}$ and the average productivity in the market. We can also express the minimum level of productivity of exporters in terms of this minimum level of productivity. Therefore, we obtain that $\hat{\varphi}_x^{\ \alpha-1} = \hat{\varphi}^{\alpha-1}\left[\left(\dfrac{2I_x(1+r_0)}{2I(1+r_0)-C_0}\right)\left(\dfrac{\tau^\alpha}{\tau\alpha-(\alpha-1)}\right)\right]$. Substituting this equation into the exit function for exporters, we are able to express this exit function in terms of the minimum productivity level in the market as follows:

$s_X(\varphi, c\hat{\varphi}) = \left[\left(\dfrac{\varphi}{\hat{\varphi}}\right)^{\alpha-1}\left(1+\dfrac{\tau\alpha-(\alpha-1)}{\tau^\alpha}\right)-1\right]\left[2I(1+r_0)-C_0\right] - 2I_x(1+r_0)$, where c is the constant that relates $\hat{\varphi}$ with $\bar{\varphi}_T$. Q.E.D.

E. Proof of the existence and uniqueness of a stationary equilibrium in the open economy

The free entry condition in the open economy is given by:

$$\bar{\Pi}(\bar{\varphi}_T, \bar{\sigma}_T) = \frac{f_e\ \bar{\delta}(\bar{\varphi}(\hat{\varphi}), \bar{\sigma}(\hat{\varphi}))}{P_{in}(\hat{\varphi})}, \tag{A4}$$

where the probability of entry in an open economy is equal to:

$$P_{in}(\hat{\varphi}) = \int_{\hat{\varphi}}^{\hat{\varphi}_x(\hat{\varphi})} g(\varphi)H(s(\varphi, a\hat{\varphi}))d\varphi + \int_{\hat{\varphi}_x(\hat{\varphi})}^{\infty} g(\varphi)H(s_x(\varphi, c\hat{\varphi}))d\varphi . \tag{A5}$$

The zero profit condition now includes the profit in the foreign market. We denote with $\overline{\Pi}(\overline{\varphi}_T, \overline{\sigma}_T)$ the average profit in the economy with trade, which is equal to:

$$\overline{\Pi}(\overline{\varphi}_T, \overline{\sigma}_T) = d_d(\overline{\varphi}_T, \hat{\varphi}) + d_x(\overline{\varphi}_T, \hat{\varphi})P_x - \left[I(1+\overline{r}_{nx}) + P_x(I + I_x)(1+\overline{r}_x)\right]. \tag{A6}$$

In the above equation, $d_d(\overline{\varphi}_T, \hat{\varphi})$, and $d_x(\overline{\varphi}_T, \hat{\varphi})$ represent the average income minus the variable costs in the domestic and foreign markets, respectively; and $P_x = \frac{1}{P_{in}} \int_{\hat{\varphi}_x(\hat{\varphi})}^{\infty} g(\varphi)H(s_x(\varphi, c\hat{\varphi}))d\varphi$ is the probability of exporting, which also represents the percentage of firms in the market that export. The average interest rates of non-exporters and exporters are $\overline{r}_{nx}$ and $\overline{r}_x$, respectively. We wish to show that, like in the autarky case, as $\hat{\varphi}$ goes from 0 to infinity, Equation (A4) increases monotonically from a positive value to infinity, and Equation (A6) decreases monotonically from infinity to zero.

First, as $\hat{\varphi}$ goes to infinity, the probability of entry, $\int_{\hat{\varphi}_x(\hat{\varphi})}^{\infty} g(\varphi)H(s_x(\varphi, c\hat{\varphi}))d\varphi$; and $\int_{\hat{\varphi}}^{\hat{\varphi}_x(\hat{\varphi})} g(\varphi)H(s_x(\varphi, c\hat{\varphi}))d\varphi$), all go to zero. Appendix 1F below proves that the probability of entry is a decreasing function of $\hat{\varphi}$. Moreover, as in the autarky case, the average probability of bankruptcy is larger than zero, and the interest rates are bounded. This implies that as $\hat{\varphi}$ goes to infinity, the average interest rates and the probability of bankruptcy are constants. Therefore, Equation (A4) goes to infinity and Equation (A6) goes to zero.

Second, as $\hat{\varphi}$ goes to zero, both the probability of entry and the probability of exporting go to one. Additionally, the average volatility tends to a constant, which we denote with $\tilde{\sigma}$. This implies that Equation (A4) goes to a constant, and Equation (A6) to infinity.

As in the autarky case, sufficient conditions for the existence of an equilibrium are that the function $\left(\frac{\overline{\varphi}_T(\hat{\varphi})}{\hat{\varphi}}\right)^{\alpha-1}$ is decreasing with respect to $\hat{\varphi}$, and that the average volatility is increasing, constant, or does not decrease too much with respect to $\hat{\varphi}$. These conditions are satisfied when the proportion of firms with high volatility and high productivity is not too high. In Equation (A6),

$d_d(\bar{\varphi}_T, \hat{\varphi})$ and $d_x(\bar{\varphi}_T, \hat{\varphi})$ depend positively on $\left(\frac{\bar{\varphi}_T(\hat{\varphi})}{\hat{\varphi}}\right)^{\alpha-1}$, which is decreasing in $\hat{\varphi}$ if $\frac{\partial \bar{\varphi}_T(\hat{\varphi})^{\alpha-1}}{\partial \hat{\varphi}}$ is not too large. As in the autarky case, the latter condition implies that the proportion of firms with high volatility is not too high. Moreover, the entrance of firms will be bounded, if, as $\hat{\varphi}$ increases, the average volatility increases, remains constant, or does not decrease too much, which happens, as in autarky, when the proportion of firms with high productivity is not too large. Q.E.D.

It is important to note that the minimum productivity in autarky is lower than under free trade. In a free trade equilibrium, the free entry condition is the same as in autarky, and is a decreasing function of $\hat{\varphi}$. However, considering that the zero profit condition is higher under free trade than in autarky (since the average profits are higher), this implies that the equilibrium $\hat{\varphi}$ has to be higher under free trade than in autarky.

F. Proof that, in the open economy, the probability of entry is a decreasing function of $\hat{\varphi}$.

The derivative of the probability of entry with respect to the minimum productivity is:

$$\frac{\partial P_{in}(\hat{\varphi})}{\partial \hat{\varphi}} = g(\hat{\varphi}_x)H(s(\hat{\varphi}_x, c\hat{\varphi})) - g(\hat{\varphi})H(s(\hat{\varphi}_x, c\hat{\varphi})) - g(\hat{\varphi}_x)H(s_x(\hat{\varphi}_x, c\hat{\varphi})) +$$

$$+\int_{\hat{\varphi}_x}^{\infty} g(\varphi)h(s_x(\varphi, c\hat{\varphi}))\frac{\partial s_x(\varphi, c\hat{\varphi})}{\partial \hat{\varphi}}d\varphi =$$

$$= -g(\hat{\varphi})H(s(\hat{\varphi}_x, c\hat{\varphi})) - (\alpha-1)\left[2I(1+r_0) - C_0\right]\left[\frac{\tau^{\alpha}}{\tau\alpha}\right]\hat{\varphi}^{-\alpha}\int_{\hat{\varphi}_x}^{\infty}\varphi^{\alpha-1}g(\varphi)h(s_x(\varphi, c\hat{\varphi}))d\varphi < 0. \text{ Q.E.D.}$$

Appendix 2: Data

Structure of the unbalanced panel

Number of observations per firm	Number of firms	Percent	Cumulative
1	1306	14.06	14.06
2	918	9.88	23.93
3	870	9.36	33.30
4	825	8.88	42.18
5	752	8.09	50.27
6	703	7.57	57.83
7	650	7.00	64.83
8	757	8.15	72.98
9	1078	11.60	84.58
10	1433	15.42	100.00
Total	9292	100.00	

Definitions of the variables used

$FAIL_{it}$: dummy variable equal to 1 if firm *i* failed in year *t*, and 0 otherwise. We define a firm as failed (dead) in a given year if its firm status is in receivership, liquidation, or dissolved.

$Size_{it}$: logarithm of the firm's total real assets. Total assets are given by the sum of fixed (tangible and intangible) assets and current assets, where current assets are defined as the sum of stocks, work-in-progress inventories, trade and other debtors, cash and equivalents, and other current assets.

$Sales_{it}$: includes both UK and overseas turnover.

$Collateral_{it}/Debt_{it}$: ratio between the firm's tangible assets and its total (long- and short-term) debt.

TFP_{it}: total factor productivity calculated using the Levinsohn and Petrin (2003) method.

$Group_i$ dummy variable equal to 1 if the firm is part of a group, and 0 otherwise. A firm is said to be part of a group if it is a subsidiary of one or more holding firms (UK or foreign). Information about whether a firm is part of a group is only provided in the last year of observations available for each firm. We therefore assume that a firm which was part of a group or foreign owned in its last available year was part of a group or foreign owned throughout the period in which it was observed. Given the short sample that we analyze, this is a reasonable assumption.

$Quiscore_{it}$ is given as a number in the range from 0 to 100. The lower its *Quiscore*, the more risky a firm is likely to be. The indicator is constructed taking into account a number of factors, including the presence of any adverse documents appearing against the firm on the public file, and the timeliness of getting the accounts filed. However, the most important factors relate to the financial performance of the firm as evidenced by its balance sheet and profit and loss accounts. The key financial items used include turnover, pre-tax profits, working capital, intangibles, cash and bank deposits, creditors, bank loans and overdrafts, current assets, current liabilities, net assets, fixed assets, share capital, reserves and shareholders funds. The underlying economic conditions are also taken into account.

$START_{it}$: dummy variable equal to 1 if firm *i* exported a positive amount in year *t*, but not in year *t*-1, and 0 otherwise.

$Totalvol_{it}$: standard deviation of the firm's total real sales growth. The standard deviation is measured over a rolling window of 5 years.

$Nationalvol_{it}$: standard deviation of the firm's real national sales growth. The standard deviation is measured over a rolling window of 5 years.

$Overseasvol_{it}$: standard deviation of the firm's real overseas sales growth. The standard deviation is measured over a rolling window of 5 years.

$Prenationalvol_{it}$: standard deviation of the firm's real sales calculated over the 5 years preceding and including year *t*.

$Prenationalvol1_{it}$: standard deviation of the firm's real sales calculated over all years preceding and including year *t*.

$LOWVOL_{it}$: dummy variable equal to one if firm *i*'s *Totalvol* in year *t* is in the lowest 50 percent of the distribution of the *Totalvol*s of all firms operating in the same industry as firm *i*'s in year *t*, and 0 otherwise.

$HIGHVOL_{it}$: dummy variable equal to one if firm *i*'s *Totalvol* in year *t* is in the highest 50 percent of the distribution of the *Totalvol*s of all firms operating in the same industry as firm *i*'s in year *t*, and 0 otherwise.

Deflators: all variables are deflated using the aggregate GDP deflator.

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Figure 1: Timing of actions

Beginning of period t End of period t

Entry of new firms
(their productivities and
volatilities are drawn)

Firms and banks → firms with:
observe market • positive expected future value → loans are contracted → firms produce → realization of z → firms that
characteristics • negative expected future value can repay the loan → continue to t+1
↓ exit → firms that
cannot repay the loan → are liquidated
↓ exit

FIGURE 2: Equilibrium interest rate

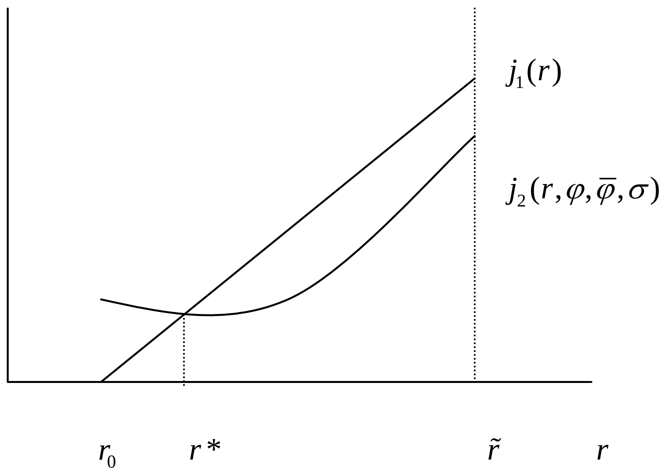

FIGURE 3: Relationship between profit and volatility

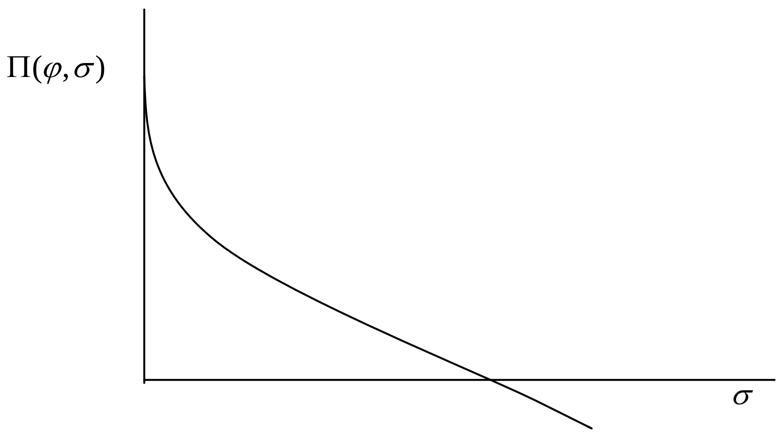

FIGURE 4: Exit function in the closed economy

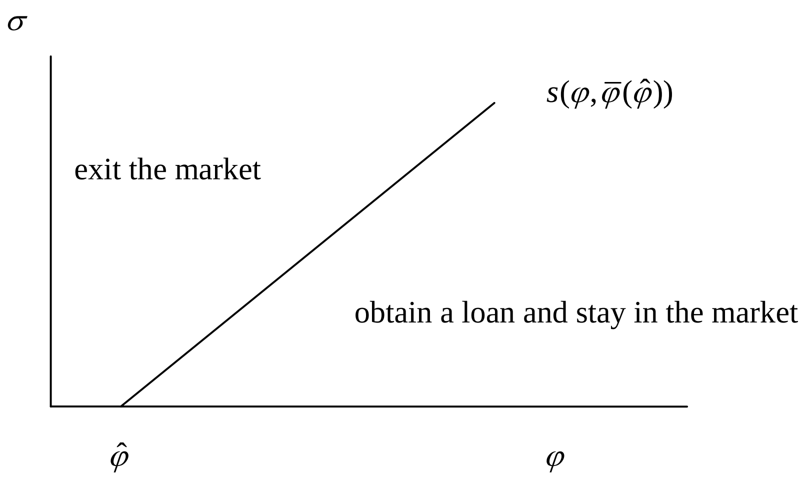

FIGURE 5: Exit functions in the open economy

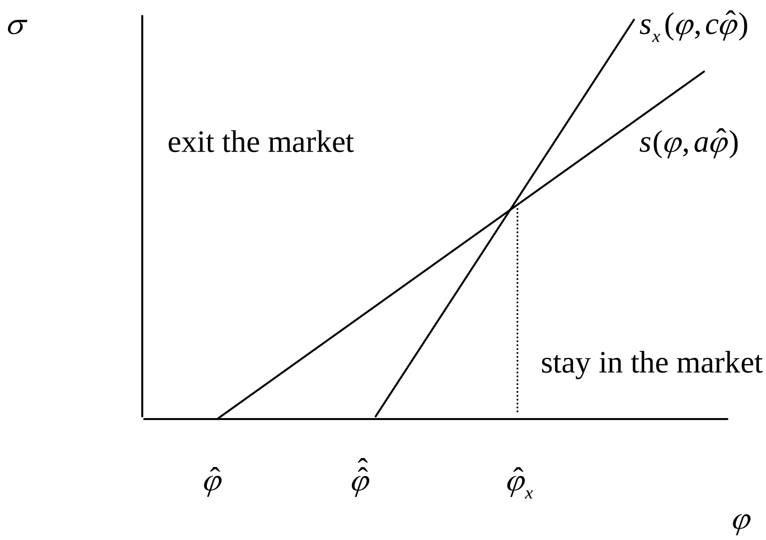

FIGURE 6a: Effects of opening up to trade: case 1

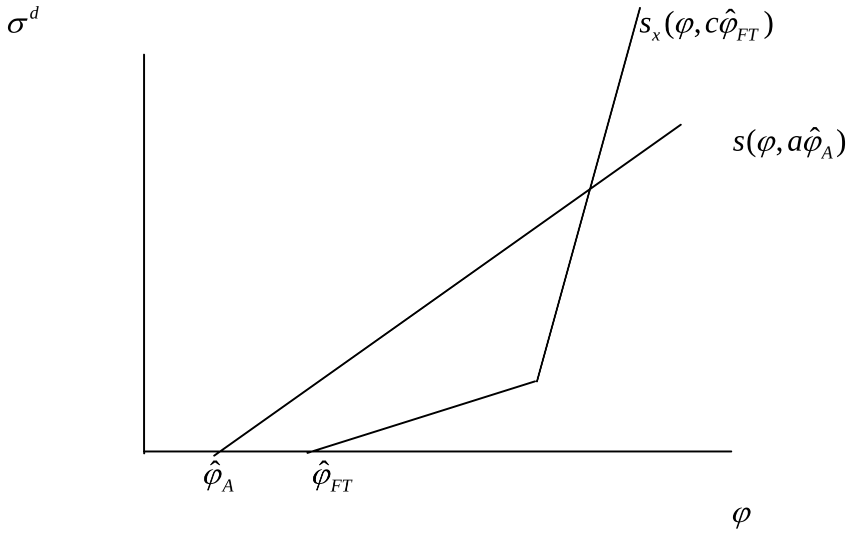

FIGURE 6b: Effects of opening up to trade: case 2

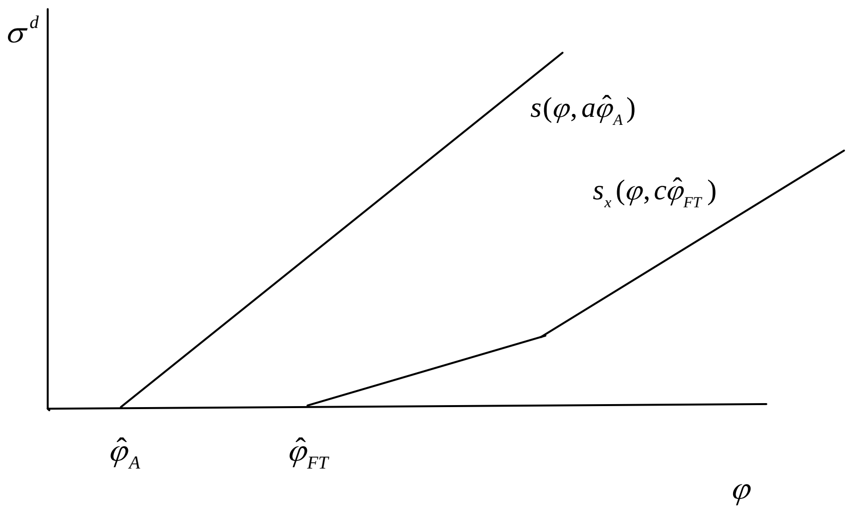

FIGURE A1: Quantifying the probabilities of bankruptcy of two firms with different volatilities when $\underline{z} < \hat{z}$.

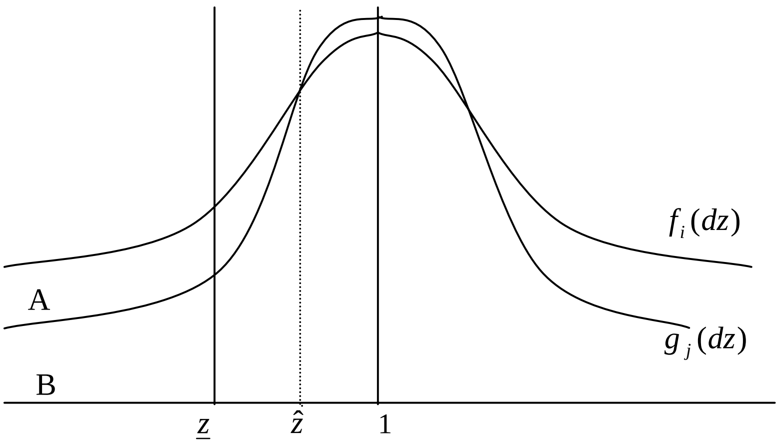

FIGURE A2: Quantifying the probabilities of bankruptcy of two firms with different volatilities when $\underline{z} > \hat{z}$.

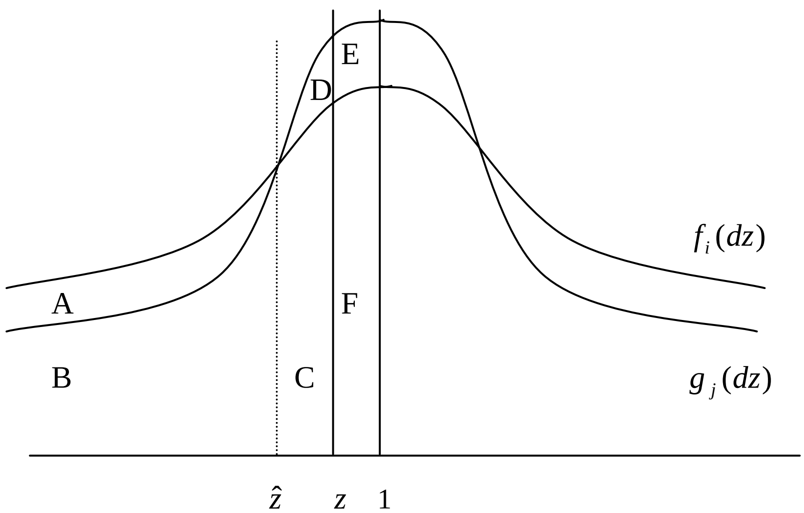

FIGURE A3: Relationship between volatility distribution and changes in average productivity as the minimum productivity increases.

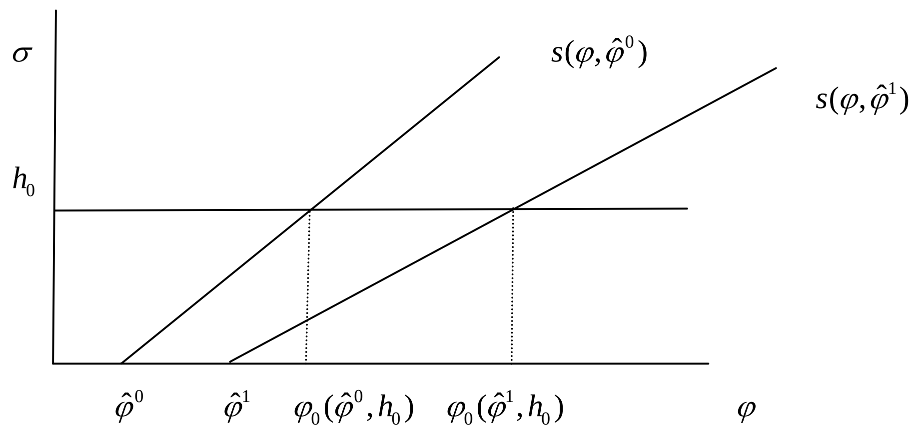

FIGURE A4: Increases in minimum productivity that increase average productivity and average volatility

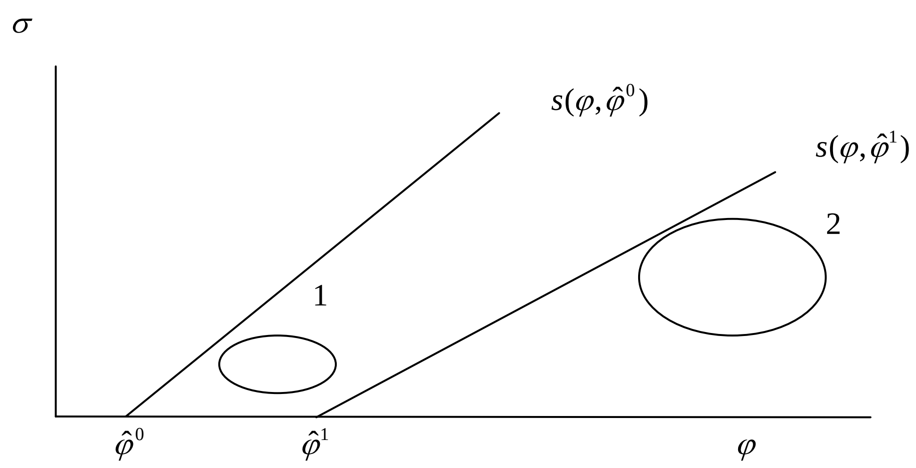

FIGURE A5: Increases in minimum productivity that decrease average productivity and average volatility

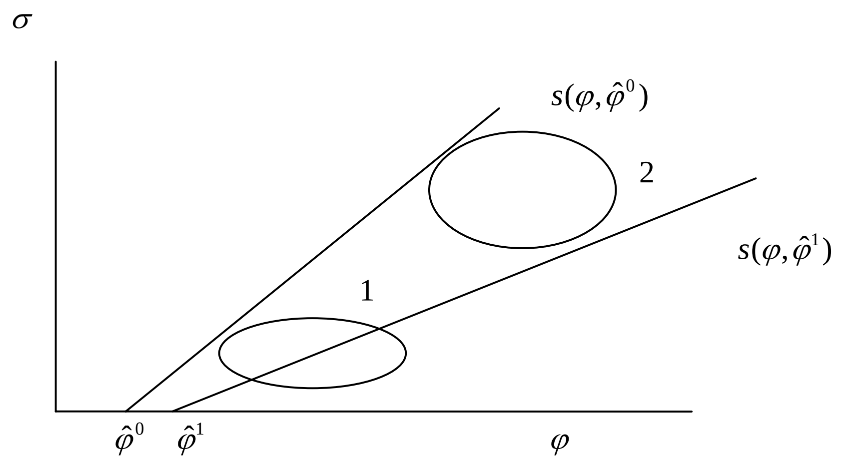

Table 1: Descriptive statistics

	(1) Total sample	(2) $FAIL_{it}$ =0	(3) $FAIL_{it}$ =1	(4) $LOWVOL_{it}$ =1	(5) $HIGHVOL_{it}$ =1	(6) $START_{it}$ =0	(7) $START_{it}$ =1
$Size_{it}$	8.834	8.881	8.341	9.033	8.972	8.311	8.739
	(1.41)	(1.42)	(1.15)	(1.34)	(1.35)	(1.35)	(1.40)
Age_{it}	27.716	27.956	25.188	33.036	28.105	25.548	23.728
	(24.13)	(24.24)	(22.70)	(24.92)	(23.81)	(22.95)	(21.27)
TFP_{it}	5.650	5.738	4.760	5.826	5.820	5.188	5.489
	(2.44)	(2.48)	(1.84)	(2.40)	(2.40)	(2.27)	(2.51)
$Group_{i}$	0.319	0.340	0.110	0.342	0.331	0.253	0.285
	(0.47)	(0.47)	(0.31)	(0.47)	(0.47)	(0.43)	(0.45)
$Collateral_{it}/Debt_{it}$	1.765	1.781	1.632	1.888	1.587	2.00	1.699
	(3.52)	(3.56)	(3.11)	(3.76)	(3.28)	(4.07)	(2.63)
$Quiscore_{it}$	54.867	55.644	46.720	59.459	54.069	55.138	51.127
	(22.31)	(22.37)	(19.94)	(20.98)	(21.74)	(21.77)	(21.68)
$Totalvol_{it}$	0.197	0.199	0.207	0.092	0.306	0.190	0.238
	(0.19)	(0.19)	(0.17)	(0.04)	(0.22)	(0.21)	(0.31)
$Nationalvol_{it}$	0.238	0.237	0.258	0.131	0.346	0.193	0.309
	(0.27)	(0.27)	(0.30)	(0.17)	(0.31)	(0.23)	(0.42)
$Overseasvol_{it}$	0.482	0.479	0.546	0.370	0.593	0.389	0.771
	(0.50)	(0.50)	(0.53)	(0.42)	(0.54)	(0.31)	(0.84)
Observations	51668	47177	4491	10576	10540	10388	681

Notes: $FAIL_{it}$: dummy variable equal to 1 if firm *i* failed in year *t*, and 0 otherwise. *$LOWVOL_{it}$/ $HIGHVOL_{it}$:* dummy variable equal to one if firm *i*'s *Totalvol* in year *t* is in the lowest (highest) 50 percent of the distribution of the *Totalvol*s of all firms operating in the same industry as firm *i*'s in year *t*, and 0 otherwise. *$START_{it}$*: dummy variable equal to 1 if firm *i* exported a positive amount in year *t*, but not in year *t*-1, and 0 otherwise. *$Size_{it}$*: logarithm of the firm's total real assets. *$Collateral_{it}/Debt_{it}$*: the ratio between the firm's tangible assets and its total (long- and short-term) debt. *TFP_{it}*: total factor productivity. *$Group_{i}$* dummy variable equal to 1 if the firm is part of a group, and 0 otherwise. *$Quiscore_{it}$* is a measure of how risky the firm is. The lower its *Quiscore*, the more risky a firm is likely to be. *$Totalvol_{it}$:* standard deviation of the firm's total real sales growth. The standard deviation is measured over a rolling window of 5 years. *$Nationalvol_{it}$:* standard deviation of the firm's real national sales growth. *$Overseasvol_{it}$:* standard deviation of the firm's real overseas sales growth.

Table 2: Links between volatility and the probability of bankruptcy

	$FAIL_{it}$ *(1)*	$QUISCORE_{it}$ *(2)*
Age_{it}	0.005	0.064
	(1.65)	(0.46)
$Size_{it}$	-0.183	-4.623
	(2.51)*	(7.28)**
$Collateral_{it}/Debt_{it}$	0.001	2.030
	(0.02)	(19.71)**
TFP_{it}	-0.128	3.189
	(3.25)**	(16.30)**
$Group_i$	-1.236	
	(8.18)**	
$Totalvol_{it}$	0.762	-4.012
	(2.53)*	(3.21)**
Observations	9610	9934

Notes: *t*-statistics are reported in parentheses. The estimates in column (1) were obtained using a random-effects Probit specification; those in column (2), using a fixed-effects specification. Time dummies were included in all specifications. Time dummies and industry dummies were included in the specification reported in column (1). * denotes significance at 5%; ** denotes significance at 1%. Also see Notes to Table 1.

Table 3: Links between volatility and total factor productivity

	TFP_{it} *(1)*	TFP_{it} *(2)*
$Totalvol_{it}*LOWVOL_{it}$	0.028 (0.13)	-0.265 (0.78)
$Totalvol_{it}*HIGHVOL_{it}/MEDIUMVOL_{it}$	0.222 (3.02)**	-0.059 (0.33)
$Totalvol_{it}*HIGHVOL_{it}$		0.170 (2.17)*
Observations	16495	16495

Notes: t-statistics are reported in parentheses. All estimates were obtained using a fixed-effects specification. In column (2), $LOWVOL_{it}$/ $HIGHVOL_{it}$ are dummy variables equal to one if firm *i*'s *Totalvol* in year *t* is in the lowest (highest) 50 percent of the distribution of the *Totalvol*s of all firms operating in the same industry as firm *i*'s in year *t*, and 0 otherwise. In column (3), $LOWVOL_{it}$ is equal to one if firm *i*'s total real sales growth volatility in year *t* is in the lowest 33 percent of the distribution of the volatilities of all firms operating in the same industry as firm *i*'s in year *t*, and 0 otherwise; $MIDDLEVOL_{it}$ is equal to one if firm *i*'s volatility in year *t* is in the middle 33 percent of the distribution, and 0 otherwise; and $HIGHVOL_{it}$ is equal to one if firm *i*'s volatility in year *t* is in the highest 33 percent of the distribution, and 0 otherwise. Time dummies were included in all specifications. * denotes significance at 5%; ** denotes significance at 1%. Also see Notes to Table 1.

Table 4: Links between volatility and the probability to start exporting

	$START_{it}$ (1)	$START_{it}$ (2)	$START_{it}$ (3)
Age_{it}	-0.001 (0.54)	-0.001 (0.38)	-0.001 (0.34)
$Size_{it}$	0.341 (5.67)**	0.272 (5.00)**	0.275 (5.06)**
TFP_{it}	-0.072 (2.42)*	-0.043 (1.67)	-0.045 (1.73)
$Group_i$	-0.037 (0.29)	0.047 (0.40)	0.052 (0.44)
$Nationalvol_{it}$	0.725 (4.14)**		
$Prenationalvol_{it}$		0.724 (3.60)**	
$Prenationalvol1_{it}$			0.730 (3.42)**
Observations	3299	3170	3170

Notes: *t*-statistics are reported in parentheses. All estimates were obtained using a random-effects Probit specification. $Prenationalvol_{it}$: standard deviation of the firm's real sales calculated over the five years preceding and including year *t*. $Prenationalvol1_{it}$:standard deviation of the firm's real sales calculated over all years preceding and including year *t*. Time dummies and industry dummies were included in all specifications. * denotes significance at 5%; ** denotes significance at 1%. Also see Notes to Table 1.