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1. Abstract

We present and test a model relating a firm's idiosyncratic cost, its exporting status, and the volatilities of its domestic and export sales. In prior models of trade, supply costs for domestic and exports were linear and thus additively separable. We introduce a nonlinear cost function in order to link the domestic and export supply costs . This theoretical contribution has two new implications for the exporting firm. First, the demand volatility in the foreign market now directly affects the firm's domestic sales volatility. Second, firms hedge domestic demand volatility with exports. The model has several testable predictions. First, larger firms have lower total and domestic sales volatilities. Second, foreign market volatility increases domestic sales volatilities for exporters. Third, exporters allocate output across both markets in order to reduce total sales volatility. We find evidence for these predictions with Danish firms operating between 1992 and 2006.

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2. Introduction

All firms face high volatilities in the domestic market. In addition, exporters encounter fickle foreign demands and fluctuating exchange rates in foreign markets. Whether these foreign sources of volatilities affect an exporter's domestic supply volatility depends on the firm's ability to flexibly adjust its outputs and inputs. This study presents and tests a model relating a firm's idiosyncratic costs, its exporting status, and the volatilities of its domestic and export sales.

In our model, exporting firms face volatile linear demands in both the domestic and export markets. Unlike previous models of trade with linear demands (Melitz Ottaviano, 2008, Kneller & Yu 2008), production involves increasing marginal costs. This cost structure links an exporter's optimal output allocation across markets; a demand shock in either market causes the exporter to reallocate output across both markets. This reallocation does not exist in the standard constant marginal cost models, where an exporter's total foreign supply does not affect its marginal cost of domestic supply.

The model relates size and export status to output volatility, or flexibility.[1] Many predictions are in line with the literature: bigger firms have lower marginal costs and are more likely to export. Our theory reveals additional adjustment margins in response to demand fluctuations. First, exporters face volatility on the foreign market that feeds back to the domestic market due to the linkage in production. Second, while additional volatility due to exporting tends to increase a firm's output volatility, the exporter can hedge high volatilities in one market by reallocating

[1] Stigler (1939) defines flexibility as the ability to vary output in response to exogenous shocks.

output to the other market. These two forces work in opposite directions. The net result may increase or decrease the firm's total volatility.

We use detailed Danish firm level data encompassing the universe of Danish manufacturing firms to test these predictions. We examine 27,000 firms over 16 years. We have data on sales as well as labor, capital, energy and assets. These data allow us to test two sets of hypotheses. First, a set of sales volatility specifications examine the impact of size and exporting on a firm's output volatilities and the allocation of output across markets. The second set of specifications examine the impact of size and export status on the volatility of the local factor demands. These results are the first firm level predictions that examine exporters' substitution mechanisms across markets in international trade and its implications for local factor and goods markets.

These results have two direct policy implications. First, export promotion programs look to facilitate firm entry into export markets.[2] To this end, a key question is what makes a successful exporter and what difficulties must new exporters overcome to successfully compete in foreign markets? Our estimation results show that exporters have considerable higher domestic and total sales volatility than non exporters. This is particularly true for medium sized firms that are on the margin of entry into the export market. This suggests that in addition to economies of scale, flexibility with respect to market fluctuations is an important factor of exporting and should be on the menu of recommendations for export promotion. Second, our results shed light on the impact of exporting on the local factor markets. The higher sales volatility of

[2]For recent examples see President Obama's Export Promotion Cabinet: http://www.nytimes.com/2010/03/12/business/economy/12trade.html or The Trade Council of Denmark http://www.um.dk/en/menu/TradeAndInvestment/

exporters goes hand in hand with a higher volatility in factor demands. This suggests that factor markets should be structured so that they can absorb this volatility.

Our study fills a gap between the existing International Trade and Industrial Organization literatures. In the International Trade literature, firms that are subject to high demand uncertainty relocate closer to the destination market to respond to demand fluctuations with just in time production (Evans and Harrigan, 2005), or, shift into a faster but more expensive transportation mix (Aizenman, 2004; Hummels and Schaur, 2009). Empirical identification of these margins requires rich variation across source countries, commodities and transport modes. The literature examines these margins using highly disaggregated trade data. However, corresponding domestic data has not existed beforehand, so the literature does not provide evidence about the feedback of foreign shocks to domestic output and factor markets. The industrial organization literature applies a sample of US firms to examine the trade off between firm size and flexibility with respect to demand uncertainty (Mills, 1984, 1986; Mills and Schumann, 1985). The empirical specifications apply detailed US firm level sales data, but do not distinguish between export and domestic sales. We examine the relationship between export and domestic sales activity to fill the gap between the two literatures.

Previous empirical and simulation studies found evidence at the country level that trade increases the transmission of shocks across countries and increases business cycle comovement (e.g (Kose and Yi, 2006), (Kose et. all., 2008)). In addition, world prices induce business cycle fluctuations in small open economies (Kose, 2001). A growing literature examines the determinants of volatility at a more disaggregated industry level. di Giovanni and Levchenko (2008) examine the risk content of trade, working through the impact of trade openness on individual sectors, changes in the comovement between sectors and changes in the pattern of specialization. Other industry-level studies examine specialization patterns (Imbs and Wacziarg, 2003; Kalemli-Ozcan et. al., 2003) and volatility independently (Raddatz, 2006; Imbs, 2006). We extend this trade and volatility literature by disaggregating to the firm level. Applying a detailed census of firms we identify a structurally higher domestic sales volatility for exporting firms. Our model interprets this result as evidence that a firm's cost function links the firm's supplies in the export and domestic markets. This link may theoretically increase or decrease a firm's total sales volatility, irregardless of whether demand shocks are correlated across markets. Firms that export to large and stable markets have lower total sales volatility than non exporters. Those that export to small and volatile markets have higher total sales volatility. We find that firms that export in all periods have lower total sales volatility, while firms that only export sometimes have higher totals sales volatility.

Buch et. all. (2006) provide firm level evidence for a negative relationship between a firm's total sales volatility and trade openness for a sample of German firms located in the state of Baden Wuerttemberg. We contribute to this finding in several ways. First, we provide a model that specifies a link between domestic and export sales. Second, instead of using a selective sample of a particular state in Germany, we examine a census of Danish firms, alleviating small sample data issues. Given this data, we find that exporting results in structurally higher volatility of domestic sales.

Our estimation results also show that exporters are more volatile in their labor inputs. (Krebs et. all., 2005) use individual level survey data to estimate the impact of trade liberalization on income uncertainty and evaluate the welfare impact. While such an exercise is beyond this current paper, our results show that exporting status has a direct and structural impact on the factor demand volatility.

3. Model

In this section, we examine the behavior of a single firm that can potentially supply to both a foreign and a domestic market. The marginal cost of the firm's first unit of output is β and rises linearly with output. This cost structure delivers interesting and testable predictions about the output allocation across markets and the feedback of volatility across output and factor markets.[3] The firm faces stochastic domestic and foreign demands for its output. Under conditions that match the patterns in the data, we derive the volatility of domestic and foreign supply and show their relationship to β. Finally, we show how the volatility of domestic, foreign, and total supply differ between a firm that exports and a firm that does not export.

3.1. Set Up

Firms produce horizontally differentiated varieties and differ from one another via their initial marginal cost of production. Specifically, firm i produces total output $Q(i)$ according to the quadratic cost function

$$c(Q(i)) = H + \beta(i)Q(i) + \frac{1}{2}Q(i)^2, \quad (1)$$

[3]The challenge of introducing this cost function is to solve the model in general equilibrium. To obtain intuitive predictions we examine a partial equilibrium where each firm is a monopolist. In particular, Melitz and Ottaviano (2008) examine a linear demand and monopolistic competition framework, where each firm's demand intercept is a function of market size, the number of firms in the market and demand parameters. This implies that a change in the demand parameters for one group of firms feeds through the intercept to all firms. We take the variance in the intercept as exogenous, but think of the volatility as if it includes the general equilibrium adjustments in the intercepts. We chose this approach, because our objective is to examine how firms adjust to multiple sources of volatility. Increasing marginal costs make this problem interesting.

where $\beta > 0$ is the firm's idiosyncratic initial marginal cost of production and H is the fixed cost of production. [4]

Firm i can potentially supply to both a domestic and a foreign market. It ships the quantity $q^d(i)$ to the domestic market and realizes the price $p^d(i) = D - q^d(i)$, where the reservation price $D \in (\underline{D}, \overline{D})$ is bounded and random with variance σ_D^2. D is common to all firms. A firm can also pay a sunk entry cost of exporting, K, and export the quantity $q^f(i)$ to the foreign market. Exporting firms realize the price $p^f = F - q^f(i)$, where the reservation price $F \in (\underline{F}, \overline{F})$ is bounded and random with variance σ_F^2. F is also common to all exporting firms. $\underline{D} > 0$ and $\underline{F} > 0$ so that there is always some demand at zero prices.

Firm i's foreign and domestic quantities supplied must sum to its total production output: $Q(i) = q^d(i) + q^f(i)$. The firm's objective is to allocate quantity across the domestic and foreign markets to maximize profits. The firm solves this problem backwards. First it examines the optimal supply for all potential realizations of demand and export status. With that information at hand, the firm compares expected profits to entry costs and decides which markets to supply.

3.2. Profit Maximization

To simplify notation, we examine a firm with $\beta(i) = \beta$ and write $q(i)^f = q^f$, $q(i)^d = q^d$. This firm maximizes profits

$$\Pi(q^d, q^f) = (D - q^d)q^d + (F - q^f)q^f - H - K - \beta(q^d + q^f) - \frac{1}{2}(q^d + q^f)^2 \qquad (2)$$

[4] We assume a quadratic coefficient of $\frac{1}{2}$ to simplify the exposition. Our theory shows how cost linkages transmit demand volatility across markets when the marginal cost increases with output. Our setup, in which $\frac{\partial c(q)}{\partial q} = \beta + q$, is the most concise approach to illustrate these linkages.

w.r.t. the optimal quantity on the domestic market q^d and foreign market q^f such that $q^d \geq 0$ and $q^f \geq 0$. The Lagrangian for this maximization problem is

$$L(q^d, q^f, \lambda_1, \lambda_2) = (D - q^d)q^d + (F - q^f)q^f H - K - \beta(q^d + q^f) - \frac{1}{2}(q^d + q^f)^2 + \lambda_1 q^d + \lambda_2 q^f.$$

The first order conditions are

$$\frac{\partial L}{\partial q^d} = D - 3q^d - \beta - q^f + \lambda_1 = 0 \tag{3}$$

$$\frac{\partial L}{\partial q^f} = F - 3q^f - \beta - q^d + \lambda_2 = 0 \tag{4}$$

$$\frac{\partial L}{\partial \lambda_1} = q^D \geq 0, \lambda_1 \geq 0, \lambda_1 q^D = 0 \tag{5}$$

$$\frac{\partial L}{\partial \lambda_2} = q^F \geq 0, \lambda_2 \geq 0, \lambda_2 q^F = 0 \tag{6}$$

The firm must decide whether to supply a positive quantity to each of the two markets. There are four cases to consider:

1. Supply Neither Market: $\lambda_1 > 0, \lambda_2 > 0, q^d = 0, q^f = 0$
2. Supply only the Export Market: $\lambda_1 > 0, \lambda_2 = 0, q^d = 0, q^f > 0$
3. Supply only the Domestic Market: $\lambda_1 = 0, \lambda_2 > 0, q^d > 0, q^f = 0$
4. Supply Both Markets:$\lambda_1 = 0, \lambda_2 = 0, q^d > 0, q^f > 0$

Case 1 is unobserved. Case 2 is inconsistent with the data; all firms we observe supply at least the domestic market. Case 3 suggests that a firm may abstain from exporting under some demand realizations. Instead of considering this case separately, we use our sunk entry cost of exporting, K, to embed case 3 into case 4. We assume that any firm will supply both markets in each period if there are no entry costs. The sunk entry cost K will dissuade small firms with high costs (firms with high β) from exporting. [5] Our assumption implies that for given Demand probability distributions, the relevant range of β is sufficiently low such that, sans fixed costs, the firm will supply to both markets for all realizations of the shock.

From (3) and (4) solve for the optimal quantities

$$q^d = \frac{3}{8}D - \frac{1}{8}F - \frac{1}{4}\beta \tag{7}$$
$$q^f = \frac{3}{8}F - \frac{1}{8}D - \frac{1}{4}\beta. \tag{8}$$

From (7) and (8), note that $q^d > 0$ and $q^f > 0$ iff

$$D > \frac{1}{3}F + \frac{2}{3}\beta \tag{9}$$
$$F > \frac{1}{3}D + \frac{2}{3}\beta \tag{10}$$

Figure 1 shows the intuition for this case. For reservation prices on the foreign market that make exporting optimal, the firm supplies both markets such that the marginal revenue in each market equals the marginal cost of producing the total output $Q = q^d + q^f$. The key insight is that due to the trade off in production and marginal revenues across markets, the optimal supply for the domestic market is a function of the shock on the foreign market and vice versa. The standard assumption of constant marginal costs cannot reproduce this link between the two markets. This has direct implications for the feed back of shocks across output markets, which we examine in the empirics. Appendix A-2.2 shows that the second order conditions hold for this case. To examine the impact of entry cost we now derive the expected profits for this case.

[5]To see a formal discussion of these cases see appendix A-1

3.3. Expected Profits

To derive the profits for an exporting firm in a given period, substitute the optimal quantities for a given realization of the shock (equations (7) and (8)) into the profit function to obtain the exporter's profit $\pi^e(\cdot)$ as a function of the domestic and foreign shocks as well as the cost parameter, β:

$$\pi^e(D, F, \beta) = \frac{1}{4}\left[\frac{1}{4}(D-F)^2 + \frac{1}{2}(D-\beta)^2 + \frac{1}{2}(F-\beta)^2\right] - H - K. \qquad (11)$$

If there are no entry costs H or K, the right hand side is always positive: the firm supplies to both domestic and foreign markets. To examine the impact of H and K on the foreign and domestic markets, we compare equation (11) with the expected profits of a non exporter. Set $q^f = 0$ in the profit function (2) and optimize with respect to the domestic supply to obtain the optimal quantity

$$q^d = \frac{1}{3}(D-\beta) \qquad (12)$$

Substitute (12) back into the profit function (sans K) to obtain the non exporter's profit $\pi(\cdot)$ as a function of the domestic shock,

$$\pi(D, \beta) = \frac{1}{6}(D-\beta)^2 - H. \qquad (13)$$

With the profit functions (11) and (13) at hand we can show the following proposition:

Proposition 3.1. *The expected profits with exporting decrease relative to the profits* *without exporting as the initial marginal cost β increases,*

$$\frac{E(\partial[\pi^e(D,F)) - E(\pi(D,F))]}{\partial\beta} = \frac{\partial E(\Delta)}{\partial\beta} < 0 \tag{14}$$

Proof Take the expectation of (11) and (13) and subtract $E(\pi(D,F))$ from $E(\pi^e(D,F))$ to obtain

$$\Delta = \frac{1}{4}\left[\frac{1}{4}(D-F)^2 + \frac{1}{2}(D-\beta)^2 + \frac{1}{2}(F-\beta)^2\right] - \frac{1}{6}(D-\beta)^2 - K \tag{15}$$

Expand the square terms including β to obtain

$$\Delta = \frac{1}{4}\left[\frac{1}{4}(D-F)^2 + \frac{1}{2}(D^2 - 2\beta D + \beta^2) + \frac{1}{2}(F^2 - 2\beta F + \beta^2)\right] \tag{16}$$

$$-\frac{1}{6}(D^2 - 2\beta D + \beta^2) - K. \tag{17}$$

Take the expectation to obtain

$$E(\Delta) = \frac{1}{4}\left[E(\frac{1}{4}(D-F)^2) + \frac{1}{2}(E(D^2) - 2\beta E(D) + \beta^2) + \frac{1}{2}(E(F^2) - 2\beta E(F) + \beta^2)\right]$$
$$-\frac{1}{6}(E(D^2) - 2\beta E(D) + \beta^2) - K.$$

Take the derivative with respect to β to obtain

$$\frac{\partial E(\Delta)}{\partial\beta} = \frac{1}{12}E(D) + \frac{1}{6}\beta - \frac{1}{4}E(F) \tag{18}$$

From inequality (10), we observe that $-(1/4)F + (1/6)\beta + (1/12)D < 0$ if $q^f > 0$. Under case four in which all firms would maximize profit (sans sunk costs) by supplying to both destinations, $q^f > 0$ for all realization of F, H. Evaluated at the mean this implies $-(1/4)E(F) + (1/6)\beta + (1/12)E(D) < 0$ $\square$

This implies that as the marginal cost increases in β, the benefits from exporting decrease relative to the profits the firm would realize by supplying only the domestic market. The intuition is that the exporter splits the marginal cost decrease from lowering β over two markets. This implies that the same increase in the quantity, has a lower negative impact on the prices compared to a non exporter who passes the entire change in the marginal cost to the domestic market. With this intuition at hand, the following corollary shows that a sufficiently high fixed cost prevents the highest cost firms from entry into the foreign market.

Proposition 3.2. *For a sufficiently high entry cost to the foreign market K and a sufficiently low set up cost H, there exists a unique value β^d and β^e such that all firms with $\beta > \beta^d$ don't supply any of the markets, all firms with $\beta^e \leq \beta \leq \beta^d$ supply only the domestic market and all firms with $\beta \leq \beta^e$ supply the domestic and foreign markets simultaneously.*

Proof First note that if H is large enough such that $E(\pi^e(D, F, \beta = 0)) < 0$ and $E(\pi(D, \beta = 0)) < 0$, the firm will never supply to either market. This is uninteresting. We examine a world where the production setup cost H is sufficiently low enough that for some positive β, firms find it profitable to produce.

Next, note that for $\beta > 0$ the profits of a firm that supplies only the domestic market (12) strictly decreases for any given realization of D. Therefore, an increase in β strictly decreases the expected profits $E(\pi(D, \beta)) = E\left(\frac{1}{6}(D - \beta)^2\right) - H$. This implies that for a sufficiently low level of H there exists a unique β^d such that $E\left(\pi(D, \beta^d)\right) - H = 0$. Since the profits are strictly decreasing in β, a firm with $\beta > \beta^d$ would not supply to the domestic market. A firm with $\beta \leq \beta^d$ supplies to the domestic market.

A firm with $\beta \leq \beta^d$ may also supply to the foreign market. Since we are under case four, $E(\pi^e(D, F, \beta)) > E(\pi(D, \beta))$ if the sunk export entry cost $K = 0$. A firm will export if the added profits from exporting are greater than the one time sunk cost of exporting: $E(\pi^e(D,F,\beta)) - E(\pi(D,\beta)) > K$. We showed in proposition 3.1 that the difference between $E(\pi^e(D,F,\beta)) - E(\pi(D,\beta)$ increases as β decreases. Therefore, there exists a β^e such that firms with $\beta < \beta^e$ will find it profitable to export. $\square$

4. Empirical Predictions

Given the firm's optimal supply and export decision, we are interested to see how size and export status impact the volatility of a firm with respect to the domestic, foreign and total market. Following Mills and Schumann (1985), let us use the coefficient of variation of output (cvo) as our measure of volatility.[6] To obtain predictions we subsequently derive the volatility of the domestic supply of the exporter and non-exporter, the foreign supply of the exporter and the total supply of both. We will use a superscript ^{e} to denote exporter-specific coefficients of variation.

We first find the standard deviation of the domestic quantity supplied in equation (12) and divide it by the expected quantity supplied to obtain

$$cvo(q^d) = \frac{\sigma_D}{E(D) - \beta}. \tag{19}$$

Similarly, we can obtain the coefficient of variation of the domestic quantity supplied by an exporting firm by taking the standard deviation of equation (7) and dividing it by the expected quantity supplied:

$$cvo^e(q^d) = \frac{\sqrt{9\sigma_D^2 + \sigma_F^2}}{3E(D) - E(F) - 2\beta} \tag{20}$$

[6]The coefficient of variation of some random variable y with variance σ_y^2 and mean $E(y)$ is defined as $cvo(y) = \frac{\sqrt{\sigma_y^2}}{E(Y)}$.

Sum the domestic and export quantities supplied by the exporter in (7) and (8) to find the total output of an exporting firm, $Q^e = \frac{1}{4}D + \frac{1}{4}F - \frac{1}{2}\beta$. The coefficient of variation of total output for an exporter is then

$$cvo^e(Q^e) = \frac{\sqrt{\sigma_D^2 + \sigma_F^2}}{E(D) + E(F) - 2\beta} \tag{21}$$

With the coefficients of variation of the supplies at hand, we derive a series of predictions.

Prediction 4.1. *For a given firm size, exporters supply the domestic market at a structurally higher volatility than non-exporters.*

The key difference between exporters and nonexporters is that the coefficient of variation of domestic supply of the exporter (20) is a function of the variance of demand on the foreign market. This is not the case for the nonexporter (19).

According to (10), a firm is just indifferent of exporting if $F = \frac{1}{3}D + \frac{2}{3}\beta$. Now suppose $E(F) = \frac{1}{3}E(D) + \frac{2}{3}\beta$ and susbtitute $E(F)$ into (20) to obtain

$$cvo^e(q^D) = \frac{3\sqrt{9\sigma_D^2 + \sigma_F^2}}{E(D) - \beta}. \tag{22}$$

From (22) it is easy to see that even if there is no variance on the foreign market ($\sigma_F^2 = 0$) and the foreign market is just large enough to leave the firm indifferent between exporting and not exporting ($E(F) = \frac{1}{3}E(D) + \frac{2}{3}\beta$), the coefficent of variation with exporting is greater than the coefficient of variation without exporting. [7] This result

[7] Note that equation (22) defines a lower bound for the structural difference. In our set up the epxected foreign market size $E(F)$ must be strictly greater than $\frac{1}{3}E(D) + \frac{2}{3}\beta$ and the exporter coefficient of variation (20) increases as the expected foreign market size increases.

is intuitive. Consider two firms with the same cost function. The firm that supplies the foreign and domestic market will supply a lower quantity to the domestic market than the firm that supplies only the domestic market. By this scale effect, the volatility of supply on the domestic market increases for the exporter because the volatility of the demand shocks on the domestic market is the same for both firms.

The null hypothesis for this prediction is the standard set up in the monopolistic trade models, in which firms supply the domestic and foreign market at constant marginal cost, c.[8] Given our demand structure, the optimal quantity an exporter would supply on the domestic market is then $q = \frac{1}{2}(D - c)$ which realizes the revenues $r = \frac{1}{4}(D^2 - c^2)$. This means that in the standard set up the domestic quantity does not depend on the foreign shock and the exporters supply the domestic market according to the marginal cost and realization of D just like non-exporters. This means, the standard set up predicts that the volatility of revenues changes in the size of the firm as far as that is correlated with β, but there is not a structural difference between exporters and non-exporters.

Prediction 4.2. *The (total, domestic, and export) output volatility of a firm decreases with it's size, irregardless of its exporting status.*

It is easy to observe that all three coefficients of variation increase in the marginal cost parameter β. Mills and Schumann (1985) show a similar result for firms that compete in perfect competition and they attribute this relationship to size. Larger firms are less flexible than small firms and supply the market at lower volatility. The same relationship holds for our firms, as a firm's mean output increases as β

[8] See Melitz and Ottaviano (2008)

decreases.

Prediction 4.3. *Accounting for the size of the firm, the total volatility of an exporter is larger than the total output volatility of a non exporter if the volatilities on the foreign markets is relatively large compared to the relative size of the foreign market.*

By dividing equation (21) by (19), we see that

$$\frac{cvo^e(Q^e)}{cvo(q^d)} = \sqrt{1 + \frac{\sigma_F^2}{\sigma_D^2}} \left(1 + \frac{E(F) - \beta}{E(D) - \beta}\right)^{-1} \tag{23}$$

Therefore, the coefficient of variation of total output for an exporter is greater than that of a nonexporter if

$$cvo^e(Q^e) > cvo(q^d) \Leftrightarrow \sqrt{1 + \frac{\sigma_F^2}{\sigma_D^2}} > 1 + \frac{E(F) - \beta}{E(D) - \beta} \tag{24}$$

Suppose the foreign and domestic markets are symmetric such that $\sigma_F = \sigma_D$ and $E(D) = E(F)$. Then the coefficient of variation of total output of the exporter is $\frac{\sqrt{2}}{2} \frac{\sigma_D}{E(D) - \beta}$. Compare this to the total output volatility of the non-exporter $\frac{\sigma_D}{E(D) - \beta}$. Under symmetry, the total output volatility of the exporter is lower than the total output volatility of the non-exporter. On first inspection this may seem counterintuitive, as the exporter has a strictly higher volatility on the domestic market and the foreign market compared to the non-exporter. However, that extra volatility is small compared to the additional output an exporter produces compared to a non exporter. This results in a lower coefficient of variation. On the other hand, the total output volatility of an exporter increases as the foreign market size decreases or the variance on the foreign market increases. Since firms usually ship a smaller amount of quantity to the foreign market this likely results in a higher total output volatility.

Mills and Schumann (1985) predict that bigger firms have lower total sales volatility, which they interpret as a loss in flexibility. Prediction 4.3 shows that it is important to break these results out by markets, because exporting provides an opportunity for large firms to hedge. Our model suggests that exporters use both the domestic and foreign markets to spread the volatility. As a result, exporting decreases the total sales volatility, if the demand volatility on the foreign market is low relative to the size of the market. Since exporters tend to be large compared to non exporters [9] this implies that large firms have low total sales volatility, because exporting allows them to re allocate quantity across the domestic and international market instead of a loss in flexibility.

Prediction 4.4. *If exporting involves a higher total output volatility, then we expect that input demands of the exporting firms are more volatile then the input demands of the firms that supply only the domestic market.*

This result is important to understand the requirements that exporting demands of the local factor markets. Following prediction 4.3, if foreign markets are small and volatile such that exporting increases total volatility, then we would expect that exporters adjust their factor inputs more frequently than nonexporters. If the export markets are large and stable, then exporters actually reduce their input adjustment frequency. All of the above predictions rely on the premise that firms substitute quantities across markets. The last prediction examines this channel directly.

[9] see, for example, Bernard and Jensen, 1995 for American firms and Munch and Nguyen, 2009 for Danish firms

Prediction 4.5. *Exporting firms substitute quantities across markets. Whenever the supply to the foreign market is high, the supply to the domestic market is low.*

To obtain predictions about the relative quantities on the domestic and foreign market apply equations (7) and (8). From these supply equations observe that an increase in the domestic demand raises the output the firm allocates to the home market and lowers the supply to the domestic market and vice versa for a shock on the foreign market. This prediction comes out of our assumption that the random variables D and F are uncorrelated.

5. Data

Our data are gathered from Statistics Denmark's Account Statistics dataset. We have data for output (DKK), exports (DKK), and Six Digit Classification of Economic Activities in the European Community (NACE) industry, for the years 1992-2006. In addition, we have data on assets, energy, and capital for 1994-2006.

We also obtain total sales from Denmark's Value Added Tax(VAT) data banks for the years 1994-2006. Total sales data from the VAT closely track those from Account Statistics.[10] From here on forth, we refer to the output data gathered from annual firm statistics as *firm sales*. Those gathered from VAT data are referred to as *Alternate firm sales*.

The Danish External Trade Statistics provides both values and weights of firm level exports from 1992-2006. We compute our export prices as the quotient of the annual

[10] A regression of VAT sales on Account statistics output for the years 1994-2006 find a marginal effect of 0.947 with a Std. Err of 0.00038.

export value and export weight of a firm. In a robustness check, we drop the top and the bottom percentile of both export prices and export weights. This does not significantly change our results.

We compute annual domestic sales as the difference between firm sales and exports for that year. We drop firms that had observations with negative firm sales, negative exports, and negative domestic sales. There were 370 of 67871 firms that were dropped due to these criteria.

Some firms keep their same name but change businesses entirely. In order to minimize error from firms that keep the same CVR register but change output product, we drop firms that switch their reported 2 digit industries. Out of our remaining 67501 firms, 2285 firms switched 2-digit NACE industries. Those 2285 firms were dropped.

On the other hand, many firms produce multiple products across several 6 digit product classifications but only report a single product category on their annual report. Firms usually report the 6 digit product in which they had the highest sales that year. This may change from year to year. When we control for a firm's 6-digit product category, we use the firm's modal 6 digit product category. In a robustness check, we also use the firm's initial product category - the results only differed in the third or fourth significant digit.

Sometimes firm exit and then re-enter the dataset. This is probably due to clerical error. We drop those 5377 firms that exit and re-entered the dataset. 59839 firms remained.

We drop observations that had less than 1 employee or less than 1 DKK of sales. Of the 371096 firm-year observations, we dropped 162622 observations because those firms had 0 employees that year. An additional 2559 observations were dropped because the firms had fewer than 1 DKK of output.

After imposing the restrictions, we were left with 167434 observations comprising 27549 firms. Using this restricted dataset, we construct our Output Share as the the firm's share of sales within the 6 digit product category for each year. We also construct 2-digit sector Output Shares. We label a firm an exporter if it reported positive exports at least once during our sample period.

We then constructed the sales volatility of the remaining firms in the sample. To do so, we regressed the log sales of a firm on a year trend and took the resultant root mean square error as our measure of firm sales volatility. We performed the same regressions to find the volatilities of each firm's reported total sales, domestic sales, total exports, export weights, employment, energy, capital, and assets. Finally, we compute the industry sales volatility by regressing the log total industry sales for each year on a year trend and using the resultant root mean square error.

In order to construct the sales volatility for a firm, we require that the firm have positive sales for at least 3 years. Of the 27549 remaining firms, 3779 were in the sample period for two years, and 4842 were in for only one year. We drop those firms from our sample. Our final dataset comprises 18928 firms over the sample period of 15 years. Table 1 summarizes some statistics. As is usual in the literature, exporters have higher sales, higher domestic sales, and employ more workers than firms on average. Table 2 summarizes the calculated volatilities.

In our model, we assume that firms that supply to the export market also supply to the domestic market. For the most part, our data is consistent with this assumption. We find that 858 of our firms exported a total of 1463 firm-years without also supplying to the domestic. This is fewer than 3% of the firms in our sample and fewer than 1% of our observations.

We also assume that our volatilities come from non-correlated demand shocks and not cost shocks. This assumption is crucial for prediction 4.5. If cost shocks are the source of volatility, we expect a positive correlation between export and domestic sales. If demand shocks are the source, and foreign and domestic shocks are either negatively correlated or uncorrelated, then we should see a negative correlation between foreign and domestic sales. We find support for the latter. Table 3 presents regressions of log exports on log domestic sales and log employment. When controlling for firm size, we see that domestic and export sales are negatively correlated.

6. Results

6.1. Impact of Export Status on Domestic Supply Volatility

Table 4 shows that exporters supply the domestic market at a volatility 24 percent to 33 percent higher than that of non-exporters. Constant marginal cost trade models cannot reconcile this difference, due to their independent domestic and export supply decisions. This is evidence consistent with cost linkages that transmit volatility acorss supply destinations.

An alternative explanation to cost linkages for our result is that across industries, firms are subject to industry specific shocks which are systematically correlated with the export potential of the industry. To mitigate this selection effect, specifications one, two, and three limit the identifying variation to within NACE6 industry specific effects.[11] Column four follows Mills and Schuman (1986) and absorbs cross-industry differences in volatility using total industry sales volatility. Our identifying assumption is that within NACE6 industries firms are subject to the same fundamentals on the domestic market. Therefore, these firms are subject to the same long term (annual) shocks.

Consistent with our theory, all specifications predict that larger firms have a lower domestic supply volatility (prediction 4.2). Specifications one and three use employment as a proxy for size, while specifications two and four use total output share within the NACE6 industry. Specification five uses both. Whether we account for size with output share or employment, the relationship between the size and volatility is essentially the same in sign and magnitude.

To be consistent with Mills and Schuman (1986), specifications three, four and five also examine the impact of the capital intensity as a measure of size on the supply volatility. Holding employment and/or output share fixed, firms that produce at a higher capital intensity supply the market at a higher volatility. However, including the capital intensity has essentially no impact on the coefficient of the other variables. We draw two conclusions. First, at least in our sample this result is not consistent with an interpretation that capital intensity proxies firm size. Instead, this result suggests that all else equal, producing at high volatility requires investment into flexible manufacturing and information processing to serve demand fluctuations. Second, the capital intensity does not impact our estimates of interest. Consequently, we drop the capital intensity from the following specifications.

[11] 320 industries

6.2. Bigger firms have lower volatility

Table 5 shows that for all three supply measures (total, export and domestic sales) the volatility decreases in the size of the firm. In addition, the specification on total and domestic sales include an interaction term between the firms export status and firm size. In both specifications, the volatility of exporters decreases at a much faster rate in firm size.

We draw three conclusions. First, on average the negative relationship between firm size and volatility is not driven by hedging. Across total, export, and domestic sales, the supply volatility is decreasing in size. Second, the interaction between firm size and exporting suggests that small exporters are especially subject to high sales volatility. Since small exporters are those that are on the margin of exporting (see Melitz, 2003), these firms may not be able to use the export market to hedge in every period. Third, the impact of exporting on volatility decreases in firm size. This may be due to the firm's presence in multiple export markets that is correlated with the firm's size.

6.3. Permanent Exporters have lower Total volatility

To further examine that the firms on the export margin have to manage substantial increases in volatility, we note that all firms in our sample permanently supply the domestic market. Export status is not as stable. Some firms are permanent exporters[12], others export in only some periods. We think of these latter firms as the marginal exporters: period productivity shocks dictate whether they export in a given period. Table 6 examines the difference between permanent exporters, marginal exporters

[12]meaning they export the entire time they are in the sample

and non-exporters.

We find that both the permanent and marginal exporters have significantly greater domestic volatilities than non exporters (column 1). Column two shows that all firms share similar relationships between size and domestic volatility; the interaction terms between export status and employment are insignificant. Column three shows that compared to the non exporters and permanent exporters, marginal exporters have a structurally higher total sales volatility. While it is true that on average across all firms exporting leads to structurally higher total sales volatility, column three shows that this result is driven by the high volatility of the marginal firms. Even after accounting for size, permanent exporters display a structurally lower total sales volatility even than the non exporters.

This suggests two conclusions. First, as stated in the results above, it is the firms on the margin that are subject to the highest total sales volatility. Second, the low total sales volatility of the permanent exports even accounting after size points to a potential impact of hedging. The really large exporters are able to hedge away much of their volatility. Further research involving destination-specific exports can pin down whether large firms have lower volatility because they are better at hedging, or whether they have access to more markets.

6.4. Input Volatility

The previous results don't give a clear indication of what the impact of exporting is on domestic factor markets. Small exporters have higher total volatility, but that impact decreases in size. The impact on the domestic factor markets then depends on the relationship between the volatility of factor demands and the firm size. We estimate several specifications to see the impacts directly. We find the effect of employment size and exporting status on the volatilities of employment, energy, and capital. Table 7 summarizes our results.

Across all specifications, input volatilities are negatively correlated with employment size. This is intuitive since we expect input volatilities to be positively correlated with output volatility.

Firms that export at least once have significantly higher employment, energy, and capital volatilities. When we separate exporters into the WT and S subgroup, we find that firms that exported the whole time have lower input volatilities. Those that only exported sometimes have higher. We conclude that on average, exporting results in a higher volatility of factor demands. The volatility increasing impact of small exporters close to the export margin dominates the volatility reducing impact of hedigng by the large exporters.

7. Robustness Checks

As a robustness check we repeat the exercise in Mills and Schumann (1985) with our data. Results are summarized in column 1 of Table 8 with Mills and Schumann's (1985) results in column 4 to compare. We arrive at nearly the same conclusions as as Mills and Schumann (1985). [13] Standard errors are larger in our results because they are robust.

We also use an alternative data source (VAT sales instead of annnual firm statistics) as our measure of output (Table 8, column 2) or two-digit industry controls instead of six-digit (column 3). We find no significant difference in our results.

[13] with the addition of the export dummy. We also do it without the export dummy, and find similar results

Because not all firms are in the markets for all periods. We account for this selection problem with controls for the number of observations. We augment our specifications with indicators for the number of observations used to calculate total (or domestic) volatility. These indicators absorb systematic variation in the output volatility, number of observation and size or export status. We report our estimations with those additional controls in Table 9. The results and conclusions remain the same.

Finally, Table 10 reports estimates at the 25th, 50th, and 75th volatility quartiles to show that our results are robust to outliers and are consistent across the distribution of firms.

7.1. Alternate Theories

The quadratic term in our cost function generates a link between the marginal costs of supplying the domestic and foreign destinations. The following section considers alternate theories that could generate this prediction while maintaining a linear cost structure.

First suppose heterogeneity in demand such that the demand equations are

$$p^d = \lambda D - q^d \tag{25}$$

$$p^f = \lambda F - q^f \tag{26}$$

where $\lambda > 1$ is a firm specific popularity (quality) term that add multiplicatively to the reservation price. Firms with high λ have higher demands for given demand shocks D and F. Let the total costs be

$$c(Q) = A + \beta Q \tag{27}$$

Given these adjustments to the theory, the profit-maximizing export and domestic quantities are

$$q^f = \frac{\lambda F - \beta}{2} \text{ if } \lambda F > \beta, \text{ else } 0 \tag{28}$$

$$q^d = \frac{\lambda D - \beta}{2} \text{ if } \lambda D > \beta, \text{ else } 0 \tag{29}$$

These quantity functions are the same whether the firm is an exporter or not. The corresponding coefficients of variation are

$$cvo^e(q^e) = \frac{\sigma_f}{E\left[F\right] - \frac{\beta}{\lambda}} \tag{30}$$

$$cvo(q^d) = cvo^e(q^d) = \frac{\sigma_d}{E\left[D\right] - \frac{\beta}{\lambda}} \tag{31}$$

In this set-up, larger firms (low β or high λ) still have lower coefficients of variation. However, since the coefficient of variation of domestic supply is identical for exporters and non-exporters, this model predicts that, once controlling for size, exporters and non exporters have identical domestic volatilities. Our estimation results reject this prediction.

A second theory would have additive demand heterogeneity. In this case, the demand equations would be

$$p^d = \lambda + D - q^d \tag{32}$$

$$p^f = \lambda + F - q^f \tag{33}$$

where λ again is a firm specific popularity (quality) term. This time, it adds additively to the reservation price. Given these adjustments, the product-maximizing export and domestic quantities are

$$q^f = \frac{\lambda + F - \beta}{2} \text{ if } \lambda + F > \beta, \text{ else } 0 \tag{34}$$

$$q^d = \frac{\lambda + D - \beta}{2} \text{ if } \lambda + D > \beta, \text{ else } 0 \tag{35}$$

These quantity functions are the same whether the firm is an exporter or not. The corresponding coefficients of variation are

$$cvo^e(q^e) = \frac{\sigma_f}{E[F] - \beta + \lambda} \tag{36}$$

$$cvo(q^d) = cvo^e(q^d) = \frac{\sigma_d}{E[D] - \beta + \lambda} \tag{37}$$

In this additive scenario, an increase in λ affects the coefficient of variation in exactly the same way as a decrease in β. Again, the *cvo* function is the same for exporters and nonexporters: this theory does not generate the structural difference between exporters and nonexporters. In short, our data rejects both theories of demand heterogeneity and linear cost.

8. Conclusion

This paper examines the linkages between a firm's foreign and domestic supplies. Due to increasing marginal costs, a shock on any of the firm's supplied markets results in a reallocation of output across all supplied markets. These linkages reject the constant marginal costs setup of standard trade models, where a firm's supply on a given market is independent of any of its other markets.

We cannot observe the firms' cost structures directly. Instead, we derive predictions relating the cost structures to domestic and total output volatilities. Our estimation results show that exporters experience greater volatilities in both domestic and total sales than non exporters.According to our model, this implies that firms do not manage market volatilities independently, but instead substitute output across markets. This suggests that the ability to respond to demand volatility by flexibly substituting sales across markets should be an important consideration in export promotion programs. In addition, our regression results show that exporting results in higher factor demand volatility. This implies that successful exporting depends on the ability of factor markets to absorb this volatility.

Our results suggest some future research ideas. First, our finding that exporters have higher domestic volatilities than nonexporters should be extended to the industry level: does exporting actually increase industry volatility, or is this effect localized to the firm? Second, our model suggests that exporting may smooth a firm's total sales volatility and our empirics show that large exporters have a lower total sales volatility than small exporters. The firms' ability to hedge volatility by exporting depends on market characteristics such as size, volatility and the correlation of demand fluctuations across multiple destination markets. Future research using destination-specific export flows will shed light on the firms' ability to smooth sales volatility by choosing destination markets according to characteristics consistent with a hedging strategy.

References

Aizenman, J. (2004), "Endogeneous pricing to market and Financing cost," **Journal of Monetary Economics** 51(4), 691-712.

Evans, C. and Harrigan, J. (2005), "Distance, Time and Specialization: Lean Retailing in General Equilibirum," **American Economic Review** 95(1), 292-313.

Hummels, D. and Schaur, G. (2009), "Hedging Price Volatility Using Fast Transport," **NBER** w15154.

, Melitz, M and G. I. P. Ottaviano (2008), "Market Size, Trade, and Productivity," Review of Economic Studies, Blackwell Publishing, vol. 75(1), pages 295-316, 01

Mills, David E. (1984) "Demand Fluctuations and Endogenous Firm Flexibility," **The Journal of Industrial Economics**, 33(1), 55-71.

Mills, David E. (1986) "Flexibility and Firm Diversity with Demand Fluctuations," **International Journal of Industrial Organization**, 4, 302-315.

Schaur, G. (2009) "Smoothing Demand Uncertainty Using Flexible Production," **University of Tennessee Working Paper**

Mills, D. and Schumann L. (1985) "Industry Structure with Fluctuating Demand," **The American Economic Review**, 75(4), 758-767

Di Giovanni J. and Levchenko A. (2008) "Trade Openness and Volatility," **Review of Economics and Statistics**, 91(3), 558-585

Kalemli-Ozcan, Sebnem, Bent E. Sørensen, and Oved Yosha, (2003) "Risk Sharing and Industrial Specialization: Regional and International Evidence," **American Economic Review**, 93(3), 903–18

Imbs J. (2006), “Growth and Volatility,”. **Forthcoming, Journal of Monetary Economics**

Imbs J. and Wacziarg R. (2003) “Stages of Diversification,” **American Economic Review**, 93(1), 63–86

Raddatz C. (2006) “Liquidity Needs and Vulnerability to Financial Underdevelopment,”**Journal of Financial Economics**, 80(3), 677–722

Krebs T., Krishna P., and Mahoney W. (2005) “Trade Policy, Income Risk, and Welfare,” Mimeo, Syracuse University, John Hopkins University, and the World Bank

Buch C., Dopke J. and Strotmann H., (2006) “Does Export Openness Increase Firm-Level Volatility?” Mimeo, University of Tubingen and Deutsche Bundesbank

Kose A. (2001) “Explaining Business Cycles in Small Open Economies: How Much do World Prices Matter?,” **Journal of International Economics**, 56(2), 299–327

Kose A. and Kei-Mu Yi (2006) “Can the Standard International Business Cycle Model Explain the Relation Between Trade and Comovement,” **Journal of International Economics**, 68(2), 267–95.

Kose A., Eswar S. Prasad, and Terrones M. (2003) “Financial Integration and Macroeconomic Volatility,” IMF Staff Papers, 50(Special Issue), 119–41

Kose A., Otrok C. and Whiteman C. (2008) “Understanding the evolution of world business cycles,” **Journal of International Economics**, 75(1), 110-130

APPENDIX

A-1. Optimization Cases

Case 1(Supply nowhere): $\lambda_1 > 0, \lambda_2 > 0$. This case says that the firm does not supply any of the markets if the reservation price does not cover the minimal marginal cost of production. From (5) and (6), $\lambda_1 > 0, \lambda_2 > 0 \Rightarrow q^d = 0, q^f = 0$. From (3) and (4), $q^d = 0, q^f = 0 \Rightarrow -D + \beta = \lambda_1, -F + \beta = \lambda_2$. Then $\lambda_1 > 0$ and $\lambda_2 > 0$ iff

$$\beta > D \text{ and } \beta > F. \tag{A-1}$$

Case 2(Supply Export): $\lambda_1 > 0, \lambda_2 = 0$. This case says that if the marginal revenue on the domestic market for the first unit ouf output is less than the marginal cost evaluated at the optimal quantity the firm ships to the foreign market, then the firm ships only to the foreign market. From (5), $\lambda_1 > 0 \Rightarrow q^d = 0$. From (4), $q^d = 0, \lambda_2 = 0 \Rightarrow q^f = \frac{1}{3}(F - \beta)$. Substitute $q^f = \frac{1}{3}(F - \beta)$ into (3) to obtain $\beta + \frac{F-\beta}{3} = \lambda_1 > 0$ which is true iff

$$D \leq \frac{1}{3}F + \frac{2}{3}\beta \tag{A-2}$$

Case 3(Supply Domestic): $\lambda_1 = 0, \lambda_2 > 0$. This case says that the firm does not export if the reservation price on the foreign market does not cover the marginal cost of producing the optimal quantity for the domestic market. As long as the marginal revenue on the domestic market is higher than on the foreign market the firm ships to the domestic market. When the domestic market is supplied optimally, the marginal cost at the optimal domestic quantity is higher than the maximum marginal revenue the firm could obtain from selling to the foreign market. To see this formally, from

(6), $\lambda_2 > 0 \Rightarrow q^F = 0$. From (3),

$$q^d = \frac{D - \beta}{3}. \tag{A-3}$$

Substitute $q^d = \frac{D-\beta}{3}$ into (4) to obtain $\lambda_2 = \beta + \frac{D-\beta}{3}$, which is true iff

$$F < \frac{2}{3}\beta + \frac{1}{3}D. \tag{A-4}$$

To complete the argument note that $\frac{2}{3}\beta + \frac{1}{3}D$ is the marginal cost at the optimal quantity on the domestic market.

To rule out cases 1 to 3 we place restriction on the supports of the probability distributions and the marginal cost parameter β

To rule out the first case we require that the initial marginal cost is lower than the reservation price on both markets,

$$\underline{F} > \beta \text{ and } \underline{D} > \beta. \tag{A-5}$$

This restriction is reasonable, since we don't observe firms that are never in the market.

Next we rule out firms that only supply the foreign market, $q^d = 0, q^f > 0$, with the restriction

$$\underline{D} > \frac{1}{3}\bar{F} + \frac{2}{3}\bar{\beta}. \tag{A-6}$$

This restriction is consistent with the data, as 99 percent of the observations that report a foreign transaction also report a domestic transaction.

Even before considering the fixed cost of entry, a firm may abstain from exporting in some periods. This is the case if the support of F, D spreads across the cutoff condition for exports. This implies that some realization of F, D is favorable to exporting and others are not. This pattern is true for about half of the exporting firms in our sample and we examine it empiricaly. To keep the theory concise, we dispense with this possibility with the restrictions

$$\underline{F} > \frac{1}{3}\overline{D} + \frac{2}{3}\overline{\beta} \tag{A-7}$$

and over all $F \in (\underline{F}, \overline{F})$ and $D \in (\underline{D}, \overline{D})$,

$$\overline{\beta} \leq \min\left\{\frac{3\underline{D} - \bar{F}}{2}, \frac{3\underline{F} - \bar{D}}{2}\right\}. \tag{A-8}$$

Condition (A-8) defines an upper bound of β sufficiently low such that the inequality conditions (A-6) and (A-7) do not intersect the support of the random variables (F, D). Conditions (A-5), (A-6), (A-7) and (A-8) limit the possible response regions to the case where the firm supplies both markets simultaneously.

A-2. Second Order Conditions

A-2.1. Case 3

The matrix of second partials is

$$\begin{bmatrix} \frac{\partial^2 L}{\partial^2 q^D} & \frac{\partial^2 L}{\partial q^D \partial q^F} & \frac{\partial^2 L}{\partial q^D \partial \lambda_2} \\ \frac{\partial^2 L}{\partial q^F \partial q^D} & \frac{\partial^2 L}{\partial^2 q^F} & \frac{\partial^2 L}{\partial q^F \partial \lambda_2} \\ \frac{\partial^2 L}{\partial \lambda_2 \partial q^D} & \frac{\partial^2 L}{\partial \lambda_2 \partial q^F} & \frac{\partial^2 L}{\partial^2 \lambda_2} \end{bmatrix} = \begin{bmatrix} -3 & -1 & 0 \\ -1 & -3 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

Given that we maximize over two variables with one active constraint we only have to check whether the determinant of the matrix of second partials D is positive. For this particulare solution $D = 3$ and the second order condition is satisfied.

A-2.2. Case 4

Similar as for Case 3 the matrix of second partials is

$$\begin{bmatrix} -3 & -1 \\ -1 & -3 \end{bmatrix}$$

Given that we maximize over two variable with no active constrain we have to check if $(-1)^i D_i > 0$, where D_i is the lower right submatrix of the matrix of second partials for $i = 1, 2$. Given the matrix $(-1)^1 D_1 = 3 > 0$ and $(-1)^2 D_2 = 8 > 0$. This solution also satisfies the second order conditions.

A-3. Expected Profits when Firms Don't Export in All Periods

To compute expected profits suppose the shocks D, F are independent and the probability distributions are degenerate such that the four possible events occurs with probabilities $P(\bar{D}, \bar{F}) = \alpha_1,\ P(D, \bar{F}) = \alpha_2,\ P(\bar{D}, F) = \alpha_3,\ P(D, F) = \alpha_4$. For a given β expected profits are then given by

$$\begin{aligned} E(\pi, \beta) = {} & \alpha_1 \max\left\{\pi^e(\bar{D}, \bar{F}), \pi(\bar{D}, \bar{F})\right\} + \alpha_2 \max\left\{\pi^e(\underline{D}, \bar{F}), \pi(\underline{D}, \bar{F})\right\} \\ & + \alpha_3 \max\left\{\pi^e(\overline{D}, \underline{F}), \pi(\overline{D}, \underline{F})\right\} + \alpha_4 \max\left\{\pi^e(\underline{D}, \underline{F}), \pi(\underline{D}, \underline{F})\right\} \end{aligned} \tag{A-9}$$

Before paying the fixed cost of entry, the profits with and without exports are

$$\begin{aligned} \pi^e(D, F) &= \frac{1}{4}\left[\frac{1}{4}(H - F)^2 + \frac{1}{2}(H - \beta)^2 + \frac{1}{2}(F - \beta)^2\right] \\ \pi(D, F) &= \frac{1}{6}(H - \beta)^2 \end{aligned}$$

with the partial derivatives

$$\frac{\partial \pi^e(D,F)}{\partial \beta} = -\frac{1}{4}H + \frac{1}{2}\beta - \frac{1}{4}F < 0$$
$$\frac{\partial \pi(D,F)}{\partial \beta} = \frac{1}{3}(\beta - H) < 0$$

Remeber from (A-4) that the firms sets exports to zero iff

$$F < \frac{2}{3}\beta + \frac{1}{3}D \tag{A-10}$$

This inequality implies that $\frac{\partial \pi^e(D,F)}{\partial \beta} < \frac{\partial \pi(D,F)}{\partial \beta}$, whenever the (F, D) are such that exporting is optimal. Note from (A-9) that the partial derivative of expected profits with respect to β is a probability weighted sum of the partial derivatives of the terms $\frac{\partial \pi^e(D,F)}{\partial \beta}$ and $\frac{\partial \pi(D,F)}{\partial \beta}$. This means that if $F > \frac{2}{3}\beta + \frac{1}{3}D$ for at least one of the realizations of D, F, then the expected profits with exporting decrease at a faster rate in β than the expected profits without exporting. This implies that as β decreases, the expected profits with exports increase relative to the expected profits without exports.

	All Firms			Exporters		
Statistic	Mean	Std. Dev	Median	Mean	Std. Dev	Median
Sales	37.4	413	4.02	78.4	618	10.7
Log Sales	15.4	1.55	15.2	16.3	1.66	16.19
Domestic Sales	23.1	280	3.52	42.4	388	6.89
Log Domestic Sales	15.24	1.45	15.1	15.8	1.67	15.8
Employment	26.7	182	5	52.7	255	12
Exports				36	345	0.95
Log Exports				15.0	2.43	15.1
No. of firms		18928			7509	

Table 1: Summary Statistics. Non-log in Millions of DKK

	Mean	Std. Dev	Median
Volatility of			
Total Sales	0.28	0.25	0.21
Total Sales (VAT)	0.28	0.27	0.20
Domestic Sales	0.32	0.31	.023
Export Sales	0.48	0.49	0.35
Energy	0.46	0.33	0.41
Employment	0.24	0.21	0.19
Capital	0.48	0.44	0.36
Assets	0.31	0.29	0.23

Table 2: Volatility Summary Statistics

	Specification	
	(1)	(2)
Domestic Sales	-.483	-.105
	(.007)***	(.007)***
Employment	1.60	0.989
	(.008)***	(.013)***
Controls	None	NACE6
Obs.	50658	50658
R2	0.546	0.915
F statistic		19.442

Table 3: Export Sales Regressions, with and without Industry Dummies

	Specification				
	(1)	(2)	(3)	(4)	(5)
Exported at least once	.240	.244	.238	.320	.330
	(.017)***	(.017)***	(.017)***	(.015)***	(.016)***
Employment	-.033		-.033		-.018
	(.006)***		(.006)***		(.008)**
NACE6 Output Share		-.033		-.024	-.015
		(.006)***		(.005)***	(.006)**
Capital Intensity			.036	.013	.015
			(.008)***	(.008)*	(.008)**
Industry Volatility				.067	.061
				(.008)***	(.009)***
Const.	-1.539	-1.790	-1.213	-1.489	-1.409
	(.013)***	(.037)***	(.065)***	(.072)***	(.079)***
Controls	NACE6	NACE6	NACE6	None	None
Obs.	18945	18945	17911	17911	17911
R^2	.083	.083	.091	.032	.032
F statistic	101.7	102.6	73.9	143.7	117.1

Table 4: Domestic Sales Volatility Regressions, Robust Std. Err's

	Total Sales	Export Sales	Domestic Sales
	(1)	(2)	(3)
Exported at least once	.224		.278
	(.027)***		(.027)***
Exported x Employment	-.084		-.021
	(.012)***		(.012)*
Employment	-.023	-.095	-.021
	(.010)**	(.010)***	(.010)**
Const.	-1.561	-.709	-1.555
	(.016)***	(.031)***	(.016)***
Controls	NACE6	NACE6	NACE6
Obs.	19013	5759	18945
R^2	.056	.109	.083
F statistic	75.4	95.7	69.4

Table 5: Volatility Regressions with Interaction terms, Robust Std. Err's

	Domestic Sales		Total Sales	
	(1)	(2)	(3)	(4)
Permanent Exporters	.190	.247	-.120	.073
	(.024)***	(.044)***	(.023)***	(.041)*
Perm Exp x Employment		-.022		-.080
		(.015)		(.014)***
Marginal Exporters	.261	.262	.155	.190
	(.017)***	(.032)***	(.017)***	(.032)***
Marg Exp x Employment		-.003		-.029
		(.015)		(.015)*
Employment	-.028	-.020	-.052	-.021
	(.007)***	(.010)**	(.006)***	(.010)**
Const.	-1.545	-1.555	-1.517	-1.559
	(.013)***	(.016)***	(.013)***	(.016)***
Controls	NACE6	NACE6	NACE6	NACE6
Obs.	18945	18945	19013	19013
R^2	.084	.084	.061	.063
F statistic	74.9	45.4	123.3	88.4

Table 6: Volatility Regressions: Permanent and Marginal Exporters, Robust Std. Err's

	Employment		Energy		Capital	
	(1)	(2)	(3)	(4)	(5)	(6)
Exported at least once	.041		.064		.052	
	(.015)***		(.015)***		(.020)**	
Permanent Exporters		-.079		-.066		-.120
		(.022)***		(.022)***		(.029)***
Marginal Exporters		.094		.115		.118
		(.016)***		(.016)***		(.021)***
Employment	-.235	-.221	-.066	-.051	-.110	-.091
	(.006)***	(.006)***	(.006)***	(.007)***	(.008)***	(.008)***
Const.	-1.138	-1.156	-.834	-.849	-.862	-.883
	(.011)***	(.011)***	(.012)***	(.012)***	(.016)***	(.016)***
Controls	NACE6	NACE6	NACE6	NACE6	NACE6	NACE6
Obs.	17053	17053	15940	15940	15824	15824
R^2	.158	.162	.104	.109	.076	.081
F statistic	912.0	642.1	56.3	71.8	115.1	115.1

Table 7: Input Volatility Regressions, Robust Std. Err's

	Total Sales	VAT Sales	Sector Controls	Results from MS1985
	(1)	(2)	(3)	(4)
Exported at least once	.115	.133	.292	
	(.014)***	(.015)***	(.016)***	
Employment			-.023	
			(.006)***	
NACE6 Output Share	-.050	-.036		-.292
	(.004)***	(.004)***		(.020)***
Capital Intensity	.011	.013	.032	-.115
	(.007)	(.007)*	(.008)***	(.063)*
Industry Volatility	.087	.050		.460
	(.008)***	(.008)***		(.036)***
Const.	-1.629	-1.649	-1.284	-3.459
	(.070)***	(.069)***	(.063)***	(.231)***
Controls	None	None	NACE2	None
Obs.	17977	17891	17911	856
R^2	.013	.008	.049	.271
F statistic	55.8	33.7	124.6	

Table 8: Mills and Schumann (1985) Robustness Check, Robust Std. Err's

	Domestic Sales		Total Sales	
	(1)	(2)	(3)	(4)
Exported at least once	.224		.056	
	(.017)***		(.016)***	
Permanent Exporters		.246		.079
		(.044)***		(.040)**
Perm Exp x Employment		-.022		-.078
		(.015)		(.014)***
Marginal Exporters		.219		.144
		(.032)***		(.032)***
Marg Exp x Employment		.008		-.017
		(.015)		(.015)
Employment	-.038	-.030	-.078	-.031
	(.006)***	(.010)***	(.006)***	(.010)***
Const.	-1.332	-1.342	-1.312	-1.373
	(.028)***	(.030)***	(.027)***	(.029)***
Controls	NACE6	NACE6	NACE6	NACE6
	# Obs	# Obs	# Obs	# Obs
Obs.	18945	18945	19013	19013
R^2	.105	.106	.076	.084
F statistic	52.2	43.9	52.0	58.2

Table 9: Volatility Regressions, Controlling for the number of observations for each firm, Robust Std. Err's

	First-Quartile	Median	Third-Quartile
	(1)	(2)	(3)
Exported at least once	.309	.240	.184
	(5.75e-15)***	(2.62e-15)***	(.0009)***
Exported x Employment	-.043	-.017	.008
	(2.55e-15)***	(1.11e-15)***	(.0004)***
Employment	-.002	-.032	-.046
	(2.07e-15)***	(8.74e-16)***	(.0003)***
Const.	-1.313	-1.243	-1.191
	(5.46e-15)***	(2.48e-15)***	(.0008)***
Controls	NACE6	NACE6	NACE6
Obs.	18945	18945	18945
e(q)	.25	.5	.75

Table 10: Quartile Regressions of Domestic Volatility, Robust Std. Err's

Figure 1: Interior Equilibrium on the Domestic and Foreign Market