Import and Export Linkages Transmit Volatility Across Markets

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Abstract

Firms that trade face volatility in foreign markets. We examine two firm-level channels that transmit foreign volatility to the domestic market. First, if marginal costs are increasing, then a demand shock on the foreign market leads to a reallocation of output on the domestic market. Second, if foreign input prices are volatile compared to domestic input prices, then importers channel input price volatility to the domestic market. Consistent with this theory, Danish firm-level data show that exporting raises a firm’s domestic sales volatility by 13 percent, while importing raises it by 15 percent. Furthermore, firms that export to larger and more volatile foreign markets lower their average domestic sales. These results show that firm-level export and import linkages are important for the transmission of shocks across markets and the impact of trade on domestic consumption.

Keywords: Exports, firm heterogeneity, volatility, increasing marginal costs.

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1. Introduction

Firms that export and import are subject to volatility on foreign markets. If a firm’s costs of supplying the domestic market are determined in part by its exports and/or its intermediate input prices, then the firm’s export and import activities link shocks on the foreign market to its domestic supply. These firm level import and export linkages transmit shocks across countries and contribute to volatility on the domestic market. This paper introduces intermediate input trade and increasing marginal costs in a standard model of trade and employs a census of firm-level data to examine the existence and extent of firm-level import and export linkages.

In the theory, firm-specific increasing marginal costs and intermediate input trade feed export-demand and input-price shocks to the trading firm’s domestic supply. For exporters, increasing marginal costs link domestic and export supplies. Demand shocks in one market affect the marginal cost of supplying to the other.\(^1\) As a consequence, exporters realize lower sales on the domestic market than nonexporters and supply the domestic market at a structurally different volatility. For importers, shocks in the price of imported intermediates impact the marginal cost of supplying the export and domestic markets. Because importers pay intermediate input prices that are on average lower but more volatile than nonimporters, importers realize higher average sales on the domestic market than nonimporters and supply the domestic market at a structurally different volatility. Through these two mechanisms, export and import activities transmit volatility from the foreign to the domestic market.

The theory delivers falsifiable tests for these import and export linkages with respect

\(^1\)For firm-level evidence on nonlinear production costs see Bresnahan and Ramey (1994) and Caballero et. al. (1997).
two competing hypotheses. First, if marginal costs do not change with output, then exporters have the same average domestic sales and domestic sales volatility as nonexporters.\(^2\) Second, if volatility in the price of intermediate imports does not affect the volatility of the marginal cost of domestic supply, then within the group of nonexporters, importers will supply the domestic market at a lower volatility than nonimporters.

We reject both of these hypotheses in favor of increasing marginal costs and import linkages. We observe the full universe of Danish firms and examine about 16,500 firms operating between 1992 and 2006 accounting for 82 percent of gross economic activity in the manufacturing sector. Exporters and importers supply the domestic market at a volatility that is between 13-14 percent higher than the volatility of non-trading firms. Importers that do not export supply the domestic market at a volatility that is about eight percent higher than the volatility of nonimporters. This is evidence that both import and export linkages are important in transmitting foreign shocks to the domestic market. As additional evidence that exporters substitute supply across the domestic and foreign markets, the data show that firms with larger export markets and firms that export to more markets realize lower domestic sales.

Identifying the channels by which shocks are transmitted across countries is an ongoing area of research. Empirical and simulation studies find country-level evidence that trade increases the transmission of shocks across countries (e.g Kose and Yi (2006); Kose et. al. (2008)). Vannoorenberghe (2010) examines the impact of a exporting firm’s share of exports in total sales on its domestic sales volatility for a sample of French exporters. Di Giovanni and Levchenko examine the risk content of trade (di Giovanni and Levchenko, 2008) and show that vertical linkages in

\(^2\)If marginal costs are constant with respect to output as is standard in the international trade literature e.g. Melitz (2003); Melitz and Ottaviano (2008), then this substitution channel does not exist and exporters and nonexporters supply the domestic market at the same level of volatility.
production in cross border industry pairs are especially important in explaining the transmission of shocks across countries (di Giovanni and Levchenko, 2010). Bergin Feenstra and Hanson (2011) examine the impact of offshoring on the transmission of volatility. They find that industry level employment volatility in Mexico is driven by the entry and exit of plants in response to volatility in U.S. offshoring demand. We contribute to this literature in several ways.

First, we examine export and import linkages jointly. Examining the export and import channels jointly is important because export activity is positively correlated with import activity and both channels impact a firm’s volatility. Therefore, omitting either export or import status likely results in biased estimates. Second, according to the theory, whether export and import activity raises or lowers the domestic sales volatility is ambiguous. Our empirical results show that export and import activities increase the volatility of a firm’s domestic sales. This suggests that at least through this direct channel import and export activities have negative welfare consequences if consumers are risk averse.\(^3\) Third, we provide firm-level evidence that entry and exit in trade relationships significantly increases an existing firm’s employment volatility. This evidence complements Bergin Feenstra and Hanson (2011) who find that entry and exit of offshoring plants in Mexico contribute to industry level employment volatility. Fourth, we use a linear demand framework to link a firm’s volatility to its productivity; based on our estimates, more productive firms supply the domestic market at lower volatility. This channel does not exist in the standard CES framework where the productivity parameters cancel out of the volatility expressions. This evidence also extends the results of Mills and Schumann (1985), who examine the relationship between firm level productivity and volatility, but do not account for

\(^3\)This does not mean that overall countries do not benefit from trade, as these negative consequences may be swamped by variety and efficiency gains. We pick back up on this discussion in the Conclusions.
import and export activity.

Our theory and empirics relates to a literature that examines the importance of increasing marginal costs on the integration of markets. Krugman (1984) works with non-constant marginal costs, but does not provide any empirical results. Spearot (2011) focuses on investment incentives rather than the feedback of demand shocks across markets. Soderbery (2010) examines the impact of capacity constraints on the substitution of sales across markets. Ahn and McQuoid (2011) provide structural evidence for increasing marginal cost in a sample of Indonesian firms.

We also contribute to current research that examines the impact of firm level import activity on the domestic economy. For example, Amiti and Davis (2011) examine the impact of tariff reductions for intermediate inputs on domestic wages in Indonesia. Consistent with a linear demand model, De Loecker et. al. (2011) provide evidence that tariff liberalization on intermediate inputs changes firm level markups in India. We focus on the impact of firm level import activity on the transmission of shocks across markets and examine the impact of firms’ import activity on their domestic sales volatility.

The next section outlines a model of international trade with increasing marginal costs and intermediate input trade. A summary of testable predictions follows. Section 4 then presents the data, explains the regression variables and tests the predictions. These results motivate some additional empirical questions as well as robustness checks. Several remarks conclude the paper.

2. Theoretical Model

In this section, we introduce a model of international trade that incorporates heterogeneous increasing marginal costs and intermediate input trade into a Melitz and
Ottaviano (2008) type trade model. This set-up results in several testable predictions regarding the firm-level transmission of shocks across markets.

2.1. Demand

Firms produce horizontally differentiated varieties to potentially sell in two countries \( j \in [d, f] \). Country \( d \) has a mass \( L_d = 1 \) of workers, each endowed with \( \bar{c}_0 \) units of a numeraire good. Country \( f \) has \( L_f \) workers with the same endowments. Preferences are identical and can be represented by

\[
U_j = c_j (0) + \alpha \int_{i \in \Omega_j} c_j (i) \, di - \frac{1}{2} \gamma \int_{i \in \Omega_j} (c_j (i))^2 \, di - \frac{1}{2} \eta \left( \int_{i \in \Omega_j} c_j (i) \, di \right)^2,
\]

where \( c_j (0) \) is the consumption of the numeraire good, \( c_j (i) \) is the consumption of differentiated variety \( i \), and \( \Omega_j \) is the set of differentiated varieties available in country \( j \).

Workers employ their endowment in an intermediate input sector and the differentiated product sector.\(^4\) Prices are in terms of the numeraire good. As in Melitz and Ottaviano (2008), \( \bar{c}_0 \) is large enough to ensure positive consumption of the numeraire good. Then, the demand for each differentiated good \( i \) can be written as

\[
p_j (i) = A_j - \gamma \frac{q_j (i)}{L_j}, \quad \text{where} \quad A_j = \frac{\gamma \alpha + \eta N_j \bar{p}_j}{(\eta N_j + \gamma)} \tag{1}
\]

and \( q_j (i) = L_j c_j (i) \) is the aggregate demand for good \( i \), \( N_j \) is the number of firms selling to country \( j \) and \( \bar{p}_j = \frac{1}{N_j} \int_{i \in \Omega_j} p_j (i) \, di \) is the average price of a differentiated good in \( j \). We refer to \( A_j \) as the reservation price for differentiated goods in \( j \).

\(^4\)This is similar to Ottaviano, et. al. (2002) where workers are endowed with the numeraire good and one unit of labor, which they can transform into the numeraire good. This model does not explicitly identify the endowment, but the reader can interpret it as labor/leisure.
2.2. **Intermediate Good Production**

The differentiated goods are produced using the numeraire good as well as an intermediate input. We follow Amiti and Davis (2011) in setting up this intermediate sector.\(^5\) Firms producing the intermediate input use a constant returns to scale technology such that the production of 1 unit of the intermediate input requires 1 unit of the numeraire good. In equilibrium, intermediate input producers earn zero profits and supply just enough to sate the demands of firms in the differentiated product sector.

2.3. **Production of the Differentiated Product**

In the differentiated product sector, firms purchase intermediate inputs and hire the workers’ endowment to transform the intermediate input into a final product. Each firm \(i\) employs \(y_i(q)\) units of the worker’s endowment to convert \(q\) bundles of the intermediate input into \(q\) units of the final good. Let \(y_i(q)\) be approximated by a second order Taylor expansion from initial output level \(q = 0\):

\[
y_i(q) = y_i(0) + y_i'(0)q + \frac{1}{2}y_i''(0)q^2
\]

and set \(y_i(0) = y(0), y_i'(\cdot) = \beta_i,\) and \(y_i''(\cdot) = \nu.\)\(^6\) The \(\beta_i\) is exogenous and known by the firm. Let \(z(i)\) denote the effective price of the bundle of intermediate inputs that firm \(i\) purchases. The total cost of production for firm \(i\) is thus a function of its exogenous cost parameter \(\beta_i\), its chosen input price \(z(i)\), and its chosen output

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\(^5\)An alternative would have been to follow more closely the approach of Bergin Feenstra and Hanson (2011), but our more abstract approach allows us to examine the impact of exporting and importing simultaneously and keeps the model somewhat tractable.

\(^6\)The linear cost function found in standard trade models, e.g. Melitz and Ottaviano (2008), assumes \(y_i(0) = y(0), y_i'(\cdot) = \beta,\) and \(y_i''(\cdot) = 0.\) Our model considers a nonzero quadratic term. Mills and Schumann (1985) provide evidence for heterogeneity in firm size and total supply volatility due to quadratic costs. They do not examine the impact of export activity. Our testable predictions do not rely on the heterogeneity of \(y_i''(\cdot)\) but rather of \(y_i'(\cdot),\) so we use a simple \(y_i''(\cdot) = \nu.\)
quantity \( q(i) \).

\[
\text{tc}(i) = y(0) + (\beta_i + z(i))q(i) + \frac{1}{2}\nu q(i)^2.
\]

The total cost function combines the costs of purchasing the bundle of intermediate inputs with the expense of converting it into the final good.

Each firm has a idiosyncratic initial marginal cost of production determined by \( \beta_i \), where \( 0 < \beta_i < \bar{\beta} \) is positive and bounded. The firm’s marginal cost increases with output at a rate equal to \( \nu \geq 0 \). Heterogeneity in (initial) marginal costs leads to heterogeneity in firm decisions. Firms know \( \beta_i \) before making any supply decisions.

In addition to \( \beta_i \), a firm’s production cost depends on the price of the bundle of inputs. Intermediate inputs are differentiated via source country in a CES production function exhibiting love of variety (Ethier (1982); Amiti and Davis (2011)). Therefore, the effective price of a bundle of intermediate inputs depends on whether the firm imports the intermediate input. Let \( \tau \) be the marginal cost of importing an intermediate input. Consistent with Amiti and Davis, firms can pay a fixed cost \( K_i^m \) to import the input. The firm’s effective price of a bundle of intermediate inputs is thus dependent on its import status:

\[
z(i) = \begin{cases} 
1 & \text{if firm } i \text{ does not import,} \\
\frac{1}{1 + (1 + \tau^{1-\theta})^{1-\theta} - \theta} & \text{if firm } i \text{ imports.}
\end{cases}
\]

The effective price the importer pays is less than what the nonimporter pays because a bundle of intermediate inputs from two sources is more productive than a bundle from one. However, \( \tau \) is volatile. In equilibrium, firms weigh the expected variable savings from importing the intermediate input against the fixed cost of establishing the import relationship.
2.4. Equilibrium Supply

We focus on interior solutions where firms supply the markets for all possible realizations of the preference shocks in all time periods.\textsuperscript{7} In an expanded model, firms may supply to the foreign market without supplying to the domestic market. However, less than two percent of firms in our sample, accounting for less than 1% of total sales, serve the export market without also serving the domestic market. Therefore, we assume model parameters such that firms either supply only the domestic market (nonexporters) or supply both the domestic and the foreign market (exporters).

To denote a firm’s mode of globalization we use a double superscript. A firm’s exporting decision is denoted by the first superscript: $x$ if it exports and $n$ if it does not export. A firms’ importing decision is denoted by the second superscript: $m$ if it imports and $n$ if it does not import. Thus, firms that neither import nor export are denoted with the superscript $nn$. Those that export but do not import are denoted by $xn$. Those that import but do not export are denoted by $nm$, and finally, those that do both are denoted by $xm$. We use a $\cdot$ to refer to one of the two cases (e.g., $\cdot m$ refers to either $nm$ or $xm$).

2.4.1. Nonexporters

Consider firm $i$ in $d$ of mode $n\cdot$ selling only to the domestic country. By setting domestic price $p^n_d$ to maximize profits, firm $i$ has total output $q^n_d$ and domestic supply $q^n_d$:

$$q^n_d(i) = q^n_d(i) = \frac{A_d - \beta_i - z(i)}{2\gamma + \nu} > 0$$

\textsuperscript{7}This restricts the distributions of the demand shocks and the cost parameters. If instead we assume CES utility, corner solutions are ruled out because consumers have an infinite willingness to pay to consume at least a small amount of any existing variety. An appendix that discusses all possible solutions and the necessary parameter restrictions is available upon request.
where \( z(i) \) is determined by the firm’s import status in equation (2). The firm’s domestic sales, conditional on import status, are then:

\[
\begin{align*}
  r_{dn}^m(i) &= \frac{A_d^2 \gamma}{(2\gamma + \nu)^2} - \frac{(\beta_i + 1)^2 \gamma}{(2\gamma + \nu)^2} + \frac{\nu A_d(A_d - \beta_i - 1)}{(2\gamma + \nu)^2} \\
  r_{dm}^n(i) &= \frac{A_d^2 \gamma}{(2\gamma + \nu)^2} - \frac{(\beta_i + z_m)^2 \gamma}{(2\gamma + \nu)^2} + \frac{\nu A_d(A_d - \beta_i - z_m)}{(2\gamma + \nu)^2}.
\end{align*}
\] (3a)

Note that the difference between the two equations is the presence of the price of the imported input \( z_m \). Shocks to \( z_m \) feed through to an importer’s domestic sales. These shocks have no direct impact on nonimporting firms.

2.4.2. Exporters

Exporting firm \( i \) sells to both markets (i.e. \( q^x_i(i) > 0, q^x_d(i) > 0 \)). Firm \( i \) supplies quantities that equate the marginal revenues of each market to the marginal cost:

\[
\begin{align*}
  A_d - 2\gamma q^x_d(i) &= \beta_i + z(i) + \nu(q^x_d(i) + q^x_f(i)) \\
  A_f - 2\gamma q^x_f(i) &= \beta_i + z(i) + \nu(q^x_d(i) + q^x_f(i)).
\end{align*}
\]

Solving this set of equations generates the optimal outputs (with \( q^x(i) = q^x_d(i) + q^x_f(i) \)):

\[
\begin{align*}
  q^x_d(i) &= \frac{A_dL_f\nu - A_fL_f\nu - 2(\beta_i + z(i))\gamma + 2A_d\gamma}{2\gamma(L_f\nu + \nu + 2\gamma)} > 0 \\
  q^x_f(i) &= \frac{A_f\nu - A_d\nu - 2(\beta_i + z(i))\gamma + 2A_f\gamma L_j}{2\gamma(L_f\nu + \nu + 2\gamma)} L_j > 0.
\end{align*}
\] (4)

Unlike a firm that produces with constant marginal cost, the exporting firm considers the conditions in the foreign market when making its domestic supply decisions. Shocks to \( A_f \) now affect \( q^x_d(i) \). Figure 1 illustrates this mechanism. In the top panel
(a), a firm with constant marginal costs ($\nu = 0$) increases its foreign supply in response to a positive foreign shock. Since its marginal cost of domestic supply is constant, the firm’s domestic quantity does not respond to the foreign shock. In the bottom panel (b), a firm with increasing marginal costs ($\nu > 0$) also increases its foreign quantity supplied. However, this drives its marginal costs higher. In response, the firm lowers its domestic supply.

The domestic sales of exporting firm $i$, conditional on import status, are:

$$r_n^d(i) = \frac{A_d^2}{4\gamma} - \frac{(A_f L_f \nu + 2(\beta_i + 1)\gamma + A_d \nu)^2}{4\gamma (\nu + L_f \nu + 2\gamma)^2}$$

(6a)

$$r_m^d(i) = \frac{A_d^2}{4\gamma} - \frac{(A_f L_f \nu + 2(\beta_i + z_m)\gamma + A_d \nu)^2}{4\gamma (\nu + L_f \nu + 2\gamma)^2}$$

(6b)

2.5. Modes of Globalization

To start producing a variety, the firm must pay the production fixed cost $y(0)$. After paying this fixed cost, the firm realizes its productivity $\beta_i$ along with firm specific sunk costs of exporting $K^e_i$ and importing $K^m_i$. Next, the firm must simultaneously choose whether to import and/or export. These choices depend on the sunk trading costs and the revenues derived in equations (3a), (3b), (6a), and (6b).

Upon entry, a firm’s sales are subject to two sources of uncertainty. First, shocks to $A_j$ represent destination-specific demand shocks that affect the firm’s sales. We define the mean and variance of the demand shock $E[A_j] = \bar{A}_j$ and $E[A_j^2] - E[A_j]^2 = \ldots$

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8This is consistent with Mrázová and Neary (2011) who discuss heterogenous fixed costs in terms of firms’ entry decision in a broad class of models.

9From here on we refer to these shocks as demand shocks. However, as discussed by Melitz and Ottaviano, the endogenous reservation price $A_j$ is a function of the number of varieties available in a destination and the average price which are determined by fixed costs and productivity parameters. In addition, $A_j$ is a function of preference parameters. Therefore, what we call demand shocks may be driven by changes in productivity and entry costs across destinations as well as changes in preference parameters.
\( \sigma_j^2 \). We term \( \sigma_j / \bar{A}_j \) the demand volatility in \( j \). \( A_d \) and \( A_f \) may be correlated with a correlation coefficient \(-1 < \rho < 1\).

Second the imported intermediate input price is volatile. While equation 2 shows that firms that import will enjoy a lower effective price for its bundle of intermediates, the exact difference is uncertain due to uncertainty in \( \tau \). The firm knows the distribution of \( \tau \) and thus knows the mean \( \bar{z}_m \) and variance \( \sigma_m^2 \) of the distribution of \( z_m \). The value \( \sigma_m / \bar{z}_m \) is the import price volatility.

Firms choose their mode of globalization to maximize expected profits in light of uncertain domestic and foreign demand and the price of imported intermediates. Since the firm knows its unique firm productivity \( \beta_i \) beforehand, the mode of globalization and expected profits \( E\pi \) are conditional on \( \beta_i \):

\[
E\pi(\beta_i) = \begin{cases} 
E[r_d^{nm}(i) - tc(i)] & \text{Domestic only} \\
E[r_d^{zm}(i) + r_f^{zn}(i) - tc(i)] - K_i^x & \text{Exporter} \\
E[r_d^{nm}(i) - tc(i)] - K_i^m & \text{Importer} \\
E[r_d^{xm}(i) + r_f^{zm}(i) - tc(i)] - K_i^x - K_i^m & \text{Export/import-er}
\end{cases}
\] (7)

The firm will choose the mode of globalization based on the highest expected profit. The intuition on which firms choose which mode of globalization is similar to the standard tradeoff between lower variable costs for higher fixed costs. For a given fixed cost of importing, firms that produce and sell a sufficiently large amount of output to recover the fixed cost will import to minimize the variable costs. For given fixed costs of exporting, firms that are productive enough to sell a sufficiently larger amount of output on the export market to recover the fixed costs will enter the foreign market to realize additional profits. For given level of productivity, firms that have sufficiently low fixed costs of exporting and importing will import to minimize the
variable costs and export to realize additional profits. Given that the uncertainty is coming from three different sources deriving the different alternatives is cumbersome. As we are not testing any of the entry conditions in this paper, we follow Amiti and Davis and don’t further formalize the entry decisions.

Since the fixed costs and productivities are firm specific, $\beta_i$ is not sufficient to predict the export and import status of a firm. This is a departure from the Melitz (2003) and Melitz and Ottaviano (2008) models where exporters and nonexporters are partitioned via their marginal costs. This additional variation in entry costs allows us to compare firms operating under different modes of globalization with the same level of initial marginal costs $\beta_i$. The next section exploits this feature of the model to derive testable predictions about the level and volatility of the domestic sales across firms operating under different modes of globalization.

3. Testable Predictions

Given our theoretical predictions for domestic sales in equations (3) and (6), we can now examine the impact of cost linkages on the firm’s domestic supply. Exposure to foreign volatility affects both the volatility of domestic sales and it’s expected value. We begin with the volatility.

3.1. Volatility and Linkages

We define the volatility of domestic sales as the coefficient of variation ($cvo(\cdot)$):

$$cvo(r_d(i)) \equiv \frac{\sqrt{VAR(r_d(i))}}{E[r_d(i)]}$$  (8)
With this measure of volatility at hand, we examine the effect of exporting, importing and size on domestic sales volatility. We do so through a series of propositions and lemmas.

**Proposition 3.1.** Consider firms with identical productivity \( \beta_i \) and import status but differing export status. If marginal costs are constant \( (\nu = 0) \), then the volatility of domestic sales for the exporter is equal to that of the nonexporter.

**Proof** If \( \nu = 0 \) then we can manipulate equations (6) and (3) to find \( r_x^n(i) = r_{d}^n(i) \). Therefore, \( cvo(r_x^n(i)) = cvo(r_{d}^n(i)) \).

Proposition 3.1 leads to a clear and falsifiable null hypothesis: If marginal costs are constant, then foreign demand does not feed back into domestic supply. All else equal, the domestic supply volatility of an exporter equals the supply volatility of a nonexporter. If the data show that the supply volatilities of exporters are structurally different from those of nonexporters after accounting for heterogeneity in \( \beta_i \) and import status, then we can reject this no-export-linkage hypothesis.

Whether exporters supply the domestic market at a greater or lower volatility under the alternative is an empirical question. Proposition 3.1 does not predict whether exporters supply the domestic market at a greater or a lower volatility than the nonexporter, because there are several channels that raise and/or lower the exporting firm’s domestic sales, and the magnitudes of the model parameters determine the net effect. Consider two examples.

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\(^{10}\)Appendix A-1 shows how we approximate the coefficient of variation using the Delta Method when we need an analytic expression for the proofs.

\(^{11}\)It is worth mentioning that the proof of proposition 3.1 does not rely on particular distributions or approximations. Therefore the empirical test is general with respect to those assumptions.
Suppose that there is neither volatility in $A_d$ nor the intermediate input market. In this case the cost linkage $\nu > 0$ introduces volatility into the domestic sales of the exporter via the foreign demand shock $A_f$. Thus, the domestic sales volatility of the exporter is greater than that of the nonexporter.\footnote{According to equation 1, if $\eta = 0$, then zero volatility on the domestic market boils down to no volatility in $\alpha$ on the domestic market.}

As a second example suppose there is volatility in $A_d$ but none in $A_f$. Exporters are able to use the foreign market to mitigate domestic shocks, but do not incur any foreign demand volatility. The relative size of the foreign market determines how much domestic volatility it can absorb. If the foreign market is sufficiently large

\[ A_f^2 > \frac{\nu A_d^2 + 2\sigma_d^2(\gamma + \nu)}{2\gamma + \nu}, \]

then the domestic sales volatility of the exporter is smaller than that of the nonexporter.\footnote{We assume certain restrictions on the model parameters in order to generate this sufficient condition. Details in Appendix A-4.} High demand in the foreign market allows the exporter to channel domestic shocks to its exports and lower the domestic sales volatility. Low demand in the foreign market restricts this channel.

The upshot from these two examples is that the domestic sales volatilities of exporters and nonexporters cannot be ranked if $\nu > 0$. Therefore, whether exporting increases or decreases the domestic sales volatility compared to nonexporters is an empirical question.

The importance of controlling for import status when testing for increasing marginal costs follows from the next proposition.

**Proposition 3.2.** Consider nonexporting firms with the same level of productivity $\beta_i$ but differing import status. If importing does not introduce volatility into the marginal cost ($\sigma_m = 0$), then the domestic sales volatility of the importer is lower than that of the nonimporter. This is independent of whether marginal costs are
constant \( (\nu = 0) \).

**Proof** See Appendix A-2. ■

Importing intermediate inputs introduces volatility into a firm’s marginal cost via the imported input price \( z_m \). If the volatility \( \sigma_m \) in this price does not affect variation in the marginal cost or if \( \sigma_m = 0 \), then importing will only reduce the firm’s marginal cost. The reduction drives the firm down the demand curve, raising domestic sales and lowering domestic sales volatility. The proposition provides us another falsifiable hypothesis: if importing does not introduce volatility into marginal costs, then, among firms that do not export, those that import have a lower domestic sales volatility than those who do not import. If we find the opposite - that (among nonexporters) importers have a higher domestic sales volatility than nonimporters, then this is evidence that importers feed volatility in the input price to the domestic market.\(^{14}\)

Propositions 3.1 and 3.2 show that it is important to examine, import and export status jointly. Both trading statuses can affect the firm’s domestic sales volatility. If import status is positively correlated with export status, then ignoring import status results in a spurious correlation between the export status and domestic sales volatility and vice versa. In order to test both hypotheses, we need to control for both channels.

All of our volatility expressions are a function of firm productivity \( \beta_i \). For firms that do not trade, the model pins down a clear prediction that allows us to examine

\(^{14}\)If \( \nu > 0 \), then the theory does not deliver a falsifiable prediction with respect to import status. Whether importing increases or decreases the domestic supply volatility depends on the impact of the import activity on the average domestic sales and how much volatility is coming from the input price. The net effect depends on the relative magnitudes of these effects.
if the relationship between productivity and volatility works as anticipated by the theory.\textsuperscript{15}

\textbf{Lemma 3.3.} Consider only firms that neither import nor export. More productive firms (with lower $\beta_i$) have lower domestic sales volatility.

\textbf{Proof} Applying the delta method to compute the coefficient of variation of the domestic sales ($A^{-1}$) we obtain

\[
cvo(r_{dn}^{nn}(i)) \approx \frac{(\bar{A}_d \nu + \gamma + \gamma \bar{A}_d + \gamma \beta_i + (\nu + \gamma) (\bar{A}_d - \beta - 1)) \sigma_d}{(\bar{A}_d \nu + \gamma + \gamma \bar{A}_d + \gamma \beta_i) (\bar{A}_d - \beta - 1)}.
\]

The derivative of the volatility of domestic sales for nonexporters, $\frac{dcvo(r_{dn}^{nn}(i))}{d\beta_i}$, is then equal to

\[
\frac{(4 \nu \gamma \bar{A}_d + 4 \gamma^2 \bar{A}_d - 2 \nu \gamma \beta_i) + \bar{A}_d^2 \nu^2 + \nu \gamma (\bar{A}_d^2 - \beta_i^2 - 1) + 4 \nu \gamma \bar{A}_d \beta_i + 4 \gamma^2 \bar{A}_d \beta_i}{(\bar{A}_d \nu + \gamma + \gamma \bar{A}_d + \gamma \beta_i)^2 (-\bar{A}_d + \beta_i + 1)^2}.
\]

The derivative $\frac{dcvo(r_{dn}^{nn}(i))}{d\beta_i} > 0$, because $\bar{A}_d > \beta_i + 1$ at interior solutions. Therefore, more productive firms (lower $\beta_i$) supply the domestic market at a lower volatility than less productive firms. \hfill \blacksquare

Lemma 3.3 shows a negative relationship between the productivity of nontrading firms and their domestic sales volatility. This is consistent with the predictions and results of Mills and Schumann (1985). In their model as well as in ours, productivity determines volatility. This is a richer prediction of the model based on linear demands and heterogeneity in the marginal cost intercepts versus a model of CES preferences.

\textsuperscript{15}We can’t sign a prediction between volatility and productivity for exporting firms. The difficulty is similar to signing the alternative of Proposition 3.1. An increase in $\beta_i$ changes the quantity and price as well as the elasticity of the quantity with respect to domestic and foreign shocks. The net effect of all of these channels depends on the parameters of the model.
with zero marginal cost intercepts and heterogeneity in the slopes of the marginal costs. Because of the log linearity of the CES type models, productivities would cancel out from the domestic volatility expression and would not predict variation in volatility across nontrading firms. This prediction complements the predictions of the CES framework. While the CES framework emphasizes heterogeneity in the slopes of the marginal costs, the linear demand framework emphasizes heterogeneity in the marginal cost intercepts. Testing lemma 3.3 provides evidence for the heterogeneity of the marginal cost intercepts.\(^{16}\)

### 3.2. Foreign Volatility and mean Domestic Sales

Instead of focusing on volatility, we now show that cost linkages affect an exporter’s expected domestic sales. We define the expected domestic sales of firm \(i\), conditional on mode of globalization, by taking the expectations of domestic sales in equations (6) and (3):

\[
E[r_d^*(i)] = \frac{\bar{A}_d^2}{(2\gamma + \nu)^2} - \frac{(\beta_i + z(i))^2\gamma}{(2\gamma + \nu)^2} + \frac{\nu \bar{A}_d(\bar{A}_d - \beta_i - z(i))}{(2\gamma + \nu)^2} + \frac{\sigma_d^2(\gamma + \nu)}{(2\gamma + \nu)^2}. \tag{9a}
\]

\[
E[r_d^*(i)] = \frac{\bar{A}_d^2}{4\gamma} - \frac{(\bar{A}_f L\nu + 2(\beta_i + z(i)) + \bar{A}_d\nu)^2}{4\gamma (\nu + L\nu + 2\gamma)^2} + \frac{\sigma_d^2 L^2 \nu^2 \sigma_f^2 + 2\nu^2 L\rho \sigma_d \sigma_f + \sigma_d^2 \nu^2}{4\gamma (\nu + L\nu + 2\gamma)^2}. \tag{9b}
\]

A comparison of the two equations above shows the discrepancy in the set of factors influencing the domestic sales of exporters and nonexporters. The mean and variance

\(^{16}\)While we set the slope of the marginal costs curve equal across all firms, the tests of our main propositions are valid even with heterogeneity in the slope parameter. To generate heterogeneity in size across firms, Vannoorenberghe (2011) introduces firm specific taste parameters. However, because of the multiplicative nature of the CES framework, these taste differences also cancel out for nonexporters.
of $A_d$ affect domestic sales of all firms, while those of $A_f$ affect only those of exporters. In this regard, we now illustrate the importance of the quadratic cost term $\nu$ in linking foreign demand shocks to expected domestic sales.

**Proposition 3.4.** Consider firms with identical $\beta_i$ and import status but differing export status.

1. If there are no cost linkages (i.e. $\nu = 0$), then (a) the expected domestic sales of the exporter are identical to the expected sales of the nonexporter, (b) the domestic sales of the exporter do not depend on foreign demand.
2. If there are cost linkages (i.e. $\nu > 0$), then (a) the expected domestic sales of the exporter are lower than those of the nonexporter, (b) an increase in demand on the export market lowers the expected sales on the domestic market, (c) if $L\sigma_f + \nu \rho \sigma_d > 0$, then an increase in foreign demand volatility lowers the expected sales on the domestic market.

**Proof** See Appendix A-3 ■

The intuition for proposition 3.4 is straightforward. If there are no cost linkages, exporters and nonexporters with identical costs supply identical quantities at identical prices to the domestic market.

If increasing marginal costs link the two markets, then an increase in exports raise the marginal cost of supplying the domestic market. To maximize profits, the firm raises its domestic marginal revenues by lowering its domestic supply. Therefore, an increase in foreign demand lowers the firm’s expected sales in the domestic market. If the correlation between the domestic and foreign demand shocks is not negative, then this substitution effect is exacerbated by the foreign demand volatility.

The following lemma shows why it is important to account for import status when we test proposition 3.4.
Lemma 3.5. Compare the domestic sales of an importer to a nonimporter with identical $\beta_i$. Let both firms have the same export status. The expected sales of the importer on the domestic market are greater than the expected sales of the nonimporter.

Proof Take the derivative of the domestic revenues of a firm with either export status in equations (3b) and (6b) with respect to the price of the intermediate input price $z(i)$ to show

$$\frac{dE(r^m_d(i))}{dz(i)} = -\frac{2(\beta_i+z(i))\gamma+\bar{A}\nu}{(2\gamma+\nu)^2} < 0$$

and

$$\frac{dE(r^\pi_d(i))}{dz(i)} = -\frac{2(\beta_i+z(i))\gamma+(\bar{A}+\bar{A}_f)\nu}{(2\gamma+\nu+L\nu)^2} < 0.$$ 

By (2), the price an importer pays for its intermediate input is less than the price a nonimporter pays. Thus $E(r^m_d(i)) > E(r^\pi_d(i))$.

Importing firms pay a lower price for the intermediate input. This lowers their marginal costs, which raises their optimal output. Because these firms never supply on the inelastic part of the demand curve, the firm with the lower initial marginal cost of production realizes the higher sales on the domestic market. For the empirical test this is important, because importing has the opposite effect of exporting on domestic sales. Therefore, if export and import statuses are correlated, then we obtain biased estimates if we don’t account for a firm’s import status.

4. Empirical Evidence

The previous section gives several tests for cost linkages in firm level data. This section explains the data, defines the estimation specifications and employs several estimators to test the predictions.

4.1. Data

We employ Statistics Denmark’s firm-level Account Statistics dataset for the years 1992 to 2006. This dataset is compiled from annual censuses of the economic activity of all Danish manufacturing firms. For each year $t$ we have annual firm-level
output as total sales. We augment this information with export sales and import expenditures in Danish Kroner (DKK) from Statistics Denmark’s Trade Statistics. Domestic output is measured as the difference between total sales and export sales. Each firm’s product is classified according to 316 six digit industries defined by the classification of economic activities in the European Community (NACE6).

Cleaning the data preserves about 82 percent of the gross total output, but drops a large amount of observations. The combined raw dataset contains 67871 firms registered with the Danish government. The sample drops 38116 firms that report 1 or zero employees over their entire lifespan. The aggregate sales of these firms are less than 1 percent of the sum of the total sales over all firms. This suggests that the vast majority of these are likely “firms” created by individuals for tax write-off purposes. Clerical entry error drops 1853 firms as they violate annual reporting requirements and 88 firms because they show negative sales. Also dropped were 1670 firms who switched 4 digit industries but kept the same name. The theory assumes that firms that supply the export market also supply the domestic market. Only 858 of our firms export for a total of 1463 \( i - t \) firm-year observations without supplying the domestic market. This is less than 1 percent of our observations. The sample drops these export-only firms. We drop the bottom percentile of firms based on mean sales to minimize the impact of outliers.\(^\text{17}\) To compute a measure of volatility on the domestic and export markets requires a minimum number of observations. Dropping firms that lack the necessary observations or variation and three outlier firms with domestic sales volatilities seven standard deviations below the mean, the final dataset contains 16671 firms. The bottom line is that the identification approach is hard on the number of observations, but preserves a significant proportion of the economic

\(^{17}\text{Including those firms in the sample does not significantly impact our estimation results. We also dropped the top percentile from our sample. The estimation results don’t change, but dropping the top percent has a significant impact on the share of economic activity we preserve.}\)
activity.

Columns (1), (2) and (5) of Table 1 provide the summary statistics for our final sample, considering the sample of all firms, exporters, and importers. Given the small size of Denmark and its location in Europe, it is not surprising that a relatively large share of about 40 percent of firms try to export or import at least once. As has been documented in previous works (Bernard Jensen (1995) for American firms, Amiti and Davis (2011) for Indonesian firms) the trade status is highly correlated with firm size. Figure 2 illustrates this pattern. It shows the log distributions of the average employments of the firms in our sample across the different trade statuses. The height of each bar corresponds to the total count of firms within a given range of size. Any bar may be separated into four parts. The darkest part represents the firms that neither export nor import. There are 8150 of these firms with an average of 6.8 employees per firm. The second darkest bars represent the 1257 firms that export but do not import. These firms average 9.2 employees. The third darkest bars represent the 1359 firms that import but do not export. These firms average 17.7 employees. Finally, the lightest bar represent 5997 firms that both export and import. These firms average 60.3 employees.

We define an exporter as a firm that exports at least one year in the sample. However, export status is not fixed for all firms. We further divide the population of Danish exporters into *Marginal* and *Permanent* exporters. *Marginal* exporters are those firms that export in some, but not all of the periods they are in the sample. *Permanent* exporters are those firms that export in all of the periods they are in the sample. Figure 3 shows the size distributions of these different exporters. Like in Figure 3, the height of each bar corresponds to the total count of firms within a given range of size. Each bar is then separated into nonexporters, marginal exporters, and permanent exporters. The permanent exporters with an average employment of 67
tend to be larger than marginal exporters with an average employment of 32. Both
are much larger than nonexporters, which have on average 8 employees. This pattern
is consistent with Melitz (2003) models where the largest firms export, the smallest
firms do not, and mediocre firms are on the cusp of exporting.

We also divide importers into marginal and permanent statuses. The corresponding
distributions are similar to those of the exporters.

Our tests require an empirical analogue to the theoretical coefficient of variation and
the expected sales of a firm. Let $\chi_{it}$ be the quantity of interest, where $\chi$ denotes either
domestic sales, total sales, or input value. We first define our empirical measure of
volatility and then a measure of average sales. To remove time trends, specify

$$
\ln(\chi_{it}) = \alpha_i + \zeta_i \text{Trend}_t + \epsilon_{it}.
$$

where $\text{Trend}_t$ is a linear time trend. Because log differences approximate percentage
change, $\hat{\epsilon}_{it}$ is approximately equal to the percentage deviation of $\chi_{it}$ from its time
varying mean:

$$
\hat{\epsilon}_{it} = \ln(\chi_{it}) - \ln(\exp(\hat{\alpha}_i + \hat{\zeta}_i \text{Trend}_t)) \approx \frac{\chi_{it} - E(\chi_{it})}{E(\chi_{it})},
$$

and

$$
\sqrt{\frac{1}{T} \sum_{t=1}^{T} [\epsilon_{it}^2]} \approx \sqrt{\frac{1}{T} \sum_{t} \left( \frac{\chi_{it} - E(\chi_{it})}{E(\chi_{it})} \right)^2} = \sqrt{\text{Variance}_i \left( \frac{\chi_{it}}{E(\chi_{it})} \right)}.
$$

where $\text{Variance}_i(\chi_{it})$ is the across-time variance of $\chi_{it}$. The most right hand side
expression captures the coefficient of variation of $\chi_{it}$ with respect to a time trending
mean. For each firm define the measure of volatility as $\text{rmse}(\chi)_i \equiv \sqrt{\frac{1}{T} \sum_{t} [\epsilon_{it}^2]}$. Next, the average domestic sales for a firm are simply defined as $\text{sales}(\chi)_i = \frac{\sum_{t=1}^{T} \chi_{it}}{T}$. 

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All of our tests require a measure of firm size. The theory and data suggest an input and an output based definition of size. The input based measure is the average number of workers hired by by firm $i$, $Employment_i$. The output based measure computes the average output share within the industry. Let $j$ denote a NACE6 industry. Then the output share of firm $i$ that belongs to industry $j$ is

$$Output Share_{it} = \frac{\text{Total Sales}_{it}}{\sum_{i \in j} \text{Total Sales}_i}.$$ Let Output Share$_i$ denote the simple average of Output Share$_{it}$ over time.

To proxy for firms’ export market characteristics, we compute firm-specific average destination market GDP, average destination market GDP volatility, average destination distance, and total number of export destinations. From the Penn World Tables (Heston, Summers, and Aten, 2006), we obtain $GDP_{ft}$, the GDP in foreign destination country $f = 1..F$ at time $t = 1..T$ and $distance_f$, the distance between Denmark and $f$. We compute country $f$’s GDP volatility $cvo(GDP)_f = \text{rmse}(GDP_{ft})$ using the same algorithm we used to find the sales volatility for each firm. Let $exports_{ift}$ be a firm $i$’s export sales to market $f$ in year $t$. Then for each of $GDP$, $cvo(GDP)$, $distance$, calculate firm $i$’s export market average $GDP_i = \frac{\sum_{t=1}^{T} \sum_{f=1}^{F} exports_{ift} GDP_{ft}}{\sum_{t=1}^{T} \sum_{f=1}^{F} exports_{ift}}$ and similar for the average GDP volatility and distance. Finally, we tally the number of export destinations to which firm $i$ exported between 1992 and 2006 (“Nr. of Destinations” in our Tables.).

In our endogeneity robustness checks, we use other firm variables such as capital per worker, materials per worker, and energy per worker. These are gathered from the same firm censuses as firms are obliged to report their annual depreciated value of capital as well as their purchases of energy and materials. In addition, firms report the municipality or zip code in which the firm is incorporated.

Table 1 summarizes the regression variables in logs as they are applied in the specifications by export status. Overall the summary statistics suggest significant variation
in the variables of interest across all firms and within the different samples split by export status. The regressions employ cross-firm variation across and within various export statuses to test the predictions from the theory.

### 4.2. Empirical Model and Identification

Let $X$ be either of three export statuses such that $X \in \{\text{Permanent X, Marginal X, All X}\}$. Similarly, let $M$ be either of three import statuses such that $M \in \{\text{Permanent M, Marginal M, All M}\}$. Let $(x_i, m_i)$ be firm $i$’s observed export and import status. Then we can define export and import indicators $\mathbb{I}[\cdot]_i$ for export/import status as follows:

\[
\mathbb{I}[X]_i \equiv \begin{cases} 1 & \text{if } x_i = X \\ 0 & \text{if } x_i \neq X \end{cases} \quad \mathbb{I}[M]_i \equiv \begin{cases} 1 & \text{if } m_i = M \\ 0 & \text{if } m_i \neq M. \end{cases}
\] (10)

This means that $\mathbb{I}[X]_i$ defines three separate export indicators, one for each possible export status: marginal, permanent and the combined all exporters and $\mathbb{I}[M]_i$ defines three import indicators, one for each possible import status.

In all our specifications the dependent variable is $\ln(y_i)$ where $y_i$ either equals our empirical measure of volatility $rmse(\chi)_i$ or the average sales $sales(\chi)_i$. The base specification

\[
\ln(y_i) = \gamma_j + \zeta_1 \mathbb{I}[\text{All X}]_i + \zeta_2 \mathbb{I}[\text{All M}]_i + \zeta_3 \ln(\text{Size}_i) + u_i
\] (11)

relates the log volatility of the firm-level variable $\chi_i$ (domestic sales, total sales, etc.) and average domestic sales to log firm size and the export activity indicator $\mathbb{I}[X]_i$ and import activity indicator $\mathbb{I}[M]_i$ defined in (10). The NACE6 industry specific intercept $\gamma_j$ accounts for cross-industry-specific volatility that may be systematically
correlated with the export potential of the industry. The identification assumption is that, within industries, firms are subject to the same fundamentals. This implies they are subject to the same long run (annual) domestic shock.

Two approaches are available to examine non linearity within the group of exporters and importers. First, split export activity and import activity by marginal and permanent status according to (10) and specify

\[
ln(y_i) = \gamma_j + \zeta_1 I[\text{Permanent X}]_i + \zeta_2 I[\text{Marginal X}]_i + \zeta_3 I[\text{Permanent M}]_i + \zeta_4 I[\text{Marginal M}]_i + \zeta_5 ln(\text{Size}_i) + u_i
\]

This specification emphasizes difference in volatility and average sales by export and import statuses. The coefficient \(\zeta_1\) identifies the difference between permanent and nonexporters. The difference \(\zeta_2 - \zeta_1\) identifies a structural difference between permanent and marginal exporters. Coefficient \(\zeta_2\) identifies the difference in between marginal and nonexporters. Similarly, \(\zeta_3\) and \(\zeta_4\) identify the difference in volatility between permanent, marginal and nonimporters. This specification is useful for two reasons. First, our predictions derived in the theory apply to permanent exporters and therefore splitting the export and import statuses controls for the issue that some firms trade for only some periods of the sample. Second, this result is interesting because it highlight the difference in volatility and average sales that firms experience when they enter or exit the export and/or import markets.

Volatility and sales differences between exporters and nonexporters may be heterogeneous in size. To examine this hypothesis interact the export and import indicator
with firm size to obtain

\[
ln(y_i) = \gamma_j + \zeta_1 I[All X]_i + \zeta_2 I[All X]_i \times ln(Size_i) \\
+ \zeta_3 I[All M]_i + \zeta_4 I[All M]_i \times ln(Size_i) + \zeta_5 ln(Size_i) + u_i
\]  

(13)

The coefficients $\zeta_2$ and $\zeta_4$ of this specification identify size-driven heterogeneity in the relative volatility and average sales of exporters and importers compared to nonexporters and nonimporters.

4.3. Impact of Export and Import Activity on Domestic Volatility

Proposition 3.1 suggests a test for export market linkages. Let the dependent variable be the domestic sales volatility of firm $i$. If marginal costs are constant ($\nu = 0$), then the theory suggests the null hypothesis $H_o : \zeta_1 = 0$. If instead marginal costs increase ($\nu > 0$), then the theory predicts $H_a : \zeta_1 \neq 0$.

Columns 1 to 4 of Table 2 report the Ordinary Least Squares (OLS) estimates that test $H_o$ employing specifications (11), (12) and (13). Across all four columns, exporters supply the domestic market at a structurally higher volatility than nonexporters. This rejects the null hypothesis of constant marginal cost and provides evidence for export linkages that transmit volatility from the foreign to the domestic market.

The results highlight the importance of accounting for import status. Column 1 includes only export status and controls for firm size with log employment. According to the estimate, exporters supply the domestic market at a volatility that is about 20 percent higher on average than nonexporters. Columns 2-4 show that importers and exporters supply the domestic market at a higher volatility than nontraders. Comparing column 1 to column 2, accounting for import status drops the impact
of export activity to about 15 percent. This suggests that if we don’t account for import status, then our estimates are subject to omitted variable bias and we over estimate the impact of export activity on domestic volatility. Both, export and import activity increases a firm’s domestic sales volatility and import and export statuses are positively correlated across firms.

Across columns 1 to 4 larger firms supply the domestic market at a lower volatility. Given the trade status of the firm, doubling employment lowers the domestic sales volatility by about 7-10 percent. Column 4 interacts firm size with the export and import status. The results are a test of lemma 3.3. More productive firms supply the domestic market at a lower volatility, independent of the trade status.\(^\text{18}\)

Column 3 splits the impact of export and import activity on volatility by marginal and permanent trade statuses according to specification (12). Accounting for differences in size and import status, marginal exporters operate with higher volatility than permanent exporters. Both types operate with higher volatility than nonexporters.\(^\text{19}\) Marginal and permanent importers supply the domestic market at a similar level of volatility, but a higher level of volatility than nonimporters.

Column 4 interacts the trade status indicators with employment and largely confirms the results reported in columns 2 and 3. The interaction between export/import status and average size is not statistically significant. This implies that the increased volatility of marginal exporters is not driven by heterogeneity in size, but is inherent to the trade status.\(^\text{20}\)

\(^{18}\)We also ran the specifications just on the nonexporters and got similar results.

\(^{19}\)A Wald test rejects the null hypothesis that the average volatility for the permanent exporters is the same as the volatility of the marginal exporters with a p value of less than 1 percent. We also estimated a specification including output share. Output Share does not have a significant impact on volatility in this specification.

\(^{20}\)We also estimated a specification with the permanent and marginal trade indicators including an interaction of the indicators with size. Again the interactions were not significant and a specification test (F-test) did not provide any evidence that the interactions should be included in the
Column 5 provides a test for proposition 3.2. This specification interacts the exporting and importing indicators, allowing us to separate out the effects of importing for exporters and nonexporters. For firms that do not export, importing raises the domestic sales volatility by 8%. This rejects the null that $\sigma_m = 0$. This is evidence that importers channel foreign intermediate input price volatility to the domestic market.\(^{21}\)

Column 6 examines a potential endogeneity bias. Firms may self select into export and import status based on their domestic sales volatility. To examine this identification problem we instrument the export and import statuses with zip code specific effects (277 zip codes in Denmark).\(^{22}\) The idea is that firms located in zip codes closer to ports and borders have lower $K_i^x/K_i^m$ and are more likely to export/import, but are still subject to the same domestic shocks. Similar as in columns 1 to 4, exporters and importers supply the domestic market at a structurally greater volatility than firms that operate only on the domestic market. Firm size still has a negative and significant impact on the domestic supply volatility.

We employ several other robustness checks in our test of Proposition 3.1, including additional/alternative controls and alternative domestic sales data. These are summarized in A-5. Detailed tables for all robustness checks are available upon request.

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\(^{21}\)We also include both the exporting and importing interaction dummy and the marginal and permanent exporting/importing statuses of the firm. The result had the same signs, but larger standard errors, resulting in insignificant results for permanent exporters that never import, and for permanent importers that never export. Given the correlation between importing and exporting, these firms make up less than 5% of our sample, which would explain the large standard errors.

\(^{22}\)Vannoorenberghe (2010) also employs firm specific location information to develop instruments.
Next we test Proposition 3.4. The theory predicts that after accounting for productivity differences, exporters realize lower sales on the domestic market than nonexporters if $\nu > 0$ and importers realize higher sales than nonimporters.

Columns 1 to 3 of Table 3 regress the log average domestic sales of all firms on our export and import indicators as well as firm size. Column 1 shows that export status by itself does not significantly predict the average sales. Columns 2 and 3 show that as we control for import status the results are consistent with our predictions: Exporter’s average supply is lower than the average supply of the nonexporters and the importer’s average supply is greater than that of the nonimporters. Again this highlights the importance of accounting for import status. Because importing and exporting work in opposite directions, the impact of export status is insignificant if we don’t account for import status.

Column 3 distinguishes by permanent and marginal trade status. Again the estimates are consistent with the predictions of the model, permanent exporters realize lower average sales on the domestic market and permanent importers realize higher sales on the domestic market. Marginal importers realize larger average sales on the domestic market than the nonimporters, but we can’t identify a significant difference between marginal exporters and nonexporters.

Column 4 augments the specification in column 2 with firm specific proxies for export market size, transportation costs and export market volatility. The signs of the coefficients are consistent with our theory. Firms that export to a larger market and firms that export to more destinations realize lower sales on the domestic market. Firms that export to a more volatile market realize lower domestic sales. Based on proposition 3.4, this is consistent with the theory if $\rho > 0$. The average distance
to the export market does not significantly predict the average domestic sales. A difficulty in identifying the distance effect is that this proxy performs a double duty. It not only proxies for transportation costs, but also may be correlated with the correlation of the export with the domestic market.

Note that in column 4, the export indicator does not have a significant impact on average domestic sales. However, the market size, distance and variance proxies are zero for nonexporters and they are equivalent to interactions of these export market characteristics with the export indicator. Therefore, we remove the export indicator in column 5. This does not significantly change the coefficients on export market characteristics.

The key channel that transmits foreign market characteristics to the domestic sales of a firm works through the substitution of quantities across markets. Firms sell a larger quantity abroad if they have a larger export market and therefore reduce the sales on the domestic market. To examine robustness with respect to this channel, we regress the export quantities of firms on their foreign market size, the average distance to the foreign market and the variance on the foreign market for several specifications. All variables predict the quantities as expected. Firms with large export markets export a larger quantity. All else equal, firms export lower quantities to far away markets. Larger firms export more than smaller firms. We employ several other robustness checks in our test of Proposition 3.1, including additional/alternative controls and alternative domestic sales data. These are summarized in A-5. Detailed tables are available upon request.
4.5. Additional Results

4.5.1. Total Sales Volatility

To examine the impact of export activity on total volatility, we estimate the specifications derived in section 4.2, but with the volatility of total sales instead of domestic sales as the dependent variable. With a few notable exceptions, the implications of export status on total firm volatility are the same as for domestic volatility. Table 4 reports the results.

Across all columns, Table 4 shows that export and import activity raises a firm’s total sales volatility. However, columns 4 and 5 separate between permanent and marginal trade status and show that this result is driven by the marginal importers and exporters. This implies that especially the firms that are on the entry margin that have to manage and increased amount of total sales volatility.²³

4.5.2. Input Demand Volatility

Next we examine how export status and size impact the firm’s factor demand volatility. If factor markets are flexible, then we expect the changes in output go hand in hand with changes in the factor demands. This implies that export status and size predict the factor demand volatility. On the other hand, firms may always respond to shocks by adjusting prices, the speed of the machinery or the number of working hours. In this case we expect no systematic relationship between export status, size and input demand volatility. Columns 1, 3 and 5 of Table 5 report estimates of specification (11) where the dependent variable is the volatility of labor, energy and capital. All three specifications show that importing raises the input demand

²³We also tried to instrument for import and export status as in Table 2. The signs an magnitudes of the export and import indicators are similar as in Column (2), but we can’t reject that the coefficients are different from zero.
volatility and larger firms hire inputs at lower volatility. Column 3 shows that for electricity, exporting raises the input demand volatility.

Similar as for the total sales volatility in Table 4, columns 1, 4 and 6 of Table 5 show that the firms that enter and exit the export and import markets exhibit a high input demand volatility. These results complement those of Bergin, Feenstra, and Hanson (2011). They find that the entry and exit of new offshoring plants in Mexico is an important mechanism that links U.S. demand volatility to Mexican industry level employment volatility. Our results provide evidence that this transmission can occur within existing firms that adjust inputs in response to new and expiring trade relationships.

5. Conclusion

This paper introduces increasing marginal costs and intermediate input trade into a model of trade with stochastic linear demands. Increasing marginal costs result in firm-level export linkages; a shock in the foreign market results in a reallocation of output on the domestic market. Intermediate input trade transmits import price shocks from the foreign to the domestic market.

Our results support the existence of export and import linkages. Accounting for the volatility that is transmitted via the import channel, exporters supply the domestic market at a volatility 14 percent greater than that of nonexporters. Importers supply the domestic market at a volatility that is about 13 percent higher than that of nonimporters. This suggests that linkages across markets impact the stability of local markets; intermediate input trade and firm-level export activity are important in the transmission of shocks across market.

Based on our results, the feedback of foreign shocks to an exporter’s domestic supply

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lowers the level and increases the volatility of domestic consumption of a particular variety. All else equal, if consumers are risk averse then the decreases in sales and increase in volatility has a negative impact on welfare. The increase in volatility can have a substantial impact on consumer welfare; Barlevy (2004) finds that the consumption volatility induced by real business cycles drop welfare by an amount equivalent to 7-8% of annual consumption. This highlights the importance of the intensive margin for welfare in the light of volatility. In the static application of these models the literature’s focus tends to be on the extensive margin.

In general equilibrium, whether these linkages increase aggregate volatility in the economy and lower overall welfare depends on a multitude of additional margins present in the model. For example, changes in volatility impact a firm’s entry, export and import decisions and the number of varieties consumed. Even if the theory predicts these margins, exporting and importing behavior impacts the correlation between trading and non trading firms. To determine the aggregate volatility this requires the empirical identification of the impact of trade on the correlation structure similar as in di Giovanni and Levchenko (2008). We show that exporting and importing has a statistically and economically significant impact on the sales volatility of a particular variety. Identifying the impact of all the other margins that determine welfare requires a substantial amount of future research.

Finally, we find that for marginal exporters and importers that jump between the domestic and foreign markets, the total sales and input volatilities are higher than for other firms. This suggests that firms on the export margin have to manage an increased amount of total volatility. This is important for export promotion officials that identify and give recommendations to firms on how to succeed in international markets.
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Figure 1: Optimal Quantity Responses to Foreign Shocks, Under Constant and Increasing Marginal Costs.

The top panel (a) shows the quantity response of an exporter with constant marginal costs $MC$. A positive foreign shock shifts out the foreign marginal revenue $MR_f$ in the top right figure, increasing the foreign quantity supplied $q_f^x(i)$. Domestic quantity supplied $q_d^x(i)$ does not change. The total quantity output $q^x(i)$ increases by the same amount as $q_f^x(i)$.

The bottom panel (b) shows the quantity response of an exporter with increasing marginal costs. A positive foreign shock shifts out the foreign marginal revenue $MR_f$ in the bottom right figure, increasing the foreign quantity supplied $q_f^x(i)$. The output increases $q^x(i)$, raising marginal costs. Domestic quantity supplied $q_d^x(i)$ must decrease to climb up the domestic marginal revenue $MR_d$. The total quantity output $q^x(i)$ increases by less than the increase in $q_f^x(i)$. 

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Importers are those firms that import for at least one year in the sample. Exporters are those firms that export for at least one year in the sample.
Permanent exporters are defined as the firms that supply the export and domestic markets simultaneously in all periods. Marginal exporters are defined as the firms that supply the export market in some periods when they supply the domestic market.
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<th>Employment</th>
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Sample mean/(standard deviation) of the regression variables. All variables are in logs.
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Dependent Variable: log of the volatility of domestic sales, ln(rmse(\chi_i)). Unit of observation: Firm. All errors are clustered by industry. All specifications include a constant. The two stage least squares estimator in column (6) instruments for import and export status with zip codes. The first stage R^2 are high, but are hard to interpret as all specifications include fixed effects.
Table 3: Impact of Export and Import Activity on Average Domestic Sales

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Dependent Variable: log average domestic sales. Unit of observation: Firm. All standard errors are clustered by industry. All specifications include a constant. The estimator is OLS.
Table 4: Impact of Export and Import Activity on the Total Sales Volatility

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Dependent Variable: log of the volatility of total sales, $\ln(\text{rmse}(\chi_i))$. Unit of observation: Firm. All errors are clustered by industry. All specifications include a constant. The estimator is OLS.
Table 5: Impact of Exporting and Importing on Input Demand Volatility

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<td>.027</td>
<td>-.015</td>
</tr>
<tr>
<td></td>
<td>(.020)</td>
<td>(.015)*</td>
<td>(.025)</td>
</tr>
<tr>
<td>Permanent Exporters</td>
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<td>-.010</td>
<td>-.088</td>
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<td>(.027)</td>
<td>(.024)</td>
<td>(.033)**</td>
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<tr>
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<td>.060</td>
<td>.039</td>
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<td>(.020)**</td>
<td>(.015)***</td>
<td>(.025)</td>
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<tr>
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<td>.066</td>
<td>.111</td>
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<tr>
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<td>(.018)***</td>
<td>(.019)***</td>
<td>(.024)***</td>
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<tr>
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<td>.023</td>
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<tr>
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<td>(.028)</td>
<td>(.031)</td>
<td>(.036)</td>
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<tr>
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<td>.101</td>
<td>.160</td>
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<td>(.018)***</td>
<td>(.018)***</td>
<td>(.025)***</td>
</tr>
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<tr>
<td>Employment</td>
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<td>-.210</td>
<td>-.103</td>
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<td></td>
<td>(.011)***</td>
<td>(.012)***</td>
<td>(.013)***</td>
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<tr>
<td>$R^2$</td>
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<td>.163</td>
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<td>$F$ statistic</td>
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<td>112.456</td>
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Dependent Variable: log volatility of inputs. Unit of observation: Firm. All standard errors are clustered by industry. The estimator is OLS.
A-1. The volatility of domestic sales

To derive the volatility of the domestic sales employ the domestic revenues of the non-exporters in (3) and the domestic revenues of the exporters in (6). Let \( r_{d}^{xm} (\beta_i, A_D, A_F, z_m) \) denote the domestic sales of an exporter that imports. Let \( r_{d}^{nm} (\beta_i, A_D, z_m) \) be the sales of a nonexporter that imports. The sales are non linear in the random variables. Therefore, we use the delta method to estimate the volatilities of domestic sales.

First apply a second order Taylor approximation to the exporter’s domestic sales to obtain

\[
r_{d}^{xm}(\cdot) \approx r_{d}^{xm}(\beta_i, \bar{A}_d, \bar{A}_f, \bar{z}_m) + \frac{\partial r_{d}^{xm}(\beta_i, \bar{A}_d, \bar{A}_f, \bar{z}_m)}{\partial z_m}(z_m - \bar{z}_m) + \frac{\partial r_{d}^{xm}(\beta_i, \bar{A}_d, \bar{A}_f, \bar{z}_m)}{\partial A_d}(A_d - \bar{A}_d) + \frac{\partial r_{d}^{xm}(\beta_i, \bar{A}_d, \bar{A}_f, \bar{z}_m)}{\partial A_f}(A_f - \bar{A}_f) \tag{A-1}
\]

The variance of the domestic sales of a firm that exports and imports are then

\[
VAR(r_{d}^{xm}) \approx \begin{bmatrix}
\frac{dr_{d}^{xm}}{dz_m} \\
\frac{dr_{d}^{xm}}{dA_d} \\
\frac{dr_{d}^{xm}}{dA_f}
\end{bmatrix}' \begin{bmatrix}
\sigma_m^2 & 0 & 0 \\
0 & \sigma_d^2 & \sigma_{df} \\
0 & \sigma_{df} & \sigma_f^2
\end{bmatrix}
\begin{bmatrix}
\frac{dr_{d}^{xm}}{dz_m} \\
\frac{dr_{d}^{xm}}{dA_d} \\
\frac{dr_{d}^{xm}}{dA_f}
\end{bmatrix} \tag{A-2}
\]

where \( \sigma_{df} = \rho \sigma_d \sigma_f \), and we assume that the covariance between the intermediate input shock and the demand shock equals zero. The coefficient of variation of an exporting firm that also imports is then

\[
cvo(r_{d}^{xm}) = \frac{\sqrt{VAR(r_{d}^{xm})}}{r_{d}^{xm}((A_d, A_f, \beta_i, z_m))} \tag{A-3}
\]
To generate the corresponding coefficient of variation for the domestic sales $r_d^{nm}(\beta_i, A_d, A_f)$ for a exporter that does not import, replace $z_m = 1$ and $\sigma^2_m = 0$ in equation (A-3), since the firm buys its intermediate input at a constant $z(i) = 1$.

For a nonexporter that imports, the domestic sales expand to

$$r_d^{nm}(\cdot) \approx r_d^{nm}(\beta_i, A_d, z_m) + \frac{\partial r_d^{nm}(\beta_i, A_d, z_m)}{\partial z_m}(z_m - \bar{z}_m)$$  \hspace{1cm} (A-4) \\
+ \frac{\partial r_d^{nm}(\beta_i, A_d, z_m)}{\partial A_d}(A_d - \bar{A}_d)  \hspace{1cm} (A-5)

with variance

$$Var(r_d^{nm}) = \left(\frac{\partial r_d^{nm}(\beta_i, A_d, z_m)}{\partial z_m}\right)^2 \sigma^2_m + \left(\frac{\partial r_d^{nm}(\beta_i, A_d, z_m)}{\partial A_d}\right)^2 \sigma^2_A$$  \hspace{1cm} (A-6)

and coefficient of variation

$$cvo(r_d^{nm}) = \frac{\sqrt{VAR(r_d^{nm})}}{r_d^{nm}(A_d, \beta_i, \bar{z}_m)}$$ \hspace{1cm} (A-7)

To generate the corresponding coefficient of variation for the domestic sales $r_d^{nm}(\beta_i, A_d)$ for a firm that neither exports nor imports, replace $z_m = 1$ and $\sigma^2_m = 0$ in equation (A-7), since the firm buys its intermediate input at a constant $z(i) = 1$.  

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A-2. Proof of Lemma 3.2

Applying the delta method to compute the coefficient of variation of the domestic sales (A-1) of a firm that does not export we obtain

\[
cvo(r^n_d(i)) \approx \sqrt{\left(\frac{\bar{A} d \nu + \gamma \bar{z}(i) + \nu + \gamma (\bar{A} d - \beta i - \bar{z}(i))}{\bar{A} d \nu + \gamma \bar{z}(i) + \nu \bar{A} d + \gamma \beta i} \right)^2} \sigma_d
\]

\[+ \sqrt{\left(\frac{-\gamma \bar{A} d - \gamma \bar{z}(i) - \nu \bar{A} d - \gamma \beta i + \gamma (-\bar{z}(i) + \bar{A} d - \beta)}{\gamma \bar{A} d + \gamma \bar{z}(i) + \nu \bar{A} d + \gamma \beta i} \right)^2} \sigma_{mi}
\]

where \(\bar{z}(i) = \bar{p}_m, \sigma_{mi} = \sigma_m\) if firm \(i\) imports and \(\bar{z}(i) = 1, \sigma_{mi} = 0\) if firm \(i\) does not.

Suppose \(\sigma_m = 0\). Taking the derivative of A-8 with respect to \(\bar{z}(i)\), we obtain

\[
\left[4 \gamma \nu \bar{A} d \bar{z}(i) - 2 \nu \gamma \bar{z}(i) \beta_i\right] + 4 \nu \nu \bar{A} d \beta_i + \nu \nu [\bar{A}^2_d - \bar{z}(i)^2 - \beta_i^2] + 4 \nu^2 \bar{A} d \bar{z}(i) + 4 \gamma^2 \bar{A} d \beta_i + \nu^2 \bar{A}^2_d
\]

\[
\left(\gamma \bar{A} d + \gamma \bar{z}(i) + \nu \bar{A} d + \gamma \beta i\right)^2 \left(\bar{z}(i) - \bar{A} d + \beta_i\right)^2 > 0
\]

because \(4 \gamma \nu \bar{A} d \bar{z}(i) - 2 \nu \gamma \bar{z}(i) \beta_i > 0\) and \(\bar{A}^2_d - \bar{z}(i)^2 - \beta_i^2 > 0\). Since \(\bar{z}(i)\) is lower if \(i\) imports, importing results in lower domestic sales volatility.

A-3. Proof of Lemma 3.4

1. Compare the domestic sales of the exporter (6) to the domestic sales of the nonexporter (3). If \(\nu = 0\), then the sales of the exporter are the same as the sales of the nonexporter, which is not a function of \(A_f\).

2. (a) To show that exporting decreases the expected domestic sales if \(\nu > 0\), subtract the domestic sales of the exporter (6) from the domestic sales of the nonexporter (3). Then \(r^n_d(i) - r^n_d(i')\) equals

\[
\kappa \nu L \frac{2(\beta_i + \bar{z}(i)) \gamma (4 \gamma + (2 + L) \nu) + \nu (A_f L (2 \gamma + \nu) + A_d (4 \gamma + (2 + L) \nu))}{4 \gamma (2 \gamma + \nu)^2 (2 \gamma + \nu + L \nu)^2}
\]
where \( \kappa = (A_f \nu - A_d \nu - 2(\beta_i + z(i))\gamma + 2A_f \gamma) > 0 \) by the assumption of positive exports in equation (4). Therefore the exporter realizes lower sales on the domestic market than the nonexporter for all realizations of demand. This implies \( E(r_d^x(i)) > E(r_d^x(i')) \).

(b) An increase in the demand on the foreign market is captured by an increase in the reservation price \( A_f \) or an increase in the population \( L_f \).

To examine the impact of an increase in \( L_f \) on the domestic sales take the derivative, \( \frac{dE(r_d^x(i))}{dL} = -\nu \kappa \left( \frac{A_f L_f^2 + 2 \gamma \beta + 2 \gamma z + A_d \nu}{(2 \gamma + \nu + \nu L)} \right)^2 < 0 \). Since \( \frac{dE(r_d^x(i))}{dL} < 0 \), \( \frac{dE(r_d^x(i))}{dA_f} = -\frac{\bar{A}_f L_f^2 + 2 \gamma \beta + 2 \gamma z + \bar{A}_d \nu}{2(2 \gamma + \nu + \nu L)^2 \gamma} < 0 \).

(c) From Equation (9b), \( \frac{dE(r_d^x(i))}{d\sigma_f} = -L_f^2 \nu^2 \sigma_f + L_f \nu \rho \sigma_d \). If \( \nu = 0 \), it’s straightforward to see that \( E(r_d^x(i)) = 0 \). On the other hand, if \( \nu > 0 \) and \( L \sigma_f > -\nu \rho \sigma_d \), then \( \frac{dE(r_d^x(i))}{d\sigma_f} < 0 \).

**A-4. Example where domestic sales volatility is lower for exporters**

The main text provided an example where cost linkages lead to higher domestic sales volatility for exporters than for non exporters. Here we present an example where cost linkages lead to lower domestic sales volatility for exporters. Assume \( \sigma_f = \sigma_m = 0 \) and \( L_f \) is large enough such that \( \gamma / L_f \approx 0 \). Exporters will then supply until the marginal revenue in the domestic market equals \( A_f \), garnering domestic sales \( r_d^x(i) = \frac{A_d^2 - A_d^2}{4\gamma} \). Using the Delta method, the variance of the domestic sales is approximated as \( \text{VAR}(r_d(i)) = \left( \frac{\partial r_d(i)}{\partial A_d} \right)^2 \sigma_d^2 \), where \( \frac{\partial r_d(i)}{\partial A_d} \) is evaluated at \( \bar{A}_d \). Thus, the coefficient of variation is approximated as \( \text{cvo}(r_d(i)) = \left( \frac{\partial r_d(i)}{\partial A_d} \right) \frac{\sigma_d}{E(r_d(i))} \). The difference between the coefficient of variation between an exporter and a non exporter is expressed as

\[
\text{cvo}(r_d^x) - \text{cvo}(r_d^n) = \frac{\sigma_d}{E(r_d^x(i))} \frac{\partial r_d^x(i)}{\partial A_d} - \frac{\sigma_d}{E(r_d^n(i))} \frac{\partial r_d^n(i)}{\partial A_d}
\]
where
\[
\frac{\partial r^x_d(i)}{\partial A_d} = \frac{\bar{A}_d}{2\gamma},
\]
\[
\frac{\partial r^n_d(i)}{\partial A_d} = \frac{\bar{A}_d(2\gamma + \nu) + (\bar{A}_d - \beta_i - z(i))\nu}{(2\gamma + \nu)^2}.
\]

Substituting the domestic sales of exporters from above and the domestic sale of nonexporters from equation 9a, we obtain
\[
cvo(r^x_d) - cvo(r^n_d) = \frac{2\bar{A}_d\sigma_d}{\bar{A}_d^2 - \bar{A}_f^2} - \frac{(\bar{A}_d(2\gamma + \nu) + (\bar{A}_d - \beta_i - z(i))\nu)\sigma_d}{\bar{A}_d^2(\gamma + \nu) - \nu(\beta + z(i))(A_d - (\beta + z(i))^2\gamma + \sigma_d^2(\gamma + \nu))}
\]

By eliminating some terms in the second fraction on the right hand side, we can show that
\[
cvo(r^x_d) - cvo(r^n_d) < \frac{2\bar{A}_d\sigma_d}{\bar{A}_d^2 - \bar{A}_f^2} - \frac{\bar{A}_d(2\gamma + \nu)\sigma_d}{\bar{A}_d^2(\gamma + \nu) + \sigma_d^2(\gamma + \nu)}
\]

Now, \(cvo(r^x_d) - cvo(r^n_d) < 0\) if
\[
\bar{A}_f^2 > \frac{\nu\bar{A}_d^2 + 2\sigma_d^2(\gamma + \nu)}{2\gamma + \nu}.
\]

Exporters will have lower domestic sales volatility than nonexporters if the foreign demand is very elastic compared to domestic supply and foreign demand is large enough to act as a sink for the exporter’s excess supply.

**A-5. Additional Robustness Checks**

Because not all firms are in the markets for all periods, variation in firm level variances may be driven by the number of observations available to compute firm level volatility. To account for this potential variation we augment our specifications.
with indicators for the number of observations used to calculate total and domestic volatility. These controls do not significantly change our results.

Mills and Schumann (1985) regress total sales volatility on various measures of firms size and industry specific volatility. We repeat this exercise and arrive at similar conclusions. For example, we add in industry output share as a measure of size.

We also augmented our main specifications with zip code indicators. We still found that exporters supply the domestic market at a volatility that is 24 percent greater than that of nonexporters. The identifying variation in these specifications is within zip codes and within industries and allows for a stricter version of our identification assumption: As long as firms that are located in the same zip code and supply the same industry are subject to the same level of aggregate demand volatility, a structural difference in the domestic supply volatility between exporters and nonexporters on the domestic market is evidence for a firm-level cost linkage. Firm size still has a negative and significant impact on the domestic supply volatility.

We also augmented our specifications with additional input measures such as Capital per worker, energy per worker and material per worker. Including these additional input measures captures variation across firms in their average domestic sales and volatility that may be driven by systematic differences in the input structure. Including these additional controls did not change our conclusions with respect to import status, export status and the size of the firm.

Applying an alternative data source,\textsuperscript{24} experimenting with alternative measures of output and industry controls we find no significant difference in our results.

\textsuperscript{24}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. A regression of VAT sales on Account statistics output for the years 1994-2006 finds a marginal effect of 0.947 with a Std. Err of 0.00038.
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 differ in the third or fourth digit. The results from all the robustness checks are available upon request.

We also experimented with a measure of exchange rate volatility in our specifications. Including exchange rate volatilities does not change our conclusions.