VOLATILITY AND DIVERSIFICATION OF EXPORTS: FIRM-LEVEL THEORY AND EVIDENCE

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Abstract

We show using detailed firm-level Chinese data that, among small exporters, firms selling to a more diversified set of countries have more volatile exports, while the opposite holds among large exporters. This result, which stands in marked contrast to standard portfolio theory for small exporters, is robust to a wide array of specifications and controls. Our theoretical explanation for these observations rests on the presence of fixed costs of exports per destination and short-run demand shocks. In this setup, the volatility of a firm's exports depends not only on the diversification of its destination portfolio but also on whether it exports permanently to all markets. Among small exporters, a more diversified pool of destinations makes the firm more likely to export occasionally to some markets, thereby raising volatility. These results cast doubts on the commonly held belief that diversification must decrease volatility.

Key Words: Volatility, diversification, exports

JEL Classifications: F1

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1 Introduction

Exporting is a risky business. Selling on foreign markets exposes a firm to sources of risk — such as exchange rate fluctuations or trade policy changes — that it does not face at home. Imperfect knowledge of local conditions may also leave exporters more vulnerable to cost or demand shocks in foreign markets. A number of studies suggest that exports are more volatile than domestic sales (Vannoorenberghe, 2012) and that openness to trade — at least in some cases — raises the volatility of output at the level of sectors (di Giovanni and Levchenko, 2009) or countries (Rodrik, 1998).

Although selling to a foreign market may be risky, firms can export to more than one destination. If shocks to these destinations are imperfectly correlated, exports should appear relatively stable from the standard diversification effect of portfolio theory. So do firms with more diversified exports really have more stable exports? Our answer, based on a large sample of Chinese exporters, is no, or at least not unconditionally. We show that the standard diversification argument only applies to firms with large exports. For small exporters, on the other hand, a more diversified pool of destinations is associated with a higher export volatility, in sharp contrast to the standard argument. Our results therefore suggest that, among small firms, diversifying the export portfolio may have the unintended consequence of raising the volatility of exports, with potentially negative effects on long run performance.[1]

Our proposed explanation rests on two assumptions: (i) short-run demand on each market is firm-specific, stochastic, and uncorrelated across markets, and (ii) firms must pay a fixed cost per country to which they export.[2] In this setup, a firm only exports to a particular market in a given year if the realization of demand is high enough to cover the fixed costs. To make the intuition transparent, assume that there are only two export markets, A and B, that the firm sells on average *more* to A than to B,[3] and consider two cases. First, if demand is such that selling each year in both markets is profitable, a firm with a less concentrated export portfolio, i.e. with slightly higher sales on B and lower sales on A, would be less sensitive to destination-specific shocks and the volatility of its exports would be lower (*diversification effect*). Second, if a bad realization of demand in B does not allow to cover the fixed costs, exports to B fluctuate between positive values and zero, making them relatively volatile. In that

[1] See, for example, Juvenal and Monteiro (2013) on the negative link between volatility and productivity.

[2] These can also be interpreted as fixed costs of shipment. A recent literature (Alessandria *et al*., 2010; Hornok and Koren, forthcoming; Kropf and Sauré, 2014) has emphasized the importance of such costs, either through direct evidence or as a necessity to explain the lumpy shipment of goods to export markets.

[3] This may be due to country-specific preferences or to different market conditions (e.g. A is a larger country).

case, a firm with a less concentrated export profile, i.e. with slightly higher sales in B and lower sales in A, sells a higher fraction of its exports to a market where it has relatively volatile sales (*composition effect*). These two effects imply that the net impact of a more diversified destination portfolio on volatility is ambiguous and can be positive if the *composition effect* dominates the *diversification effect*. We show that the relative size of the two effects depends on the firm's size. The larger the exporter, the more likely it sells continuously to both markets. When comparing two large exporters with different Herfindahl indices, the *diversification effect* should therefore dominate the *composition effect*, generating a positive link between the Herfindahl index and volatility. Among small exporters, however, the likelihood of selling occasionally to B is relatively large, implying that the *composition effect* can dominate the *diversification effect*. In that case, a more diversified portfolio of destinations is associated with a higher volatility of exports among small exporters.

Our empirical analysis uses customs data on the universe of Chinese exporting firms from 2000 to 2006, matched with detailed balance sheet data from the Annual Survey of Industrial Firms. We show that the variance of a firm's export growth depends (i) negatively on its worldwide exports, (ii) negatively on the diversification of its export destination (Herfindahl index), and (iii) positively on the interaction between the two. These results, which are robust to a wide array of controls and dummies as well as to different measures of the main variables, are the basis for our claim. We also present evidence that the results are driven by the destinations to which firms only export occasionally, as suggested by our theory. We also test for different confounding factors, such as other sources of export dynamics (à la Albornoz *et al.*, 2012) or other dimensions of diversification (product diversification) and show that these do not drive the results. Although the lack of a strong instrument for firm-level export diversification prevents us from making a causal statement, we provide suggestive evidence that at least some of the channels through which reverse causality may run are unlikely to drive our results.

This paper contributes to the large literature which examines the link between international trade and the volatility of economic activity. The question — mostly addressed from a macroeconomic perspective — has received renewed attention after a stream of works showing that macroeconomic volatility has detrimental effects on growth (Ramey and Ramey, 1995) or development (Koren and Tenreyro, 2007). Early theoretical arguments by Newbery and Stiglitz (1984) recognize that international trade, by increasing volatility, may reduce welfare and a number of studies has examined the link between trade and volatility at the country or sector level (e.g. Rodrik, 1998; Easterly *et al.*, 2001; Bejan, 2006; di Giovanni and Levchenko, 2009). Caselli *et al.* (2014) show that, at the macroeconomic level, the diversification of sales across countries made possible by international trade can act as a source of stability.[4]

At the level of firms, the idea that export diversification should stabilize exports is not new but there is only scant research on the topic. A classical paper by Hirsch and Lev (1971) shows, based on a panel of 500 firms from the Netherlands, Denmark and Israel, that firms with more diversified exports have less volatile sales, in line with standard portfolio theory. A more recent study by Juvenal and Monteiro (2013) shows that the exports of Argentinian firms with more diversified exports are more stable. Since volatility can have a strong negative effects on firms and their development, a recent literature has looked at how diversification, through the implied decrease in volatility, can improve productivity (Juvenal and Monteiro, 2013), help to finance investment (Shaver, 2011) or improve profitability (Wagner, 2014).[5]

The rest of the paper is structured as follows. Section 2 describes the data and presents some preliminary empirical observations. Section 3 develops a simple theory that can explain the observed patterns and puts the link between volatility and diversification in perspective. Section 4 provides the main empirical results and a number of robustness checks and Section 5 concludes.

2 Export Market Diversification and Volatility: A First Look at the Firm-level Data

In this section we describe the data, provide the definition of the main variables and outline some preliminary facts on the link between the volatility of a firms' export sales and the diversification of its export destinations. Further exploration of the data and econometric evidence are presented in Section 4.

2.1 Data

We use detailed firm-level export transaction data from the Chinese Customs Trade Statistics (CCTS) Database maintained by the General Administration of Customs of China during the period of 2000-2006. All export transactions going through the Chinese customs from 1 January 2000 to 31 December 2006 are included. The value of this data set is mainly in the rich information it contains; most relevantly, it records firm identifier, dates of transaction, HS8 product code, value and quantity of goods, means of

[4]Note that our analysis is not inconsistent with these results as the positive link between diversification and volatility across small exporters has no direct implications for the aggregate relationship.

[5]Baum *et al.* (2013) show that firms with more diversified export destinations invest more in R&D, although their argument does not rely on the link with volatility.

transportation, as well as the destination (origin) of exports (imports).[6] For the purpose of this study, we aggregate exports for each firm by year, product (HS8 level), and export destination. We only keep firms that export in all years of our sample to ensure that the volatility of exports is based on a large enough number of observations. We focus on production firms only, and exclude companies which serve as middlemen in trade from the sample.[7] The resulting sample includes 23,822 firms, which contributed about 50% of China's total export sales during our sample period.

Since the Chinese customs data lack information on firms' production activities (e.g. employment, domestic sales or capital investment), we complement our analysis with a new dataset linking the customs transactions to firms' balance sheet information in the Annual Surveys of Industrial Firms (ASIF) of the National Bureau of Statistics (NBS) in China. The ASIF data include state-owned firms of all sizes and other firms with annual turnover exceeding 5 million yuan (equivalent to around 700 thousand U.S. dollars during that period) in the manufacturing sectors. We matched the observations in the CCTS customs data with those in the ASIF data using firm names and their key contact details such as postcode, legal person name, and telephone number as the identifier.[8] This leaves us with a sample of 8,387 matched firms exporting continuously from 2000 to 2006, accounting for 55% of export sales in the customs sample.

2.2 Volatility and diversification

We define the volatility of firm j's exports over the period as the variance of the growth rate of its exports (see Vannoorenberghe, 2012):

$$Vol_j = \sum_t \left(g_{jt} - \frac{1}{T} \sum_t g_{jt} \right)^2 , \tag{1}$$

and define g_{jt} as the mid-point growth rate of firm j's exports at t (see Davis *et al.*, 2006; Bricongne *et al.*, 2012):

$$g_{jt} = \frac{exports_{jt} - exports_{j,t-1}}{(exports_{jt} + exports_{j,t-1})/2}.$$

We choose the mid-point growth rate since it is has the advantage of being bounded and symmetric around zero, but our results are robust to using alternative definitions such as the log change in exports.

[6] See Wang and Yu (2012) and Upward *et al.* (2013) for further details of the description of the data.
[7] See Upward *et al.* (2013) for the procedures of how to identify these trading companies in the data we use.
[8] See Upward *et al.* (2013) for more details on the matching approaches.

To measure export market diversification, we compute a firm-level Herfindahl index defined as:

$$Herf_j = \sum_{i=1}^{N_j} \frac{X_{ji}^2}{\left(\sum_{i=1}^{N_j} X_{ji}\right)^2}, \tag{2}$$

where i denotes the export market, X_{ji} is the total value of exports from firm j to country i and N_j is the total number of (foreign) markets firm j exports to.[9] By definition, $Herf_j$ is between zero and one, with lower values indicating higher degrees of export market diversification. In extreme cases, a Herfindahl of zero means an infinitely large number of destinations with each of them sharing an infinitely small fraction of exports, and a Herfindahl of one represents single-destination exporters.

Table 1 provides extensive summary statistics for both samples: the Chinese customs sample (CCTS) (Columns 1-5) and the matched sample (Columns 6-10). These show a great degree of variation across firms with respect to export sales volatility and export market diversification. It is worth emphasizing that firms are relatively large since we only consider those which export in all years of our sample. The variation in diversification is also reflected in other indicators than the Herfindahl index. On average, a firm exports to 18 markets but the share is unevenly distributed with 70% of the export value going to the top destination. Some firms export only to a single market (Herfindahl of one) whilst some ship goods to almost every country (low Herfindahl). In comparison with the customs sample, the matched firms are on average bigger (measured by export sales), slightly more volatile, and more diversified in export destinations (measured by Herfindahl index, share of top export destination, and number of destinations). However, the two samples have similarly large standard deviations in all these variables, thus ensuring sufficient variations for econometric identification.

2.3 Relationship between volatility, diversification, and firm size

Before turning to a full-fledged econometric analysis of the link between export volatility and diversification, we provide a graphical account of this relationship at the firm-level in Figure 1. We plot the average volatility of firms in the CCTS sample by decile of the Herfindahl index (with industry-province-ownership[10] effects removed) for three size categories (defined as export sales): large, medium, and small.[11] The most striking pattern emerging from Figure 1 is that the volatility-diversification relation

[9]The paper concentrates on the diversification of exports across destination markets We present some results on the relationship between volatility and product diversification in Section 4.3.

[10]Ownership refers to whether the firm is state-owned, foreign-owned or a private domestically-owned firm.

[11]Firm size categories are defined according to the firms export sales relative to the top and bottom third sales quantiles within corresponding industry-province-ownership cell.

Table 1. Summary of the data

	CCTS					Matched CCTS-ASIF				
	# Firms (1)	Mean (2)	SD (3)	Min (4)	Max (5)	# Firms (6)	Mean (7)	SD (8)	Min (9)	Max (10)
Log total export sales	23,822	16.1	1.8	7.2	24.3	8,387	17.0	1.6	7.2	24.3
Volatility	23,822	-2.9	1.4	-9.0	1.1	8,387	-2.1	1.3	-6.9	1.2
Herfindahl index	23,822	0.6	0.3	0.0	1.0	8,387	0.5	0.3	0.0	1.0
Share of top export destination	23,822	0.7	0.3	0.1	1.0	8,387	0.6	0.3	0.1	1.0
Number of destinations	23,822	18.5	20.7	1.0	174.0	8,387	20.8	19.6	1.0	157.0
Number of product-destination pairs	23,822	95.1	391.9	1.0	14,094.0	8,387	77.3	109.7	2.0	3,361.0
Log income of destinations	23,819	10.1	0.6	3.2	10.6	8,387	10.1	0.5	5.5	10.6
Volatility of destinations	23,819	-8.1	0.9	-11.5	-2.6	8,387	-8.1	0.9	-11.5	-2.6
Log sales						8,387	18.0	1.3	15.3	24.8
Log employment						8,387	5.8	1.1	2.2	10.6
TFP						8,387	4.7	0.9	0.6	8.5
Log age						8,354	1.8	0.7	0.0	5.0
Log wage						8,387	9.5	0.5	7.3	12.0
Log capital intensity						8,387	3.7	1.3	-2.5	8.9
Leverage ratio						8,387	0.5	0.2	0.0	5.0
Average export growth rate						8,387	-0.1	0.3	-1.2	1.2

Note. This table provides summary statistics for firms in the CCTS sample (Columns 1-5) and firms in the matched sample (Columns 6-10). Volatility is measured as log of squared deviation in export growth rate from firm's own average across the sample period. Herfindahl index is the sum of the squared shares of sales by each export destination. Income of destinations is the average real GDP per capita measured in US dollars in 2003 across destinations weighted by share of exports. Volatility of destinations is the log of average variation of real GDP growth rate across destination markets weighted by share of exports. TFP is constructed using Levinson-Petrin method and taken out of the industry mean. Age is the length of firm's operating years since opening. Wage is average wage paid per work. Capital intensity is net fixed asset per worker. Leverage ratio is debt-asset ratio. Average growth rate is the average annual growth rate of export sales over the sample period. Products are defined as HS6 (1996 version) categories.

can be either positive or negative, depending on firms' size category. For large exporters (firms with large exports), volatility decreases monotonically when the Herfindahl index declines, indicating that firms' export sales become less volatile when their export market profiles are more diversified (less concentrated). For small exporters, on the other hand, the volatility of exports increases when the Herfindahl index decreases, suggesting a positive association between diversification and volatility. For medium-sized exporters, volatility does not seem to vary by the degree of diversification. This indicates that the size of firms' exports plays a crucial role in the firm-level volatility-diversification relation, which, to the best of our knowledge, has not been reported before in the literature. We will provide a more thorough econometric investigation of this relationship in Section 4.

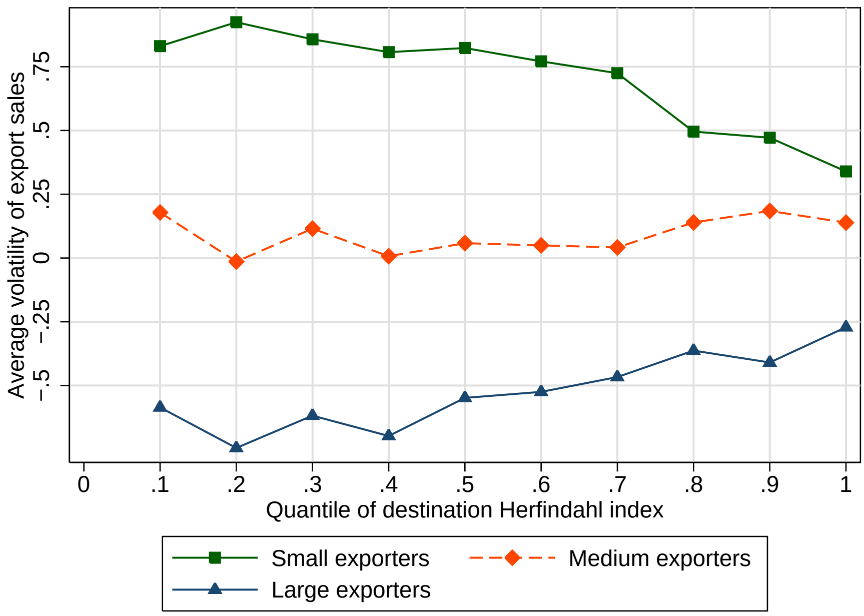

Figure 1. Volatility and diversification. Export volatility is measured as log of squared deviation in export growth rate from firm's own average. Quantiles of the Herfindahl index are defined on the whole population of firms. Firm size category is defined according to the firm's exports (averaged over years) relative to the 1/3 and 2/3 quantiles of its corresponding industry-province-ownership cell. Volatility and Herfindahl index are removed of industry, province, and ownership effects. Source: China Customs Trade Statistics (CCTS) Database.

It also appears from Figure 1 that small exporters exhibit higher degrees of export volatility than medium-sized exporters, which in turn have more volatile exports than large exporters. In other words, the volatility of exports is on average lower for larger exporters. It is however worth noting that the volatility differential between the different size groups decreases with the level of concentration of exports (i.e. with the Herfindahl index).[12] The result that firms exporting more have less volatile exports is in line with Vannoorenberghe (2012), who shows that the volatility of exports is decreasing in the export

[12]For example, for Herfindahl index within the first quantile (0.1), the volatility difference between small and large firms is around 1.25 (0.75-(-0.5)), whilst the discrepancy declines to 0.52 (0.27-(-0.25)) for the Hef index within the 10th quantile (1).

openness, and echoes the standard result that larger firms have less volatile sales (e.g. Buch *et al.*, 2009; Kelly *et al.*, 2013).

3 Theory

Before we turn to a detailed econometric analysis of the relationship between export size, diversification and volatility, the present section develops a stylized model helping to think about this relationship in a more systematic way. We show in the context of this model how the patterns observed in Figure 1 can arise. Although we concentrate on a model with two export markets for simplicity, we show in the Appendix using simulations that the reasoning extends to a setup with many countries.

3.1 Setup

We consider firms located in a Home country, which can export to two markets: market 1 and 2. Firms produce using exclusively labor at a wage normalized to one. Each firm draws a productivity parameter φ which captures the units of output produced per unit of labor:

$$y = \varphi l. \tag{3}$$

Firms, indexed by j, face an inverse demand function for their product in market $i \in \{1,2\}$ at time t given by:

$$p_{jit}(q) = (\zeta_{jit}\chi_{ji})^{\frac{1}{\sigma}} q^{-\frac{1}{\sigma}}, \tag{4}$$

where σ is the price elasticity of demand. The price that firm j obtains depends on the quantity it sells and on two exogenous demand parameters. The first, χ_{ji}, is time invariant and firm-specific and captures the long run differences in taste or market conditions faced by different firms on different markets.[13] The second, ζ_{jit}, is a time-varying idiosyncratic shock to the demand for firm j's product on market i at time t. For simplicity, we assume that the ζ_{jit} are drawn independently from the same distribution across firms and markets:

$$\zeta_{jit} = \begin{cases} \bar{s} & \text{with probability } \frac{1}{2}, \\ \underline{s} & \text{with probability } \frac{1}{2}. \end{cases} \tag{5}$$

[13] See Vannoorenberghe (2012). χ_{ji} consists of idiosyncratic shocks to the firm as well as of the price index in i and the size of market i. We take a partial equilibrium perspective for simplicity and do not explicitly solve for the price index in each country. Doing so would have no effect on the analysis.

Selling on market i requires the payment of a fixed cost of exporting f. Firms decide whether to export after the realization of the time-varying shock ζ_{jit}. Maximizing profits with respect to q, gives the optimal export sales of firm j on market i ($x_{jit} = p_{jit}q_{jit}$) as a function of the demand shock:

$$x_{jit} = \begin{cases} \sigma\zeta_{jit}\lambda_{ji} & \text{if } \zeta_{jit}\lambda_{ji} > f, \\ 0 & \text{otherwise,} \end{cases} \tag{6}$$

where $\lambda_{ji} \equiv (\sigma-1)^{\sigma-1}\sigma^{-\sigma}\chi_{ji}\varphi^{\sigma-1}$ is larger the more productive the firm and the higher the demand for its product on market i. A firm only exports to a market at time t if the variable profits are sufficient to cover the fixed costs of export to that market.

It is worth emphasizing at this stage how our setup compares to the existing literature on the choice of export destinations by firms (e.g. Eaton *et al.*, 2011, among others). As in this literature, our firms decide optimally on the set of destinations to which they export by comparing their variable profits to the fixed costs of selling on a market.[14] In our model, however, firms face short-run demand shocks on export markets, which leads some of them to export only occasionally to a destination (j exports occasionally to i if $\lambda_{ji}\underline{s} < f < \lambda_{ji}\bar{s}$). Our analysis will therefore concentrate on the volatility of exports arising from demand shocks *given the firms' choice of destinations* to which they regularly (i.e. occasionally or permanently) export.[15] We compare our perspective to the literature on short-lived export spells or sequential exporting (Besedes and Prusa, 2011; Albornoz *et al.*, 2012), in which the set of markets to which a firm regularly exports changes, in Section 3.3.

3.2 Volatility and Herfindahl

Since a firm faces a stochastic demand on its export markets, its total exports ($x_{jt} = x_{j1t} + x_{j2t}$) are time-varying. We denote the expected value of firm j's exports to market i as $X_{ji} = E_t[x_{jit}]$, its expected total exports as $X_j = X_{j1} + X_{j2}$, and the variance of its exports to market i as VAR_{ji}. The volatility of a firm's

[14] Although firms take the demand parameter on each market as given in the current setup, our model easily extends to a case where firms perform a market-specific investment to raise the demand for their product (χ_{ji}) as in Arkolakis (2010). This additional margin endogenizes the level of exports on each market - and therefore the diversification of sales across markets - but comes with substantial complexity for little additional insight.

[15] The long-term choice of destinations in which the firm exports - which is the one typically considered by the literature - can be made more explicit by assuming that, at stage 0, a firm pays a sunk cost of export f_e to each market where it wants to export. The firm therefore "enters" a market and pays f_e if the expected profits of selling on the market are sufficient to cover the sunk costs. The set of markets in which the firm is active in the long run is those markets where it paid f_e, while the markets where it actually sells in a given period are markets where $\zeta_{jit}\lambda_{ji} > f$.

total exports is the squared coefficient of variation of x_{jt}:

$$V_j = \frac{VAR_{j1} + VAR_{j2}}{X_j^2}, \tag{7}$$

where we make use of the assumption that shocks to market 1 and 2 are uncorrelated.[16] The use of the coefficient of variation as a measure of volatility has the advantage to be size independent and can be thought of as an approximation of the variance of the growth rate of exports which we use as our empirical counterpart to volatility (Vol_j in (1)). The extent to which a firm j's exports are concentrated in a particular destination is captured by the Herfindahl index of exports, which we define as:

$$Herf_j = \frac{X_{j1}^2 + X_{j2}^2}{X_j^2}. \tag{8}$$

Keeping expected total exports (X_j) constant and totally differentiating (7) and (8) shows the following link between the volatility and the Herfindahl of exports for a given size:

$$\frac{\mathrm{d}V_j}{\mathrm{d}Herf_j} = \frac{1}{2(X_{j1} - X_{j2})}\left(\frac{\mathrm{d}VAR_{j1}}{\mathrm{d}X_{j1}} - \frac{\mathrm{d}VAR_{j2}}{\mathrm{d}X_{j2}}\right). \tag{9}$$

Considering two firms with the same total exports but marginally different Herfindahl indices, equation (9) shows that the export volatility of the two firms will differ if the variance of exports on a market is a non-linear function of the average exports on that market.[17] We now turn to a detailed analysis of (9) for different groups of exporters in our model. For simplicity, we will focus only on firms which always export and which sell at least in some periods to both markets,[18] i.e. we consider firms for which $\underline{s}\lambda_{ji} \geq f$ for at least one market and $\bar{s}\lambda_{ji'} \geq f$ on the other market. The first condition ensures that firm j always exports to i while the second guarantees that j sometimes exports to i'. Under these restrictions, there are two potential scenarios which we now turn to.

[16]Allowing for a positive partial correlation between shocks on the two markets would not change any of the qualitative results (see Appendix for a proof) but complicate exposition. Markets 1 and 2 can also be thought of as two groups of countries among which demand shocks are perfectly correlated. We address these issues empirically in Section 4.3.

[17]Note that, in the textbook case of portfolio theory, the variance of X is a quadratic function of the average X and a higher Herfindahl (lower diversification) raises volatility.

[18]Since our analysis concentrates on firms which always export, we do not consider firms which occasionally export to both markets, as they would not export in all years in our model. Firms which export permanently to one market and never sell to the other can easily be integrated and have a Herfindahl index of one.

(a) Continuous exporters to both markets

We first consider firms with $\lambda_{ji} > f/\underline{s}$ for $i = 1,2$. These have a combination of high enough productivity and/or high enough demand on both markets, such that they always find it profitable to export to both destinations. Firm j's average exports in market i (X_{ji}) and the variance of its exports to i (VAR_{ji}) are respectively given by:

$$X_{ji} = \frac{\sigma}{2}(\underline{s}+\bar{s})\lambda_{ji} \,, \tag{10}$$

$$VAR_{ji} = \frac{\sigma^2}{4}(\bar{s}-\underline{s})^2\lambda_{ji}^2 = \frac{(\bar{s}-\underline{s})^2}{(\bar{s}+\underline{s})^2}X_{ji}^2. \tag{11}$$

The volatility of exports of a firm exporting continuously to both markets (V^C) is, from (7), (10) and (11):

$$V_j^C = \mu Herf_j, \tag{12}$$

where $\mu \equiv (\bar{s}-\underline{s})^2/(\bar{s}+\underline{s})^2 < 1$ is the squared coefficient of variation of ζ_{jit}. The above equation implies that sales diversification is negatively associated with sales volatility, in line with the *diversification effect* of portfolio theory. Since VAR_{ji} is a quadratic function of X_{ji}, reducing exports to the larger market reduces the variance of exports much, while increasing exports to the smaller market raises the variance only moderately. From (9), it implies that the volatility of exports decreases.

(b) Firms occasionally exporting to one market

We then consider exporters with a relatively high demand in a market and a relatively low demand in the other, i.e. exporters with $\lambda_{ji} > f/\underline{s} > \lambda_{ji'} > f/\bar{s}$. Such firms always export to market i but only export to market i' if they receive a high enough demand shock there. The expected sales and the variance of sales on market i, where j continuously exports, are given by Equations (10) and (11), while on market i', they are:

$$X_{ji'} = \frac{\sigma}{2}\bar{s}\lambda_{ji'}, \tag{13}$$

$$VAR_{ji'} = \frac{\sigma^2}{4}\bar{s}^2\lambda_{ji'}^2 = X_{ji'}^2. \tag{14}$$

Two remarks are in order. First, the variance of sales on a market is a quadratic function of the average sales on that market, no matter if the firm exports occasionally (Equation (14)) or permanently (Equation (11)) to that market. Second, for a given average export X_{ji}, the variance of exports to i is larger if firm j exports occasionally to i than if it exports permanently to i. As evident from comparing (11) and (14), the variance differential between the two cases is stronger the larger the $\underline{s}$. If $\underline{s}$ is close to zero, a firm exporting permanently sells only very little when the demand shock is low, and is similar to an exporter selling only occasionally, which sells zero if demand is low. We plot the relationship between the variance of sales on a market and the expected sales on that market for a firm continuously exporting on market i and occasionally on market i' in Figure 2, where the distance between the two curves is a function of $\underline{s}$.

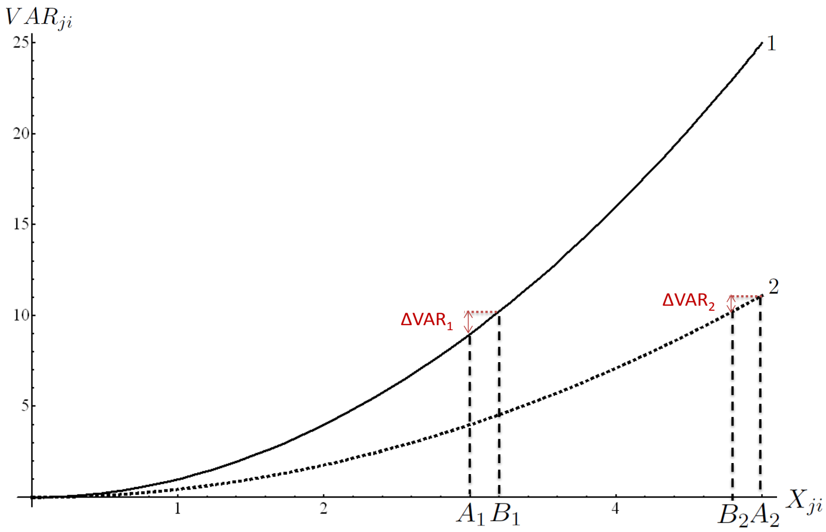

Figure 2. Variance of sales on a market as a function of expected sales on that market. Curve 1 shows the relationship for markets on which the firm exports occasionally (Equation (14)), while curve 2 shows the relationship for markets on which the firm always exports (Equation (11)). In this example, $\bar{s} = 1$, $\underline{s} = 0.2$. A_1 and A_2 are the average sales of firm A on markets 1 and 2 and such that $\sigma\lambda_{A1} = 6$, $\sigma\lambda_{A2} = 8.33$. B_1 and B_2 are the sales of firm B on markets 1 and 2. ΔVAR_i is the variance differential on market i between firms A and B.

We can now express the volatility of exports of a firm selling continuously to i and occasionally to i' (V_j^O) as a function of the Herfindahl index:[19]

$$V_j^O = \mu Herf_j + (1-\mu)\left(\frac{X_{ji'}}{X_j}\right)^2 = \frac{1}{(\bar{s}+\underline{s})^2}\left[Herf_j(\bar{s}^2+\underline{s}^2) - 2\bar{s}\underline{s}\sqrt{2Herf_j - 1}\right]. \qquad (15)$$

The first equality in (15) makes apparent that two forces determine V_j^O. The first ($\mu Herf_j$) is the standard *diversification effect*, captured by the Herfindahl index, which enters in an identical way to (12). The second ($(1-\mu)(X_{ji'}/X_j)^2$) shows that the volatility of exports depends positively on the share of sales going to the market where the firm sells occasionally (*composition effect*). Since sales to i' are relatively volatile compared to their size, a larger fraction of sales to i' for a given Herfindahl is associated with a

[19] To derive the second equality, rewrite the variance of sales on the continuous market (from (11)) as $X_{ji}^2\left[\frac{1}{2}(\mu+1)+\frac{1}{2}(\mu-1)\right]$ and use a similar decomposition for the variance on the market with occasional exports (from (14)). Plugging in (7), rearranging and noting that $2Herf_j - 1 = \left(\frac{X_{ji}-X_{ji'}}{X_{ji}+X_{ji'}}\right)^2$ gives (15).

higher volatility of exports. The second equality in (15) shows that the volatility can be written solely as a function of the Herfindahl index, where $\sqrt{2Herf_j - 1} > 0$. Differentiating Equation (15) with respect to $Herf_j$ shows that $\mathrm{d}V_j^O / \mathrm{d}Herf_j < \mathrm{d}V_j^C / \mathrm{d}Herf_j$ (see Appendix) and that $\mathrm{d}V_j^O / \mathrm{d}Herf_j$ can be negative as long as $Herf_j$ is not too large and $\underline{s}$ is not too small. The intuition behind this result can be best explained from (9). If a firm reallocates exports from its larger to its smaller market,[20] the volatility of its total exports will only rise if the increased variance of exports on the smaller market dominates the decreased variance of exports on the larger market. Two channels govern this relationship. First, due to the quadratic relationship between the variance and the average size of exports on a market (see (11) and (14)), the marginal decrease in volatility on the large market is relatively strong compared to the increased volatility on the small market, thereby decreasing the volatility of total exports. This *diversification effect* is therefore stronger the larger the difference in average sales on both markets (i.e. the larger the $Herf_j$). Second, the firm reallocates sales from a market where it exports continuously to a market where it exports occasionally (*composition effect*). The latter has a structurally (i.e. for any given level of average exports) higher variance and the variance differential between the two markets is increasing in $\underline{s}$. The *composition effect* is therefore more likely to dominate the *diversification effect* if $\underline{s}$ is large and the Herfindahl index is small. Figure 2 illustrates these effects comparing two firms, A and B, which export continuously to market 2 and occasionally to market 1 and have the same average worldwide exports. Denoting the average exports of A and B to $i \in \{1,2\}$ as A_i and B_i respectively, we assume that $A_1 < B_1 < B_2 < A_2$ and that $A_1 + A_2 = B_1 + B_2$. Firm B has more diversified sales, but sells a higher fraction of exports to market 1, making its worldwide exports more volatile.

The model developed in this section highlights a simple mechanism through which export diversification can increase the volatility of exports, namely by increasing the weight of markets to which a firm only exports occasionally. Since large exporters are likely to sell continuously to both markets, the *diversification effect* dominates when comparing the volatility of large exporters with different Herfindahl indices. Among small exporters, however, the weight of markets to which firms export occasionally is substantially larger, making it more likely that the *composition effect* dominates the *diversification effect* and that the relationship between the Herfindahl index and volatility turns negative. We provide a more formal discussion of this intuition in the theory appendix, and show using simulations that the mechanisms of the model extend to a setup with more than two countries.

[20]Market i is "large" from firm j's perspective if $\chi_{ji} > \chi_{ji'}$.

3.3 Discussion

(a) Empirical relevance and alternative channels

The simple model presented above is of course not the only possible mechanism generating a negative relationship between the Herfindahl index and the volatility of exports for small exporters. From (9), any channel making the variance of exports to market i (VAR_{ji}) a concave function of the average exports to i (X_{ji}) for small X_{ji} would be enough to generate the observed relationship between diversification and volatility.[21] A model with no fixed costs of exports could for example generate such a pattern if the variance of short-run shocks on a market was decreasing quickly with the average exports to that market.[22] Justifying such a relationship between export size and the variance of shocks would however require strong assumptions and violate some empirical features that our approach matches very strongly. In particular, Table A1 in the appendix tests that the main features of Figure 2 hold empirically. It confirms that, across all firm-destination pairs in our sample, the following two facts hold: (i) when controlling for X_{ji}, VAR_{ji} is decreasing in the number of years that the firm-destination pair is active (the empirical counterpart to the distinction between permanent and occasional exports in the model) and (ii) when controlling for the number of years in which $x_{jit} > 0$, VAR_{ji} is a convex function of X_{ji} with a power very close to 2, in line with (11) and (14). Furthermore, we emphasize the role of fixed costs of exports in the model since there is substantial evidence that these do play an important role on export markets. The fixed costs f are costs that firms have to incur per year and per country to which they actually ship and are in line with a growing literature pointing to the existence of substantial fixed costs of shipment to a market (see Alessandria *et al.*, 2010; Hornok and Koren, forthcoming; Kropf and Sauré, 2014).[23]

Finally, our explanation for the differential impact of the Herfindahl index on volatility among small and large exporters relies on the idea that the *composition effect* is stronger among small exporters. In other words, our theoretical explanation requires that (i) occasional exports to some destinations are more prevalent among small exporters and that (ii) a marginal increase in the Herfindahl index raises the prevalence of occasional exports more among small than among large exporters.[24] We look at these

[21] Note that the fixed costs of export are akin to introducing some degree of concavity around the point where a firm switches from being an occasional to a permanent exporter on a market.

[22] In terms of our notation, this would mean that $\bar{s}$ and $\underline{s}$ become a function of χ_{ji} such that $\partial(\bar{s}_{ji} - \underline{s}_{ji})^2/\partial\chi_{ji} << 0$ for small χ_{ji}. The rationale behind such an effect could be that firms selling more to a market have a less volatile consumer base or a better information on which consumers to target, generating more stable sales.

[23] Other theoretical contributions, such as Irarrazabal and Opromolla (2009) or Impullitti *et al.* (2013), also include per-period fixed costs of export.

[24] This can be seen formally from (27) in the Theory Appendix.

two assumptions in turn. First, Figure 3 plots the relationship between the size of a firm's exports and the share of destinations to which it sells for 1 to 7 years, where we think of the number of years as an empirical counterpart to the "continuity" of export flows in the model. As expected, larger exporters tend to sell longer to each of their destinations, i.e. occasional exports are less prevalent among large exporters. Second, we regress the average number of years in which a firm has positive exports to a market[25] on the Herfindahl index and an interaction of the Herfindahl with a dummy for each quintile of firms' export size. The results are reported in Table 2. The linear regressions (OLS) show that the Herfindahl index has a stronger marginal impact on the prevalence of occasional exports for small than for large exporters, and this result is robust to using Poisson pseudo-maximum-likelihood (PPML) estimation which deals with the problem that our dependent variable is bounded.

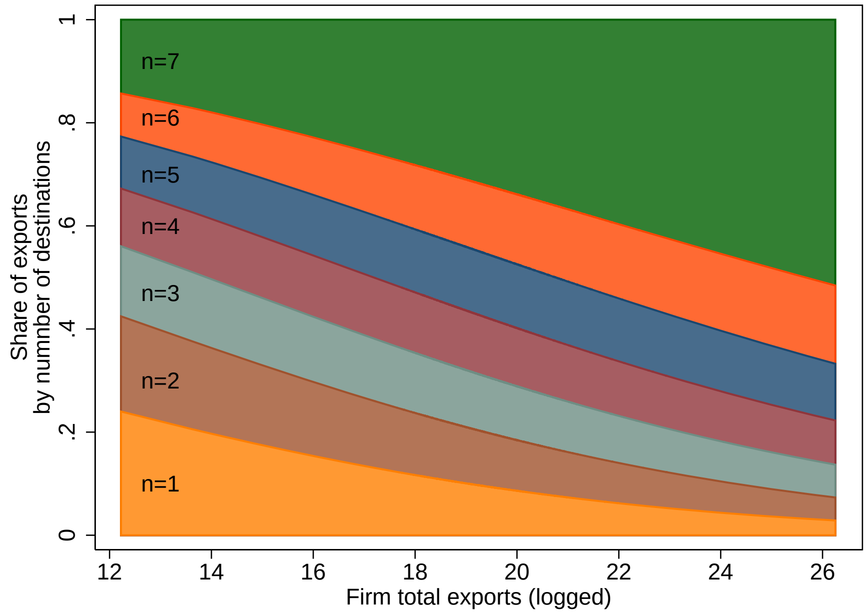

Figure 3. Firm size and export continuity. The y-axis depicts the share of destinations and the x-axis the log total exports of the firm. It shows, for different sizes of exporters, what is the share of destinations to which the firm exports only once (n=1), twice (n=2), etc.. Source: CCTS Database.

(b) Alternative interpretation: experimenting new destinations

The analysis in Section 3.2 takes a steady state perspective in the sense that firms have in each period the same probability of exporting to a given market. The period 2000-2006 is however a time of large export growth for China, in which many Chinese firms experimented new destination markets.[26] To understand the impact of these particular circumstances, we provide a simple extension of the theoretical setup.

[25] We compute the number of years in which firm j exports to i (n_{ji}) and use the weighted average: $\sum_i \frac{X_{ji}}{X_j} n_{ji}$ as the dependent variable.

[26] For example, on the balanced sample of continuous exporters present in our CCTS sample, the median number of destinations to which a firm exports grew from 3 in 2000 to 5 in 2006.

Table 2. Firm size and the composition effect

Dependent variable: weighted average number of years of exporting. Samples: CCTS and matched CCTS-ASIF.

	CCTS			Matched CCTS-ASIF		
	OLS (1)	OLS (2)	PPML (3)	OLS (4)	OLS (5)	PPML (6)
1(size≤20%)	3.764***	3.755***	1.388***	4.048***	4.060***	1.438***
	(0.025)	(0.025)	(0.007)	(0.036)	(0.042)	(0.011)
1(size>20% & size≤40%)	0.785***	0.842***	0.153***	1.011***	1.061***	0.196***
	(0.034)	(0.033)	(0.009)	(0.050)	(0.057)	(0.013)
1(size>40% & size≤60%)	1.314***	1.376***	0.250***	1.447***	1.452***	0.273***
	(0.033)	(0.032)	(0.009)	(0.050)	(0.057)	(0.013)
1(size>60% & size≤80%)	1.736***	1.836***	0.324***	1.717***	1.815***	0.318***
	(0.032)	(0.032)	(0.008)	(0.049)	(0.057)	(0.012)
1(size>80% & size≤100%)	2.228***	2.399***	0.405***	2.139***	2.214***	0.386***
	(0.031)	(0.032)	(0.008)	(0.049)	(0.057)	(0.012)
Herfindahl	3.233***	3.155***	0.565***	2.922***	2.882***	0.515***
	(0.035)	(0.035)	(0.008)	(0.060)	(0.069)	(0.014)
Herfindahl*1(size>20% & size≤40%)	-0.776***	-0.809***	-0.153***	-0.997***	-1.087***	-0.200***
	(0.049)	(0.048)	(0.011)	(0.082)	(0.090)	(0.016)
Herfindahl*1(size>40% & size≤60%)	-1.328***	-1.366***	-0.255***	-1.437***	-1.470***	-0.280***
	(0.048)	(0.047)	(0.010)	(0.082)	(0.089)	(0.016)
Herfindahl*1(size>60% & size≤80%)	-1.756***	-1.812***	-0.331***	-1.695***	-1.824***	-0.324***
	(0.048)	(0.048)	(0.009)	(0.081)	(0.090)	(0.015)
Herfindahl*1(size>80% & size≤100%)	-2.286***	-2.414***	-0.420***	-2.157***	-2.261***	-0.399***
	(0.048)	(0.048)	(0.009)	(0.083)	(0.090)	(0.015)
Province-industry-ownership dummies	No	Yes	Yes	No	Yes	Yes
# Observations	23,822	23,822	23,822	8,387	8,387	8,387
R-squared	0.478	0.600	0.474	0.448	0.734	0.446

Note. Columns 1-3 report results from the CCTS sample, and Columns 4-6 from the matched CCTS-ASIF sample. The dependent variable is the weighted average number of years of exporting, with the weight being the country's share in the firm's total export sales. The explanatory variables are dummies for firm size quintiles, Herfindahl index (defined as the sum of the squared shares of firms' exports in each destination), and their interactions. Industry dummy is proxied by the HS2 category which has the highest share in the firm's exports in Columns 2 and 3, and 4-digit GB/T industry code from the ASIF data in Columns 5 and 6. Robust standard errors are in parentheses, and superscripts *, **, *** indicate significance at 10%, 5%, and 1% levels respectively.

Assume that a firm does not know its demand parameter χ_{ji} on market i if it has never exported there (this assumption is similar to Albornoz *et al.* (2012)). In the first year where it does so, the firm needs to pay the fixed costs f before it observes χ_{ji} and the realization of ζ_{jit}. This means that the firm sells a positive amount on i (we assume $\chi_{ji} > 0$) if it decides to sell there for the first time. If firm j observes a high enough χ_{ji} on i (such that $f < \bar{s}\lambda_{ji}$), it subsequently behaves as an occasional or permanent exporter to that market as described in Section 3.2.[27] If firm j observes a low χ_{ji} ($f > \bar{s}\lambda_{ji}$), on the other hand, it exports $\zeta_{jit}\lambda_{ji}$ in the first year and never exports again. As shown in the theory appendix, this case is in many respects similar to the one developed in Section 3.2 and we show that firms with a higher Herfindahl index can have a lower volatility if $\underline{s}$ is large enough and if the Herfindahl index of the firm's exports is not too large. In both cases, it is because firms export only in some years to some destinations that a decrease in the Herfindahl index is associated with an increased export volatility

Although they generate similar predictions, the interpretation of the present extension fundamentally differs from the model developed in Section 3.2. In Section 3.2, a firm is active in a given set of countries[28] and, given this set, reacts to short-run shocks by adapting its sales to these countries. In particular, if there were no short-run shocks, the volatility of exports would be equal to zero. In the present section, however, the link between the Herfindahl index and the volatility of exports comes from a temporary change in the set of markets to which the firm sells. In other words, the volatility of exports would be positive even if there were no short-run shocks, and the relationship between the Herfindahl and the volatility of exports has little to do with what we understand as diversification. We distinguish these two interpretations empirically in Section 4.

4 Econometric Evidence

In this section, we provide an econometric test of the relationship between the volatility and diversification of export sales pictured in Figure 1. In a first step, we show that the patterns highlighted in Figure 1 hold for a wide array of controls, specifications and definitions in different samples. In a second step, we provide some evidence on the importance of destinations to which firms occasionally export for the

[27] Strictly speaking, the exports in the first year may differ from the analysis in Section 3.2 if the firm draws the short run shock $\underline{s}$ and has χ_{ji} and φ such that $\underline{s}\lambda_{ji} < f < \bar{s}\lambda_{ji}$. In all subsequent years, however, the firm behaves as previously described and the variance and expected sales on i converge to their values in (13) and (14) as the number of years of observation increases.

[28] A firm is "active" on a market if its long-run demand parameter is such that it sells a positive amount for some values of the short run demand shocks.

relationship between diversification and volatility, as suggested by the theory. In a third step, we examine other potential channels which could generate the observed relationship, and discuss in particular the issues of reverse causality, export dynamics and product diversification.

4.1 Baseline specification

The baseline specification of our empirical analysis is:

$$Vol_j = \beta_0 + \beta_1 Herf_j + \beta_2 Size_j + \beta_3 Herf_j \times Size_j + \gamma\Theta_j + d_r + d_s + d_o + \varepsilon_i, \quad (16)$$

where Vol_j is the volatility of firm j's export sales (as defined in (1)), $Herf_j$ is the Herfindahl index of the firm's export market destinations (see (2)) and $Size_j$ is the log of firm j's average worldwide exports over the period. We also include province (d_r), industry (d_s), and ownership (d_o) dummies to control for any omitted region, industry, and ownership specific effects. Θ_j is a vector of firm-level characteristics which may affect the volatility of firms' exports and be correlated with some of our variables of interest. First, we control for the average income of the destination countries to which firm j exports as well as the average variance of GDP in these countries.[29] Firms exporting to richer or less volatile countries may have less volatile exports and could differ systematically in terms of size or diversification. Second, when using the matched sample, we control for a wide range of firm-level balance sheet items such as the total (including domestic) sales of the firm, its TFP, age, employment, wage, capital intensity, or leverage ratio (all of these in logs). It is worth emphasizing that we run Equation (16) on a cross-section of continuous exporters and that all controls are computed as averages over the period 2000-2006.

The results of the baseline estimations are reported in Table 3, where Columns 1-4 present the results using the customs sample without balance sheet controls while Column 5-8 are based on the matched sample and include a full set of firm-level balance sheet controls. Interestingly, the main coefficients of interest (β_1, β_2, β_3) confirm the pattern observed in Figure 1. The coefficient on the Herfindahl index (β_1) is negative and significant, showing that for small exporters (firms with low exports), more diversification of export destinations is associated with a higher volatility of exports. This result, which goes against standard portfolio theory, is in line with the downward slope of the upper curve in Figure 1. The coefficient β_2 on size is negative, reflecting that firms exporting more have on average more stable exports. The negative relationship between the volume and the volatility of exports at the firm level, as

[29] Details on the construction of these variables are available in the Data Appendix.

highlighted in Section 2.3, is in line with the literature. The positive coefficient β_3, on the interaction between the Herfindahl index and the size of exports, shows that the marginal effect of the Herfindahl on the export volatility is increasing in the export volume. The firm size threshold (proxied by the log of export sales) for the overall Herfindahl-volatility association to turn positive is 19.5 (i.e. 1.654/0.085) in log terms in the most restrictive specification with full firm-level controls (Column 8), which lies below the upper bound of firm level export sales (24.3 in Table 1). In other words, more diversification, i.e. a lower Herfindahl index, is associated with a higher export volatility for small exporters, and with a lower (although mostly insignificant) export volatility for large exporters. As shown in Section 3, and as is well-known from the literature (Melitz, 2003), the productivity of a firm is an important determinant of its export sales. Columns 9-12 of Table 3 show that the results are similar when using a firm's total factor productivity instead of its total exports as a measure of size. The main difference is that the negative association between the Herfindahl index and volatility is weaker among low TFP firms than among small exporters. On the other hand, among productive exporters, more diversified exports are strongly associated with a lower export volatility, in line with the diversification effect.

The estimated coefficients on the other controls are as expected from the literature: more experienced (older), more skill-intensive (higher-wage), and better financed (lower leverage ratio) firms have less volatile exports. Controlling for log exports ($Size_i$), firms with higher total sales (exports plus domestic sales) have a higher volatility of exports, in line with Vannoorenberghe (2012). Firms exporting to high income countries have lower export volatility, while the direct control for destination volatility is insignificant. Finally, the average growth of exports over time is very positive and significant, and captures the fact that faster growing firms are mechanically more volatile. The coefficients of interest are virtually unaffected by the inclusion of the average growth rate.

Correlation between size and Herfindahl. One concern with the above regression is that our measures of diversification and firm size may be correlated, since large firms are more likely to have a diversified sales profile. This is confirmed in a simple correlation analysis which shows that the Herfindahl index and and the log export sales indeed are negatively correlated at the 1% significance level in both the customs and the matched samples. Note, however, that the correlation is only imperfect, with the correlation coefficient being -0.18 and -0.07 in the the customs and the matched samples, respectively. As can be seen in Table 4, the Herfindahl index is not too unevenly distributed for each firm size category. Particularly, there is a nontrivial proportion of large firms which exhibit high Herfindahl index (highly

Table 3. Baseline results: volatility and diversification.

Dependent variable: volatility of export sales. Samples: CCTS and matched CCTS-ASIF.

	CCTS				Matched CCTS-ASIF							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Herfindahl	-1.741***	-1.867***	-1.676***	-1.786***	-1.279***	-1.747***	-1.215***	-1.654***	-0.303***	-0.324***	-0.091*	-0.109
	(0.239)	(0.264)	(0.240)	(0.266)	(0.439)	(0.604)	(0.439)	(0.606)	(0.049)	(0.068)	(0.052)	(0.072)
Herfindahl*Exports	0.077***	0.085***	0.076***	0.084***	0.063**	0.088**	0.061**	0.085**				
	(0.015)	(0.016)	(0.015)	(0.017)	(0.026)	(0.035)	(0.026)	(0.035)				
Herfindahl*TFP									0.126**	0.167**	0.135**	0.163**
									(0.061)	(0.083)	(0.060)	(0.083)
Exports	-0.390***	-0.402***	-0.388***	-0.400***	-0.533***	-0.571***	-0.528***	-0.564***				
	(0.009)	(0.010)	(0.009)	(0.010)	(0.017)	(0.024)	(0.017)	(0.025)				
TFP									0.004	-0.008	-0.006	-0.017
									(0.044)	(0.063)	(0.043)	(0.063)
Log sales					0.296***	0.316***	0.294***	0.313***	-0.176***	-0.207***	-0.164***	-0.191***
					(0.016)	(0.022)	(0.016)	(0.022)	(0.021)	(0.029)	(0.021)	(0.029)
Log age					-0.177***	-0.139***	-0.176***	-0.137***	-0.148***	-0.141***	-0.148***	-0.130***
					(0.018)	(0.028)	(0.018)	(0.028)	(0.020)	(0.031)	(0.020)	(0.030)
Log wage					-0.035	-0.093**	-0.033	-0.093**	-0.020	-0.092*	-0.012	-0.084
					(0.033)	(0.046)	(0.033)	(0.046)	(0.039)	(0.055)	(0.039)	(0.055)
Log capital intensity					0.052***	0.059***	0.052***	0.057***	0.109***	0.135***	0.102***	0.121***
					(0.014)	(0.019)	(0.014)	(0.019)	(0.018)	(0.025)	(0.018)	(0.025)
Leverage ratio					0.443***	0.424***	0.440***	0.422***	0.509***	0.499***	0.495***	0.487***
					(0.062)	(0.075)	(0.062)	(0.075)	(0.068)	(0.083)	(0.068)	(0.082)
Income of destinations			-0.068***	-0.068***			-0.062**	-0.061			-0.253***	-0.283***
			(0.016)	(0.019)			(0.026)	(0.041)			(0.029)	(0.047)
Volatility of destinations			0.011	0.017			-0.014	0.000			0.091***	0.107***
			(0.011)	(0.012)			(0.017)	(0.024)			(0.018)	(0.027)
Average export growth rate			0.165***	0.190***			0.085**	0.108**			0.115***	0.141**
			(0.033)	(0.036)			(0.038)	(0.051)			(0.042)	(0.057)
Province dummies	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Industry dummies	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Ownership dummies	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Province-industry-ownership dummies	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
# Observations	23,584	23,584	23,581	23,581	8,271	8,271	8,271	8,271	8,271	8,271	8,271	8,271
R-squared	0.221	0.301	0.223	0.302	0.352	0.564	0.353	0.564	0.187	0.452	0.200	0.461

Note. Columns 1-4 report results from the CCTS sample, and Columns 5-12 from the matched CCTS-ASIF sample. The dependent variable is the export volatility measure, defined as log of squared deviation in export growth rate from firm's own mean averaged over the sample period. Exports is the log of firms' total export value averaged over years. TFP is constructed using Levinson-Petrin method and taken out of the industry mean. Age is the length of firm's operating years since opening. Wage is average wage paid per work. Capital intensity is net fixed asset per worker. Leverage ratio is total debt-asset ratio. Income of destinations is the average real GDP per capita in 2003 across destinations weighted by share of exports. Volatility of destinations is the log of average variation of real GDP growth rate across destination markets weighted by share of exports. Average growth rate is the average annual growth rate of export sales over the sample period. All other variables are defined as in the previous tables. Robust standard errors are in parentheses, and superscripts *, **, *** indicate significance at 10%, 5%, and 1% levels respectively.

concentrated), and a fraction of small firms with low Herfindahl index (highly diversified).

Table 4. Firm size, TFP, and diversification

		Herfindahl index			
		Low	Medium	High	*Total*
Panel A: Firm size and diversification (CCTS)					
Firm size	Small	14%	13%	11%	38%
	Medium	13%	12%	9%	34%
	Large	11%	10%	7%	28%
	Total	38%	35%	27%	100%
Panel B: Firm TFP and diversification (matched CCTS-ASIF)					
Firm TFP	Low	31%	13%	7%	51%
	Medium	13%	14%	6%	32%
	High	7%	6%	4%	17%
	Total	51%	32%	17%	100%

Note. Numbers reported denote percentage of observations in both the CCTS and the matched samples. Different firm groups are defined according to the tertiles of the distribution of firm size, TFP or Herfindahl index by province-industry-ownership cell.

4.2 Occasional exports to some destinations

Our model suggests that the observed volatility-diversification relationship obtains because some firms do not export continuously to some markets. As shown in Figure 4, there is a very large prevalence of non-continuous export flows at the firm-level and we now explore whether such flows drive the results of Table 3. For this, we replicate our analysis disregarding the exports of any destination to which a firm does not continuously export. For example, if a firm exports in all years to the U.K. and France, but only during five years to Germany, we re-compute the "worldwide" exports of that firm as the average sales to the U.K. and France over the period as well as a Herfindahl index and a volatility measure based solely on the firm's sales to France and the U.K.. The results of this exercise are reported in Columns 3 and 4 of Table 5, where the Herfindahl index has a positive and in Column 4 significant effect on volatility. The interaction between the Herfindahl index and size or TFP is now close to zero and insignificant. In other words, conditioning on markets to which it continuously exports, a firm with more diversified export destinations has if anything more stable export sales, in line with the *diversification effect*. This exercise confirms the role of markets to which firms export occasionally in explaining the diversification-volatility relationship and is in line with our theory.[30] Columns 5-8 of Table 5 conduct a similar exercise but keeping all markets to which a firm exports at least 6 years or at least 2 years. The observed patterns are consistent with our expectations: including destinations to which the firm exports less often makes

[30] In terms of the theory, this exercise is akin to comparing the observations located on the lowest curve in Figure 2 and preventing comparison across different curves.

the result more similar to our baseline results. In particular, the estimates confirm that our main results are not driven solely by destinations to which firms export only one year.

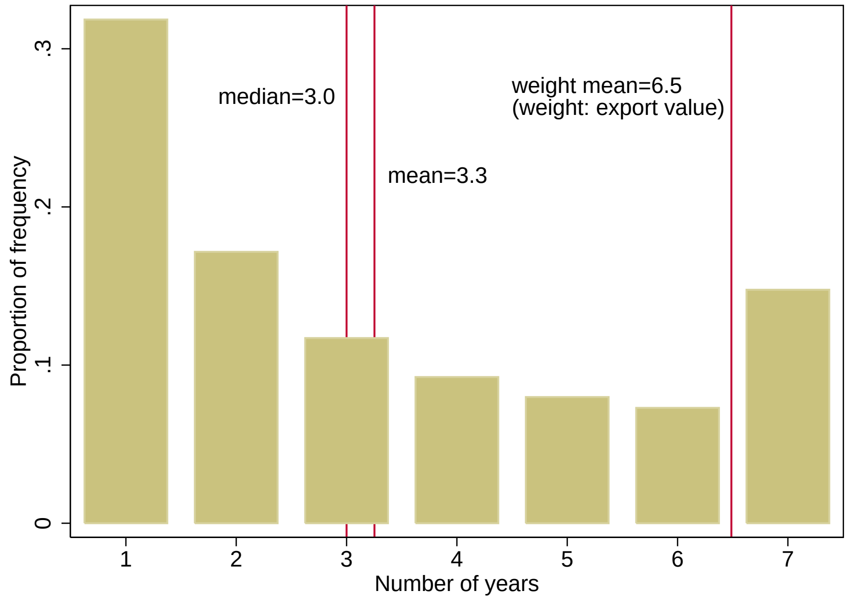

Figure 4. Distribution of number of years for which a firm exports to a destination. This figure shows the distribution of the number of years for which a firm-destination export value is positive. The y-axis is the proportion of the frequency. Source: CCTS Database.

4.3 Robustness and discussion

Market experimentation. As emphasized in the theory section, a firm that sells occasionally (i.e. not every year) to a market may do so because it tries its luck in a destination before permanently exiting it upon seeing that the demand for its product is too low. We assess the extent to which this behavior - which has little to do with diversification - drives the results through two tests.

In the first, we construct the size, Herfindahl and volatility of exports keeping only the destinations to which a firm continuously exports or to which it exports again after having stopped. In other words, we disregard the destinations to which a firm exports in successive years for less than seven years. The rationale is that, if a firm observes bad long-run demand conditions for its product (i.e. a low χ_{ji} as described in Section 3.3 (a)), it should not re-enter after exiting that market. By keeping markets to which a firm first had a sequence of positive sales, zero sales, positive sales again, we should capture the firms which are in line with the description of Section 3.2 (b).[31] The results, reported in the first two

[31]Note that we are taking a more restrictive approach than suggested by our theory. From Section 3.3, if a firm sees poor demand conditions on a market, it sells only one year there. In practice, obtaining the information about χ_{ji} may take more time, which is why a firm may export two or three years before realizing it should definitely exit. With this strategy, we also exclude markets to which the firm enters and starts selling continuously, thereby partialing out the role of growth in the set of markets more generally.

Table 5. Further tests of the model

Dependent variable: volatility of export sales. Sample: matched CCTS-ASIF.

	All markets		Always export (all years)		Exports $\geq$ 6 years		Exports $\geq$ 2 years	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Herfindahl	-1.654***	-0.109	0.876	1.338***	-0.177	1.063***	-1.242**	0.021
	(0.606)	(0.072)	(0.711)	(0.070)	(0.666)	(0.070)	(0.607)	(0.071)
Herfindahl*Exports	0.085**		0.007		0.051		0.065*	
	(0.035)		(0.040)		(0.038)		(0.035)	
Herfindahl*TFP		0.163**		0.008		0.124		0.146*
		(0.083)		(0.086)		(0.086)		(0.083)
Exports	-0.564***		-0.383***		-0.490***		-0.552***	
	(0.025)		(0.040)		(0.035)		(0.026)	
TFP		-0.017		-0.003		-0.048		-0.016
		(0.063)		(0.081)		(0.076)		(0.063)
Further controls: sales, age, wage, cap int, lev ratio, income & vol of destinations, avg export growth rate								
Province-industry-ownership dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# Observations	8,271	8,271	7,597	7,597	8,046	8,046	8,271	8,271
R-squared	0.564	0.461	0.545	0.502	0.552	0.488	0.562	0.461

Note. This table report results from the matched CCTS-ASIF sample. The dependent variable is the export volatility measure, defined as log of squared deviation in export growth rate from firm's own mean averaged over the sample period. Columns 1 and 2 repeat the baseline results (Columns 8 and 12, Table 3), Columns 3 and 4 present the results based on the set of markets to which firms always export (i.e. for 7 years), Columns 5 and 6 show the results for the set of markets to which firms export for at least 6 years, and Columns 7 and 8 show the results for the set of markets to which firms export for at least 2 years. The volatility measure (dependent variable) and Herfindahl index are adjusted accordingly depending on different subsets of markets. All other variables are defined as in the previous tables. Robust standard errors are in parentheses, and superscripts *, ** and *** indicate significance at 10%, 5%, and 1% levels respectively.

columns of Table 6, are similar to the baseline specification, suggesting that the observed relationship between volatility and diversification is not driven by the experimentation motive.

Second, we rerun the analysis using the beginning of sample value (year 2000) of the Herfindahl index and of export size. As emphasized in Section 3.3, if a firm is testing new markets over time, this will create a mechanical negative relationship between the Herfindahl index and the volatility of exports, which should however not be interpreted as the role of diversification on volatility. By taking beginning of sample values for the Herfindahl index and for export size, we very much reduce the risk that the results are driven by such a mechanical relationship. Columns 3 and 4 of Table 6 shows that results are unchanged.

These tests, together with the fact that we control for the average export growth rate and that the results hold when excluding markets to which firms export only one year (Columns 7 and 8 of Table 5) make us confident that the market experimentation channel does not drive the results.

Alternative measures. To check whether our results are sensitive to alternative measures of the main variables, we first re-estimate (16) using total employment or assets as a measure of size. We also experiment with alternative measures of diversification, such as the share of a firm's exports going to its top destination. The results, shown in Table 6, confirm our baseline estimates.[32] We also recompute the Herfindahl index of each firm's exports based not on the countries to which it exports but on 7 groups of countries: the European Union, NAFTA, ASEAN, Australasia, Africa, other OECD and other countries.[33] This exercise addresses the concern that demand shocks across markets are unlikely to be independent, in particular in neighboring countries. A firm exporting equally to France and Germany may therefore be thought of as less diversified than a firm exporting equally to France and Kenya, between which shocks are probably less correlated. A Herfindahl index based on regions and not countries takes care of the issue by assigning a Herfindahl of one to the first firm and a Herfindahl of 0.5 to the second, thereby taking into account the possible cross-country correlation of shocks. The results, reported in Columns 1-3 of Table 7, are very similar to our baseline estimates. Finally, we recompute the Herfindahl index and exports of firms dropping exports to Hong Kong. A substantial amount of Chinese

[32] Since a low Herfindahl index can result both from a high number of destination markets or from a more even split of sales for a given number of markets, we also investigate in unreported regressions whether controlling directly for the number of destinations a firm exports to and its interaction with size affects the results. The coefficients on the Herfindahl index and its interaction with size remains very similar, suggesting that our results also hold conditioning on the number of markets a firm exports to over the sample period.

[33] In other words, we recompute the Herfindahl index based on the share of exports of a firm going respectively to each of the 7 groups.

Table 6. Alternative measures of diversification and firm size

Dependent variable: volatility of export sales. Sample: matched CCTS-ASIF.

	Excluding experimental exporters		Size and diversification measured in 2000		Alternative measures of firm size		Alternative measures of diversification	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Herfindahl	-3.928***	-0.424***			-1.168***	-1.824***		
	(0.669)	(0.079)			(0.339)	(0.517)		
Herfindahl*Exports	0.199***							
	(0.039)							
Herfindahl*TFP		0.319***						
		(0.089)						
Herfindahl*Employment					0.178***			
					(0.057)			
Herfindahl*Asset						0.159***		
						(0.048)		
Share_top_dest							-1.889***	-0.084
							(0.687)	(0.083)
share_top_dest*exports							0.100**	
							(0.040)	
Share_top_dest*TFP								0.199**
								(0.096)
Herfindahl00			-1.055**	0.536***				
			(0.488)	(0.065)				
Herfindahl00*Exports00			0.072**					
			(0.030)					
Herfindahl00*TFP00				0.118**				
				(0.054)				
Exports	-0.657***						-0.582***	
	(0.028)						(0.030)	
TFP		-0.114*						-0.059
		(0.069)						(0.077)
Exports00			-0.407***					
			(0.025)					
TFP00				-0.058				
				(0.042)				
Employment					-0.372***			
					(0.046)			
Asset						-0.181***		
						(0.046)		
Further controls: sales, age, wage, cap int, lev ratio, income & vol of destinations, avg export growth rate								
Province-industry-ownership dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# Observations	8,195	8,195	8,271	7,950	8,271	8,271	8,271	8,271
R-squared	0.566	0.473	0.575	0.473	0.470	0.462	0.564	0.461

Note. This table report results from the matched CCTS-ASIF sample, excluding the subsample of experimental exporters or using alternative measures of export market diversification and firm size. The dependent variable is the export volatility measure, defined as log of squared deviation in export growth rate from firm's own mean averaged over the sample period. Columns 1 and 2 excludes experimental exporters as defined in Section 4.3. Columns 3 and 4 use size and diversification measures (variables with suffix "00") defined in the initial year (2000). Columns 5 and 6 use firm employment and total asset (both logged) as alternative measures of firm size. Columns 7 and 8 use export sales share of top destination market (Share_top_dest) as the measure of diversification alternative to Herfindahl index. All other variables are defined as in the previous tables. Robust standard errors are in parentheses, and superscripts *, **, *** indicate significance at 10%, 5%, and 1% levels respectively.

Table 7. Country groups and exclusion of Hong Kong

Dependent variable: volatility of export sales. Samples: CCTS and matched CCTS-ASIF.

	Country groups			Excluding the market of Hong Kong		
	CCTS (1)	CCTS-ASIF (2)	CCTS-ASIF (3)	CCTS (4)	CCTS-ASIF (5)	CCTS-ASIF (6)
Herfindahl	-1.864***	-1.657**	-0.143*	-0.960***	-0.867	0.073
	(0.316)	(0.699)	(0.080)	(0.277)	(0.688)	(0.083)
Herfindahl*Exports	0.086***	0.085**		0.037**	0.049	
	(0.020)	(0.041)		(0.017)	(0.040)	
Herfindahl*TFP			0.207**			0.138
			(0.097)			(0.091)
Exports	-0.408***	-0.572***		-0.393***	-0.534***	
	(0.014)	(0.030)		(0.011)	(0.027)	
TFP			-0.061			-0.038
			(0.076)			(0.068)
Further controls: sales, age, wage, cap int, lev ratio, income & vol of destinations, avg export growth rate						
Province-industry-ownership dummies	Yes	Yes	Yes	Yes	Yes	Yes
# Observations	23,581	8,271	8,271	21,032	7,565	7,565
R-squared	0.302	0.564	0.460	0.346	0.593	0.497

Note. This table report results from the CCTS and matched CCTS-ASIF samples. The dependent variable is the export volatility measure, defined as log of squared deviation in export growth rate from firm's own mean averaged over the sample period. In Columns 1-3 markets are defined on 7 country groups: the European Union, NAFTA, ASEAN, Australasia, other OECD countries, and the rest of the world. In Columns 4-6 Hong Kong is excluded as a market from the sample. The Herfindahl index is adjusted accordingly based on the new definition of markets. All other variables are defined as in the previous tables. Robust standard errors are in parentheses, and superscripts *, ** and *** indicate significance at 10%, 5%, and 1% levels respectively.

exports are sent to foreign markets through Hong Kong, and appear as exports to Hong Kong in the sample. Although we expect this problem to be classical measurement error, biasing our results towards zero, we check the importance of Hong Kong by conducting the analysis excluding all flows to Hong Kong.[34] The results, reported in Columns 4-6 of Table 7, show that the main coefficients are smaller but does not change the qualitative conclusions.

Product diversification. Although our analysis focuses on the geographic dimension of diversification, the volatility of firms' exports can also be affected by the diversification of their product portfolio. To control for this possibility, we compute a Herfindahl index capturing the product diversification of the firm, based on the share of each HS6 (1996 version) product in their total exports over the period. Columns 1-4 of Table 8 show that the product diversification of exports has very little or no effect on export volatility. Controlling for product volatility does furthermore not affect the results on geographic diversification. Table A2 in the Appendix replicates the analysis when constructing the Herfindahl index

[34] A similar issue may arise with other export hubs. A firm exporting to Uganda and Kenya may for example ship all its merchandise to Kenya and re-export from there. These flows would however be recorded as an export to Kenya only in the Chinese customs. Since our results are robust to using a Herfindahl based on the 7 regions described above, regional hubs do not appear to drive the results.

based on the share of each product-destination pair in the firm's total exports and shows that the results are similar to using only the geographic dimension of diversification.

Reverse causality. Our theory assumes that causality runs from the diversification of export sales to the volatility of exports. In the simple framework of Section 3.2, firms do not choose their exposure to different markets and they maximize profits with no consideration for volatility. In reality, however, causality may run from volatility to diversification. Consider a firm selling a product with a very volatile demand. As long as demand shocks are not perfectly correlated across markets, a risk-averse or financially-constrained firm may wish to diversify its sales across destinations to stabilize its exports, giving rise to a positive link between diversification and volatility. To the extent that large firms are less sensitive to volatility (e.g. because they are less financially constrained), this reverse causality may be dampened for larger firms, generating the observed positive coefficient on our interaction term. The lack of a strong instrument for firm-level export diversification prevents us from addressing the issue of reverse causality formally. In the following, we however discuss and exclude a number of potential channels through which reverse causality may drive the results, thereby lending some additional credibility to our theoretical interpretation. First, we include in our regressions many balance sheet items, as well as a rich set of industry and province fixed effects, thereby controlling for any systematic difference in volatility due to these observable characteristics. Second, the results of Table 6 which use the 2000 value of total exports and of the Herfindahl index should be less subject to reverse causality, as beginning of period size and diversification are less likely to depend on subsequent volatility. Interestingly, the results are strengthened using these beginning of sample measures, although we recognize that this does not solve the problem if volatility is persistent or expected. Third, we control directly for measures of predicted volatility at the firm-level to reduce the risk that unobserved differences in volatility drive the reverse causality. On top of the volatility of the destinations to which the firm exports, we add a measure of volatility based on the product-mix of the firm's exports. This additional control ("Volatility_p"), present in Columns 7-10 of Table 8, shows that a firm exporting a high share of typically volatile products has a higher export volatility.[35] The other coefficients however remain unaffected. Finally, Columns 1-3 of Table A4 in the Appendix splits the sample according to the financial leverage of firms (defined as firm debt-asset ratio) and shows that the results are not particularly driven by high or low leveraged firms. Financial leverage can proxy for the sensitivity of firms to shocks (see Sharpe, 1994) and more leveraged firms may be more willing to diversify exports if it stabilizes them, so that the issue

[35]The detailed computation of this measure is explained in the Data Appendix.

Table 8. Controlling for characteristics of product profile

Dependent variable: volatility of export sales. Sample: matched CCTS-ASIF.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Herfindahl			-1.682***	-0.100	-1.619***	-0.085	-1.617***	-0.078
			(0.611)	(0.072)	(0.605)	(0.072)	(0.607)	(0.072)
Herfindahl*Exports			0.087**		0.084**		0.085**	
			(0.036)		(0.035)		(0.035)	
Herfindahl*TFP				0.169**		0.174**		0.175**
				(0.083)		(0.083)		(0.083)
Herfindahl_p	-0.330	-0.134*	-0.208	-0.127*			-0.197	-0.097
	(0.639)	(0.073)	(0.638)	(0.073)			(0.635)	(0.074)
Herfindahl_p*Exports	0.011		0.005				0.006	
	(0.038)		(0.037)				(0.037)	
Herfindahl_p*TFP		-0.059		-0.062				-0.062
		(0.087)		(0.087)				(0.087)
Exports	-0.527***		-0.572***		-0.567***		-0.571***	
	(0.028)		(0.033)		(0.025)		(0.033)	
TFP		0.105		0.014		-0.028		0.007
		(0.065)		(0.079)		(0.063)		(0.079)
Volatility_p					1.003***	1.104***	0.974***	1.076***
					(0.221)	(0.245)	(0.222)	(0.247)
Further controls: sales, age, wage, cap int, lev ratio, income & vol of destinations, avg export growth rate								
Province-industry-ownership dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
# Observations	8,312	8,312	8,312	8,312	8,312	8,312	8,312	8,312
R-squared	0.567	0.464	0.568	0.464	0.570	0.467	0.571	0.467

Note. This table reports results using diversification index (Herfindahl_p) defined across products instead of markets. The dependent variable is the export volatility measure, defined as log of squared deviation in export growth rate from firm's own mean averaged over the sample period. Volatility of products (HS6 1996 version) at the firm level (volatility_p) is defined as the weighted average of product export sales for each firm with the weights being the shares of the products in the firm's total export sales. All other variables are defined as in the previous tables. Robust standard errors are in parentheses, and superscripts *, **, *** indicate significance at 10%, 5%, and 1% levels respectively.

of reverse causality should be particularly acute among them. We however do not find any evidence that the observed relationship is driven by more leveraged firms, casting doubt on this particular channel as a driver of reverse causality. Although none of the above four arguments can fully address the issue of reverse causality, they provide suggestive evidence that at least some of the channels through which reverse causality may run are unlikely to drive our results.

Additional robustness checks. Table A3 in the Appendix shows that the conclusions are robust to splitting the sample in three size categories instead of using the interaction between Herfindahl and size. As expected, the coefficient on the Herfindahl index is negative and strongly significant for the smallest size category and positive, although insignificant, for the largest size category. Unreported robustness checks also show that the conclusions are robust to excluding firms with a Herfindahl index higher than 0.95, meaning that the results are not driven by a comparison between exporters to a single market versus exporters to multiple markets. Finally, we use different definitions of growth rates and thresholds for the exclusion of outliers, with no changes to our conclusions.

5 Conclusions

The contribution of this paper is twofold. First, we show that, in a large sample of Chinese exporters from 2000 to 2006, the geographic diversification of exports is positively associated with volatility among small exporters. Among large exporters on the other hand, the relationship appears weakly positive. These results, which stand in marked contrast to standard portfolio theory for small exporters, are robust to a wide array of controls and dummies. Second, we develop a simple model to explain these empirical patterns. We show in a setup featuring idiosyncratic destination-specific demand shocks and fixed costs of exports per country that selling occasionally to a destination raises the volatility of exports. The model predicts that, among small exporters, the geographic diversification of exports is associated with a higher fraction of exports going to a destination where the firm sells occasionally, thereby raising export volatility. This channel provides a counteracting force to the standard diversification argument and can even overturn it, giving rise to a negative link between the Herfindahl index of exports and export volatility. Our empirical analysis provides strong evidence that this channel is the main driver of the observed empirical patterns, and that the conclusions are unlikely to be driven by other channels such as experimenting on foreign markets or reverse causality. Our results cast doubts on the commonly held belief that export diversification necessarily reduces export volatility.

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Appendix A Appendix

A.1 Theory appendix

(a) Volatility in the dynamic case

On such a market, the expected sales and the variance of sales are trivially given by:

$$X_{ji} = \frac{1}{T}\zeta_{jiF}\lambda_{ji}, \tag{17}$$

$$VAR_{ji} = (T-1)X_{ji}^2, \tag{18}$$

where ζ_{jiF} is the short-run demand shock faced by firm j in the first (and last) year it sells on market i. If j exports continuously to market i, and sells only once to market i', its volatility can be rewritten as:

$$V^D(Herf_j) = \frac{Herf_j}{2}(T-1+\mu) + (\mu-(T-1))\frac{\sqrt{2Herf_j-1}}{2}. \tag{19}$$

Consider the case $\underline{s} = \bar{s}$, i.e. the firm sells in each period the same amount on its continuous export market ($\mu = 0$). In one year, it explores a second market and sells a positive amount there before realizing that it is not worth selling further on that market. The one-time export to a market creates a variation in total exports, which therefore raises the volatility and also makes the Herfindahl index lower than one. This generates a negative correlation between the Herfindahl index and volatility, even though there are no short-run shocks. It therefore becomes explicit that this correlation can obtain even if

(b) The theory's implications for the empirical link between diversification, size and volatility

As shown in Section 3.2, the model implies that firms exporting occasionally to a market may have more volatile exports than firms selling continuously to both markets. Since small exporters are more likely to export occasionally (as confirmed empirically by Figure 3), we argue that this may account for the observed relationship between volatility, diversification and size. The aim of this section is to formalize and qualify these insights.

First, note that the volatility of continuous and occasional exporters in (12) and (15) can be rewritten as:

$$V_j^C = \mu Herf_j, \tag{20}$$

$$V_j^O = \mu Herf_j + \frac{1-\mu}{2}\left(Herf_j - \sqrt{2Herf_j-1}\right), \tag{21}$$

so that, for a given Herfindahl index, the volatility of an occasional exporter is smaller than the volatility of a permanent exporter. Furthermore:

$$\frac{\partial V_j^C}{\partial Herf_j} = \mu, \tag{22}$$

$$\frac{\partial V_j^O}{\partial Herf_j} = \mu - \frac{1-\mu}{2}\left(\frac{1}{\sqrt{2Herf_j - 1}} - 1\right), \tag{23}$$

which shows that an increase in the Herfindahl index has a positive effect on the volatility of exports among continuous exporters to both markets, but a smaller effect among firms which export occasionally to one of the markets, i.e. $\partial V_j^C/\partial Herf_j > \partial V_j^O/\partial Herf_j$. For a small enough Herfindahl, and as illustrated in Figure A1, an increase in the Herfindahl index can even decrease volatility.

The expected volatility of sales conditional on the size and Herfindahl of exports — which is the main object of the empirical analysis — is, in our model, given by:

$$E[V|Herf,X] = P^C(Herf,X)V^C(Herf) + (1 - P^C(Herf,X))V^O(Herf), \tag{24}$$

where $V^C(Herf)$ and $V^O(Herf)$ are defined by (12) and (15) respectively and where $P^C(Herf,X)$ is the probability that a firm continuously exports to both markets conditional on an $\{X,Herf\}$ combination ($1-P^C(Herf,X)$) is the probability that it exports occasionally to one of the markets). To shorten the notation, we leave out the conditionality in the following and refer to $E[V|Herf,X]$ as $E[V]$. The three main comparative statics of interest for our analysis are:

$$\frac{\partial E[V]}{\partial X} = \frac{\partial P^C}{\partial X}(V^C(Herf) - V^O(Herf)), \tag{25}$$

$$\frac{\partial E[V]}{\partial Herf} = \frac{\partial P^C}{\partial Herf}(V^C(Herf) - V^O(Herf)) + P^C\frac{\partial V^C(Herf)}{\partial Herf} + (1-P^C)\frac{\partial V^O(Herf)}{\partial Herf}, \tag{26}$$

$$\frac{\partial^2 E[V]}{\partial Herf \partial X} = \frac{\partial^2 P^C}{\partial Herf \partial X}(V^C(Herf) - V^O(Herf)) + \frac{\partial P^C}{\partial X}\left(\frac{\partial V^C(Herf)}{\partial Herf} - \frac{\partial V^O(Herf)}{\partial Herf}\right), \tag{27}$$

which make explicit the central role played by the function P^C. Our intuitive reasoning at the end of Section 3.2 relies on the idea that $\partial P^C/\partial X \geq 0$ (i.e. the fraction of firms exporting continuously to both markets is larger among firms with large total exports) — which we illustrate in Figure 3 — and neglects the dependence of P^C on $Herf$ (i.e. neglects the first term on the right hand side of (26) and (27)). Assuming that this is the case, it immediately implies that (i) $E[V]$ is decreasing in X, (ii) the interaction term $(\partial^2 E[V]/(\partial X \partial Herf))$ is positive and (iii) if, for small X, P^C is small enough and $\partial V^O/\partial Herf < 0$, the Herfindahl index has a negative effect on the volatility of exports for small exporters. These three results are in line the baseline outcome of the empirical analysis ($\partial E[V]/\partial X < 0$, $\partial E[V]/\partial H < 0$ for X small and $\partial^2 E[V]/\partial H \partial X > 0$).

We now characterize the function $P^C(Herf,X)$ to assess the plausibility of the above assumptions. Consider a firm j with a given fixed cost of exporting f_j.[36] Firm j exports continuously to both markets if: $\lambda_{ji}\underline{s} > f_j$, implying that the total exports of firm j are $X_j > \sigma\left(\frac{\bar{s}}{\underline{s}}+1\right)f_j$. Furthermore, given X_j, firm j must have a small enough Herfindahl index $Herf_j < \tilde{H}(1+\bar{s}/\underline{s})$ where:

$$\tilde{H}(y) = \frac{1}{2} + \frac{1}{2}\left(1 - \sigma\frac{f_j}{X_j}y\right)^2.$$

Similarly, if firm j exports continuously to market i but occasionally to market i', its size is at least equal to $X_j > \sigma f_j\left(1+\frac{\bar{s}}{2\underline{s}}\right)$ and the Herfindahl index of exports must be such that $\tilde{H}(1+\bar{s}/\underline{s}) < Herf_j < \tilde{H}(1)$ if $X_j < \sigma f_j(\bar{s}/\underline{s}+1/2)$ and $\tilde{H}(\bar{s}/\underline{s}) < Herf_j < \tilde{H}(1)$ otherwise. We plot in Figure A1 the admissible values of X_j and of $Herf_j$ for two different levels of the fixed costs of exports. For a given f_j, the combination of $\{X_j, Herf_j\}$ fully determines whether a firm is a continuous exporter to both markets ($P^C = 1$) or occasionally exports to one market ($P^C = 0$). It also appears that some combinations of $\{X_j, Herf_j\}$ cannot be observed for a given fixed costs level (in white, P^C undefined). Figure A1 confirms that, for a given Herfindahl index, larger exporters are more likely to continuously export on both markets. It also shows that, for a given X, firms with larger Herfindahl index are more likely to be occasional exporters to one market.

Although the function $P^C(Herf, X)$ as depicted in Figure A1 exhibits a discrete jump and is undefined for a large range of $\{Herf, X\}$ combinations, it should be noted that some degree of firm-level heterogeneity between the fixed costs of exports[37] or the presence of more than two markets would shrink the inadmissible (white) range and smoothen the function $P^C(Herf, X)$. We show in a number of unreported simulations for a wide range of plausible values that $\partial P^C/\partial X \geq 0$ while $\partial P^C/\partial Herf$ and the cross partial $\partial^2 P^C/\partial X\partial Herf$ depend on the particular distributional assumptions. Note that in our sample of Chinese exporters, it appears from Table 2 that $\partial P^C/\partial Herf > 0$ and $\partial^2 P^C/\partial X\partial Herf < 0$, which contribute to make (26) negative and (27) positive, i.e. to generate the empirically observed coefficients.

Since $\partial P^C/\partial Herf$ and $\partial^2 P^C/\partial X\partial Herf$ have an ambiguous sign in theory, we complement the analysis with a simulation of the model to show that it can replicate the empirical patterns for plausible distributions of the parameters.[38] We should emphasize that it does not necessarily generate such patterns, but that it can under reasonable assumptions. Second, we simulate an extended version of our model to five export markets to show that the intuition of our two market case readily extends to a setup with more markets.

We follow Eaton *et al.* (2011) and Hsieh and Ossa (2011) in assuming that the distribution of productivity (φ) is

[36] In this appendix, we allow the fixed costs of exports to differ between firms, in line with Lileeva and Trefler (2010).

[37] For example, if 50% of firms have $f = 1$ and 50% have $f = 0.5$, this means superimposing both parts of Figure A1. The size of the white range shrinks, and the discrete jump in P^C disappears as some range of the $\{Herf, X\}$ now admits intermediate values of P^C.

[38] We need to look at simulations due to the complexity of the function P^C, which depends on the distribution of (i) productivity (φ), (ii) firm-level demand χ_{ji} on each market, and (iii) export fixed costs (f_j) if these are heterogeneous across firms.

Pareto with a coefficient of 5 and in setting the elasticity of substitution to $\sigma = 3$. As in Eaton *et al.* (2011), we assume that the distribution of χ_{ji} for each i is log normal and we arbitrarily set the parameters of the distribution to 0 and 1. Finally, we assume that $Log(f)$ is distributed normally across firms with mean 0 and standard deviation 0.25 and set $\bar{s} = 2$ and $\underline{s} = 1$. We conduct these simulations for the case of 5 export markets (see Figure A2) and show that the regression of volatility on size, Herfindahl and their interaction generates qualitatively similar results to the ones we observe. Detailed results and codes are available from the authors upon request.

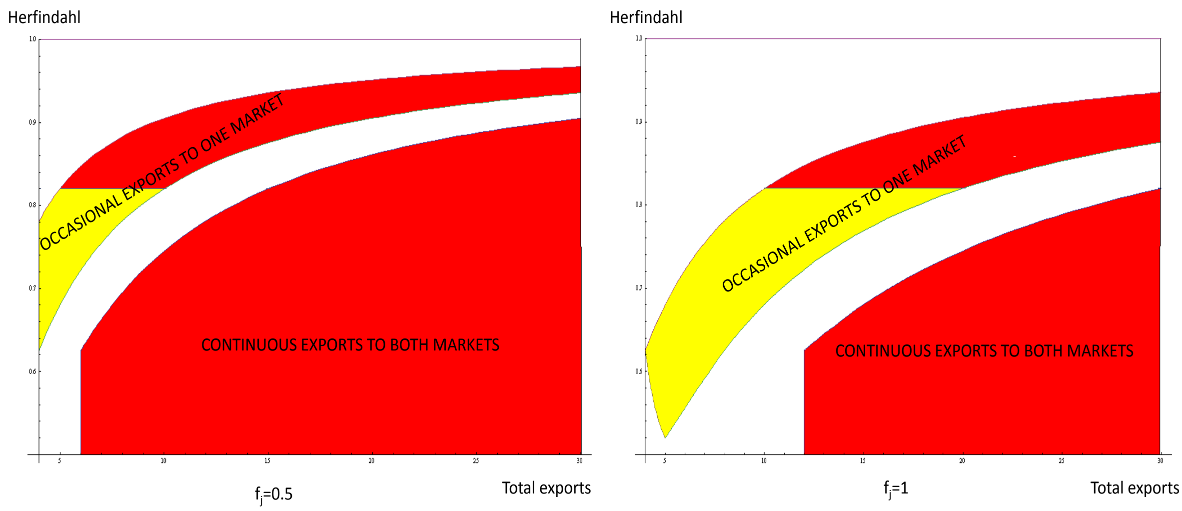


Figure A1. Range of continuous and occasional exporters. The figures shows the range of $\{H, X\}$ for which firms are continuously exporting to both markets or occasionally exporting to one of the market. The left panel assumes lower fixed costs of exports ($f = 0.5$) than the right panel ($f = 1$). The red area corresponds to the $\{H, X\}$ combinations for which $\mathrm{d}V_j/\mathrm{d}Herf_j > 0$ while in the yellow area: $\mathrm{d}V_j/\mathrm{d}Herf_j < 0$.

(c) Allowing for a positive correlation of shocks between markets

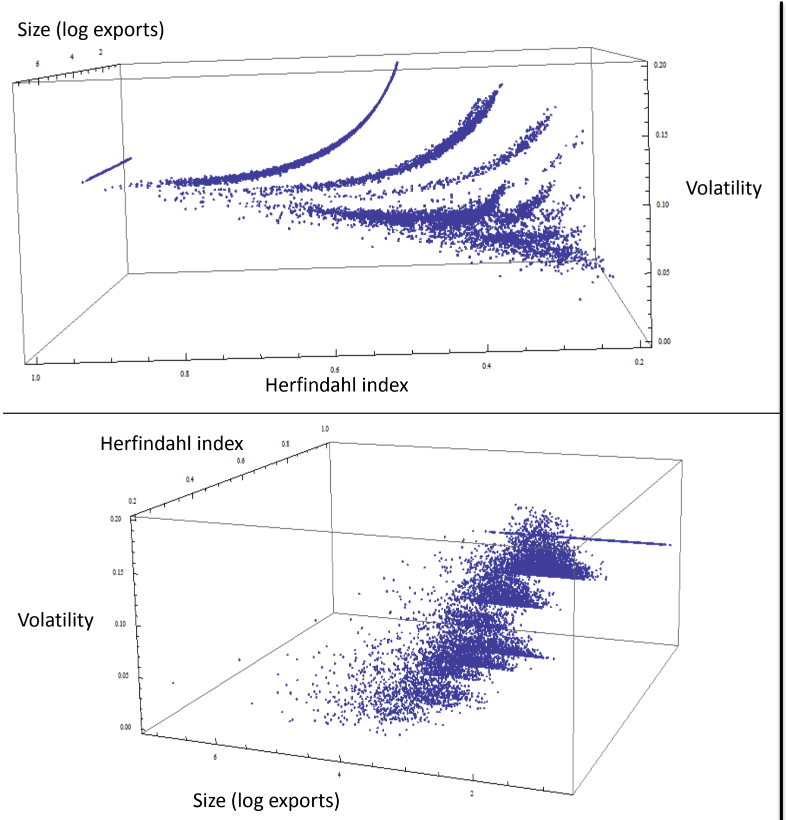
We here show that our results extend to the case where shocks are positively (but imperfectly) correlated between markets. To keep the analysis simple, we define $\alpha/2$ as the probability that both shocks are high ($\bar{s}$ on both markets) or low ($\underline{s}$ on both markets). The probability of having $\underline{s}$ in market 1 and $\bar{s}$ on market 2 is equal to the probability of having $\bar{s}$ on market 1 and $\underline{s}$ on market 2 and is equal to $(1-\alpha)/2$. With this simple parameterization, $\alpha \geq 1/2$ indexes the degree to which shocks between the two markets are correlated ($\alpha = 1/2$) corresponds to zero correlation).

If firm j exports continuously to both markets, it can easily be shown that the covariance of its sales on markets 1 and 2 is:

$$Cov^C_{j12} = \lambda_{j1}\lambda_{j2}\sigma^2 \frac{2\alpha - 1}{4}(\bar{s} - \underline{s})^2 = \mu(2\alpha - 1)X_{j1}X_{j2}, \tag{28}$$

while the covariance of its sales if it exports occasionally to one of the markets is:

$$Cov^O_{j12} = \lambda_{j1}\lambda_{j2}\sigma^2 \frac{2\alpha - 1}{4}\bar{s}(\bar{s} - \underline{s}) = \sqrt{\mu}(2\alpha - 1)X_{j1}X_{j2}. \tag{29}$$



OLS regression based on the simulated data for 5 export markets (as depicted on the left panel) excluding firms with a Herfindahl of one. Dependent variable: Volatility of exports

Herfindahl	-0.124***
	(0.004)
Herfindahl*Exports	0.0655***
	(0.002)
Exports	-0.069***
	(0.001)
# Observations	11,212
R-squared	0.53

Figure A2. Simulation of the model for 5 markets. The left hand side of the figure shows the simulated data for the case of 5 export markets using the parameters described in the appendix. The top and bottom graphs on the left hand side plot the same data and only vary the angle of the plot. The top graph shows the counterpart to Figure 2 in the case of 5 markets, while the bottom graph emphasizes the role of export size in shaping the relationship between Herfindahl and volatility. The right hand side of the figure shows the result of a regression of volatility of exports on the log exports, the Herfindahl index, and the interaction between the two. We simulate 50,000 observations and keep those which correspond to continuous exporters with a Herfindahl index below one, leaving 11,212 data points.

The derivative of the volatility with respect to the Herfindahl index becomes:

$$\frac{\mathrm{d}V_j}{\mathrm{d}Herf_j} = \frac{1}{2(X_{j1}-X_{j2})}\left(\frac{\partial VAR_{j1}}{\partial X_{j1}} - \frac{\partial VAR_{j2}}{\partial X_{j2}} + 2\frac{\partial Cov_{j12}}{\partial X_{j1}}\right), \tag{30}$$

which is:

$$\frac{\mathrm{d}V_j^C}{\mathrm{d}Herf_j} = 2\mu(1-\alpha), \tag{31}$$

$$\begin{aligned}\frac{\mathrm{d}V_j^O}{\mathrm{d}Herf_j} &= 2\mu(1-\alpha)+\sqrt{\mu}(1-\sqrt{\mu})(1-2\alpha)+(\mu-1)\frac{X_{j2}}{X_{j1}-X_{j2}} \\ &= 2\mu(1-\alpha)+\sqrt{\mu}(1-\sqrt{\mu})(1-2\alpha)-\frac{1-\mu}{2}\left(\frac{1}{\sqrt{2Herf_j-1}}-1\right).\end{aligned} \tag{32}$$

Therefore: $\mathrm{d}V_j^O/\mathrm{d}Herf_j < \mathrm{d}V_j^C/\mathrm{d}Herf_j$ if $\alpha \geq 1/2$. For $Herf_j$ sufficiently small, the effect of the Herfindahl index on the volatility of exports can again turn negative among occasional exporters.

A.2 Data appendix

Export value and domestic sales used in this research are deflated using GDP deflator based on the price of the year 2000. The country-level data are from World Bank Development Indicators maintained by the World Bank. We use GDP per capita (in US dollars) in 2003 as the measure of the *income levels of countries*. *Destination market volatility* is measured as the variance of the growth in the country's real GDP. The firm-level variables of *destination income* and *destination volatility* are constructed as the weighted averages of the destinations' income and volatility respectively with the weights being the destinations' shares in the firm's total export sales. *Product volatility* is defined as the average annual growth rate of the export sales of HS6 (1996 version) products. Similar to the above firm-level measures, firm-level *product volatility* is defined as the weighted average of the volatility of products a firm exports with the weights being the products' shares in the firm's total export sales.

Throughout our regression analysis for both the CCTS and the matched CCTS-ASIF samples, we exclude the 1% observations with the highest volatility to minimize the effect of outliers on our results. However, we also tried keeping all observations in the regression samples, and the differences in estimates are minimal.

A.3 Additional tables

Table A1. Volatility of firm-destination exports

Dependent variable: volatility of export sales. Sample: CCTS.

	(1)	(2)	(3)	(4)	(5)
Log(X_ji)	1.717***	1.986***	1.976***	1.976***	1.970***
	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)
Number of exporting years		-0.440***	-0.434***	-0.435***	-0.425***
		(0.001)	(0.001)	(0.001)	(0.001)
Log(X_j)			0.023***	0.026***	
			(0.001)	(0.001)	
Industry dummies	No	No	Yes	No	No
Destination dummies	No	No	No	Yes	No
Firm fixed effects	No	No	No	No	Yes
# Observations	440,859	440,859	440,859	440,854	440,854
R-squared	0.967	0.987	0.987	0.987	0.989

Note. The dependent variable is the export volatility measure, defined as log of squared deviation in export growth rate from firm's own mean averaged over the sample period. X_{ji} is the export sales of a firm j at market j and X_j is the total export sales of fim j. Robust standard errors are in parentheses, and superscripts *, **, *** indicate significance at 10%, 5%, and 1% levels respectively.

Table A2. Volatility and diversification for product-market pairs

Dependent variable: volatility of export sales. Samples: CCTS and matched CCTS-ASIF.

	CCTS		Matched CCTS-ASIF			
	(1)	(2)	(3)	(4)	(5)	(6)
Herfindahl_cp	-2.226***	-2.276***	-1.073	-1.722**	-0.104	0.015
	(0.316)	(0.316)	(0.750)	(0.726)	(0.083)	(0.084)
Herfindahl_cp*Exports	0.109***	0.115***	0.045	0.093**		
	(0.020)	(0.020)	(0.044)	(0.043)		
Exports	-0.390***	-0.385***	-0.371***	-0.553***		
	(0.009)	(0.009)	(0.019)	(0.022)		
TFP					-0.211***	0.029
					(0.041)	(0.055)
Herfindahl_cp*TFP					0.141	0.130
					(0.103)	(0.103)
Further controls: sales, age, wage, cap int, lev ratio, income & vol of destinations, avg export growth rate						
Further controls	No	Yes	No	Yes	No	Yes
Province-industry-ownership dummies	Yes	Yes	Yes	Yes	Yes	Yes
# Observations	23,584	23,581	8,327	8,294	8,327	8,294
R-squared	0.298	0.300	0.526	0.566	0.433	0.461

Note. The dependent variable is the export volatility measure, defined as log of squared deviation in export growth rate from firm's own mean averaged over the sample period. Columns 1 and 2 present the results based on the CCTS customs sample, and Columns 3-6 on the matched CCTS-ASIF sample. Herfindahl index (Herfindahl_cp) is generated at the product-market dimension. Products here are defined by HS6 (1996 version) categories. All other variables are defined as in the previous tables. Robust standard errors are in parentheses, and superscripts *, **, and *** indicate significance at 10%, 5%, and 1% levels respectively.

Table A3. Volatility and diversification by firm size and TFP

Dependent variable: volatility of export sales. Sample: matched CCTS-ASIF.

	Sample split by firm size			Sample split by TFP		
	Small (1)	Medium (2)	Large (3)	Low (4)	Medium (5)	High (6)
Herfindahl	-0.325**	-0.245*	0.063	-0.151	-0.389**	0.317**
	(0.144)	(0.141)	(0.132)	(0.161)	(0.164)	(0.158)
Exports	-0.496***	-0.511***	-0.371***			
	(0.042)	(0.117)	(0.074)			
TFP				-0.211*	-0.266	0.297**
				(0.119)	(0.246)	(0.120)
Further controls: sales, age, wage, cap int, lev ratio, income & vol of destinations, avg export growth rate						
Province-industry-ownership dummies	Yes	Yes	Yes	Yes	Yes	Yes
# Observations	2,729	2,769	2,773	2,759	2,760	2,752
R-squared	0.699	0.598	0.570	0.562	0.587	0.626

Note. The dependent variable is the export volatility measure, defined as log of squared deviation in export growth rate from firm's own mean averaged over the sample period. Firms are split up by their size relative to the 1/2 and 2/3 quantiles, which are defined on log exports in Columns 1-3 and by their relative TFP in a similar way in Columns 4-6. All other variables are defined as in the previous tables. Robust standard errors are in parentheses, and superscripts *,** , and *** indicate significance at 10%, 5%, and 1% levels respectively.

Table A4. Volatility and diversification by firm leverage ratio

Dependent variable: volatility of export sales. Sample: matched CCTS-ASIF.

	Sample split by leverage ratio		
	Low (1)	Medium (2)	High (3)
Herfindahl	-1.940 (1.205)	-0.551 (1.302)	-2.104 (1.436)
Herfindahl*Exports	0.099 (0.071)	0.026 (0.076)	0.120 (0.083)
Exports	-0.563*** (0.052)	-0.513*** (0.055)	-0.598*** (0.055)
Further controls: sales, age, wage, cap int, income & vol of destinations, avg export growth rate			
Province-industry-ownership dummies	Yes	Yes	Yes
# Observations	2763	2759	2749
R-squared	0.648	0.662	0.688

Note. The dependent variable is log of squared deviation in export growth rate from firm's own mean, averaged over years. Firms are split up by their leverage ratio (as a measure of dependence on external finance), relative to the 1/2 and 2/3 quantiles. All other variables are defined as in the previous tables. Robust standard errors are in parentheses, and superscripts *,** , and *** indicate significance at 10%, 5%, and 1% levels respectively.