Exports versus Multinational Production under Nominal Uncertainty

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Abstract

I consider the effects of nominal uncertainty on the decision firms face between exporting and multinational production. I develop a stochastic general equilibrium model of trade and multinational production and examine its implications under monetary uncertainty. If both exports and multinational production are priced in the local (destination) currency, the model implies that nominal uncertainty does not affect the relative decision. Because the vast majority of U.S. exports are priced in dollars, however, I consider an alternative model in which exports are producer-cost priced while multinational production is local-currency priced. In this model environment, an increase in foreign nominal volatility reduces multinational sales relative to exports. Intuitively, a foreign nominal contraction benefits an exporter through both the increased home-currency value of profits and the automatically lower prices faced by foreign consumers. Because multinational firms set their prices in the foreign currency, they do not benefit from the latter. I take the model's prediction to U.S. data, using inflation volatility as a proxy for nominal volatility. Using sectoral data on sales by majority-owned foreign affiliates matched with U.S. exports, I find that an increase in inflation volatility leads to a significantly lower ratio of multinational production to total foreign sales.

JEL classifications: F12, F23, F41

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1 Introduction

Multinational production plays an important role in how firms serve foreign markets. For a typical major trading partner, sales of foreign affiliates of U.S. firms are greater than exports. This paper considers how nominal uncertainty affects the decision firms make between serving the foreign market through multinational production or exports. There is strong evidence that U.S. export prices are very sticky and are denominated in dollars. Because multinational production is priced in the foreign currency, there is a potentially important distinction in how foreign nominal uncertainty affects the choice firms make on the margin.

I develop a model with heterogeneous firms and an endogenous decision to export or set up foreign production. Firms set prices and make production-location decisions in advance, so foreign nominal uncertainty affects expected profits. Nominal uncertainty takes the form of a stochastic money growth rate rule. I show that if both exports and multinational production are priced in the foreign currency, nominal uncertainty does not affect the choice of how to serve the foreign market. If, as in U.S. data, exports are instead priced in dollars, then exporting becomes relatively more attractive as foreign volatility rises. The intuition is that given a foreign nominal contraction, an exporter with a price stuck in dollars gains a pricing advantage over an equivalent multinational producer whose price is stuck in the foreign currency. This makes expected profits of exporters highly convex in foreign volatility.

Recent work demonstrates that nominal uncertainty is important for understanding international transactions. Schoenle (2010) shows that U.S. export prices are more sticky than domestic U.S. prices, with durations of at least one year on average. Gopinath and Rigobon (2008) provide evidence that nearly all such prices are denominated in US dollars. By contrast, production abroad is likely to be denominated in the local currency. This distinction is crucial for understanding how firms react to differences in nominal uncertainty in the model.

The analysis is based on the canonical Helpman et al. (2004) framework of trade and multinational production, extended to a stochastic environment. Firms are heterogeneous in productivity, and face higher fixed costs to produce abroad than to export. Firms with high productivity find it more desirable to produce abroad to avoid per-unit transportation costs. Uncertainty plays a role through the non-linear effects of monetary shocks on expected profits. This in turn affects the extensive margin of firm participation in each market. I start with a straightforward benchmark, where both exports and multinational production are priced in advance in the local currency. Here, nominal uncertainty affects neither the extensive nor intensive margin of exporting relative to multinational production. Because U.S. exports are priced in dollars rather than the local currency, however, I consider an alternative where exports are priced in the exporter's currency and multinational production is priced in the local currency. In this case, exporter profits are more convex in foreign nominal volatility. This in turn implies that as volatility rises, multinational production as a fraction of total foreign sales (multinational production plus exports) falls in the model.

I then consider the empirical evidence. Using bilateral data for U.S. exports and sales by foreign affiliates of U.S. multinationals, I examine the impact of inflation volatility on the relative choice. I find that, as predicted by the model, inflation volatility tends to decrease the share of MP relative to exports. Separating the regressions for each major sector, I find that the coefficient on volatility is significant for information, electrical, food, machinery, and transportation manufacturing. Other manufacturing sectors have the expected sign, while mining has a positive and insignificant sign. Since mining is a commodity industry where prices tend to be very flexibly spot-priced, this is unsurprising. The results underscore the importance of sectoral heterogeneity in short-term behavior caused in part by the price-setting characteristics of that sector.

On the other hand, exchange rate volatility has, if anything, the opposite effect. The coefficient on exchange rate volatility tends to be positive but not statistically significant. This suggests that while the mechanism in the model holds for inflation volatility, there may be additional effects from exchange rate volatility which may be derived from different underlying shocks. The mechanism in my model simply requires that the exchange rate volatility caused by nominal volatility goes in the modeled direction; that is, a foreign nominal contraction leads to a foreign exchange rate appreciation. Since exchange rate volatility can be caused by a multitude of other sources, the empirical results are consistent with the model. I conclude with a discussion of these results and mechanisms by which exchange rate volatility may have different effects from the nominal volatility typically modeled.

This paper contributes to a recent and rapidly growing literature on understanding the effects of various forms of uncertainty in general equilibrium. Most of the recent work focuses on real uncertainty, including Ramondo and Rappoport (2009), Irarrazabal and Opromolla (2009), Fillat and Garetto (2009), and Ramondo et al. (2010). These papers study either country or firm-specific uncertainty about productivity under flexible prices. In particular, Ramondo et al. (2010) studies the choice of exporting versus multinational production given aggregate uncertainty about country output. They find that the U.S. exports more to countries with more volatile GDP.[2]

The literature considering nominal uncertainty is relatively sparse. In a partial equilibrium context, Giovannini (1988) studies the effects of exchange rates on exports given assumptions about the currency of prices set in advance. Goldberg and Kolstad (1995) study the production-location decision under a combination of exchange rate and demand shocks, with production capacity set in advance and flexible prices. The main results in that paper are driven by firms having some degree of risk aversion. In more recent general equilibrium work, Russ (2007) analyzes the effects of foreign versus domestic nominal uncertainty on multinational production (and by extension, FDI).[3] She demonstrates that while either source of volatility translates to exchange rate volatility, foreign volatility encourages multinational production in the foreign market while domestic volatility deters it. All prices are local-currency priced, and firms cannot export.

This paper differs from the literature in two respects. First, I study nominal uncertainty in the form of inflation volatility. Since we observe substantial price stickiness as noted above, it is important to understand how nominal volatility interacts with this stickiness to affects firms' decisions in general equilibrium. Second, the economic mechanism I propose in this paper is distinct, focusing on the difference between the currency denomination of exports compared to multinational production. Thus, differences in foreign volatility change how domestic firms serve the foreign market.

The rest of the paper is organized as follows. Section 2 presents the overall model environment.

[2] My model predicts the same basic comparative static with a completely different channel. I explore the empirical relationship between the two papers in Section 5.2.

[3] In addition, Cavallari (2009) studies real and nominal uncertainty with exports and multinational production in a model without firm heterogeneity and thus without an explicit choice of how to serve the foreign market. See also Cavallari (2008) and Cavallari (2007).

Section 3 details the specifics of the model in which exports are priced in the local currency. Section 4 describes the alternative model with exports priced in the producer's currency. Section 5 introduces the data and estimation strategy for testing the model. Section 6 concludes.

2 Model setup

Consider a 2-country model (home H and foreign F) inhabited by representative households that maximize utility over consumption, labor (leisure), and real money holdings. The countries trade a complete set of state-contingent bonds; this focuses the model's implications of uncertainty on firms. Each country has its own currency with a stochastic growth rate which is exogenously driven.

Firms face fixed costs for producing domestically, exporting, and serving foreign markets via multinational production (MP). Exporters face relatively smaller fixed costs but pay per-unit transportation costs, while multinationals avoid transportation costs and face higher fixed costs. This structure is the basis of Helpman et al. (2004) and a subsequent literature focusing on static determinants of trade and multinational patterns.

To keep the benchmark model as tractable as possible, prices are set one period in advance. With a period defined as a year, this is consistent with empirical evidence of export price durations of at least one year. Trade consists of monopolistically competitive intermediate goods and firms have heterogeneous production based on a permanent fixed draw from a productivity distribution. Labor is the only input of production.

2.1 Households

Each country is occupied by a representative household which maximizes the expected discounted stream of utility $U(\cdot)$, choosing consumption C_t, labor supplied L_t, bond holdings B, and real money balances M_t/P_t. For tractability, assume that utility is separable and of the form:

$$\max \sum_{t=0}^{\infty} \beta^t E_t \left[\frac{C_t^{1-\rho}}{1-\rho} - \kappa L_t + \chi \ln \left(\frac{M_t}{P_t} \right) \right].$$

The representative household faces a standard budget constraint:

$$P_tC_t + \sum_{s^{t+1}} Q(s^{t+1}|s^t)B(s^{t+1}) + M_t = M_{t-1} + W_tL_t + B(s^t) + \Pi_t + T_t,$$

where s^t denotes the state of the world at time t, $Q(s^{t+1}|s^t)$ are the price of state-contingent bonds, Π_t are profits from domestic firms, and T_t are transfers of seigniorage revenue from changes in the money supply. This leads to familiar first order conditions shown in the appendix.

Foreign households have an analogous problem, and the real and nominal exchange rates are solved by equating the price of state-contingent bonds $Q(s^{t+1}|s^t)$ and iterating backwards (see Chari et al. (2002)). The nominal exchange rate, defined as the ratio of the home currency to the foreign currency, can be expressed as a function entirely of exogenous variables (see appendix):

$$S_t = \frac{M_t}{M_t^*}\frac{1-\beta\alpha}{1-\beta\alpha^*},$$

where $\alpha \equiv E_t\left[\frac{M_t}{M_{t+1}}\right]$, the expected inverse of the money growth rate, and α^* is its foreign counterpart. Intuitively, the nominal exchange rate in any given period depends on the ratio of the money supplies; an increase in home currency M leads to a depreciation (increase in S) of the home nominal exchange rate. The money growth rate terms are derived from the partial derivative of utility with respect to money holdings. As the volatility of the foreign money growth rate rises, so does α^*. This, all else equal, leads to a higher S_t (home currency depreciation).[4]

Households consume a basket of domestic and foreign varieties through CES aggregation, with a common elasticity of substitution θ:

$$C = \left[\int y(i)^{\frac{\theta-1}{\theta}}\, di\right]^{\frac{\theta}{\theta-1}}.$$

While there is no explicit home-bias in preferences over varieties in this setup, transportation costs and fixed costs will yield lower imports relative to a frictionless economy. In addition, complete markets and labor entering linearly in the utility function imply that wages between the two countries

[4] Obstfeld and Rogoff (1998) discuss the effects of relaxing the log-utility assumption over money balances. They also emphasize that this result holds regardless of whether prices are sticky.

are equalized ($W_t = S_t W_t^*$). Section 3.6 discusses factor price equalization in more detail.

2.2 Monetary process

The uncertainty and volatility in the model stem from a stochastic money growth rate rule, found commonly in the literature[5]. I assume that the money supply grows at a stochastic log-normal rate with a mean-preserving spread:

$$\frac{M_t}{M_{t-1}} = e^{\epsilon_m}, \quad \epsilon_m \sim N\left(-\frac{\sigma_m^2}{2}, \sigma_m^2\right).,$$

with a similar process for the foreign country. This implies that the inverse of the money growth rate $\alpha = e^{\sigma_m^2}$.[6]

2.3 Intermediate goods producers

Each firm i faces a linear production technology with heterogeneous productivity $\phi(i)$ and uses labor $l(i)$, so that $y(i) = \phi(i)l(i)$.

To maximize tractability and keep the focus on nominal uncertainty, I follow Helpman et al. (2004) and Russ (2007) and assume that firms face per-period fixed costs for domestic entry f, exporting f_X, and multinational production f_{MP}. Firms which export pay an iceberg trade cost $\tau > 1$ to have one unit arrive at the destination. For choices of f and f_X consistent with the data, no firm will choose to export but not produce domestically. As in Helpman et al. (2004), I assume that multinational production fixed costs are higher than export fixed costs $f_{MP} > f_X$, consistent with data on firm sales.[7]

[5] e.g. Obstfeld and Rogoff (1998), Chari et al. (2002), Russ (2007).

[6] For notational simplicity, I abstract from a constant growth rate term, which does not qualitatively affect the results.

[7] While in principle firms could produce abroad for re-export to the home market, transportation costs work in both directions and thus this will be undesirable without some sort of cost advantage. If factor price equalization does not hold and re-exports were permitted, this would be dependent on the calibration of transportation costs versus the wage differentials. For simplicity in all setups, I exclude the possibility of foreign affiliates exporting back to the parent country. Such production technology is often associated with vertical integration and is outside the scope of this paper.

3 Model with exports priced in the local currency

In this section, I demonstrate that if exports and multinational production are both priced in the foreign currency (local currency pricing), then nominal uncertainty does not affect the relative choice of how to serve the foreign market. I derive the optimal price setting behavior and feed this into the zero-profit cutoff conditions for being an exporter or a multinational producer.

3.1 Price setting

Before considering prices set in advance, consider the optimal flexible prices. This will make the effects that price setting in advance will have clearer. With CES demand over varieties, this is the familiar condition that prices are set as a fixed markup $\frac{\theta}{\theta-1}$ over marginal costs. For a home firm selling in the home market, those marginal costs are $\frac{W_t}{\phi}$, where ϕ is the productivity of the firm. For a home firm exporting to the foreign market, those costs are $\frac{W_t \tau}{\phi S_t}$ (denominated in the foreign currency), as the firm must pay the iceberg trade cost. Finally, multinationals face marginal costs in the foreign currency of $\frac{W_t^*}{\phi}$.

3.1.1 Domestic price setting in advance

Domestic firms set prices for domestic sales through the following optimization:

$$\max_{p_{H,t}} E_{t-1}\left[d_t(p_{H,t}y_{H,t} - W_t l_{H,t})\right],$$

where $d_t \equiv \beta \frac{P_{t-1}C_{t-1}^{\rho}}{P_t C_t^{\rho}}$ is the stochastic discount factor of the investors. One can show that the optimal price choice is then:

$$p_{H,t}(\phi) = \frac{\theta}{\theta-1}\frac{1}{\phi}\frac{E_{t-1}\left[d_t W_t P_t^{\theta} C_t\right]}{E_{t-1}[d_t P_t^{\theta} C_t]},$$

where again ϕ is the productivity of the firm.[8]

[8]Note that if P_t is non-stochastic (e.g. if all prices are set in the local currency), then it may be canceled out of the expectation operators. This proves crucial in simplifying the expressions analytically, making the case of producer cost pricing in Section 4 substantially more difficult.

3.1.2 MP price setting in advance

Consider home firms who choose to engage in multinational production in the foreign market.[9] I make the reasonable assumption that these prices are pre-set in the foreign currency (LCP), as the products are produced and consumed entirely in the foreign country. The maximization problem takes the form:

$$\max_{p_{H,MP,t}} E_{t-1}\left[d_t S_t \left(p_{H,MP,t} y_{H,MP,t} - \frac{W_t^*}{\phi} y_{H,MP,t}\right)\right],$$

where $p_{H,MP,t}$ is the price choice of home-owned multinationals in the foreign market, and ϕ is the productivity of the firm. This yields the following optimal price choice:

$$p_{H,MP,t}(\phi) = \frac{\theta}{\theta-1}\frac{1}{\phi}\frac{E_{t-1}\left[d_t P_t^{*\theta} C_t^* S_t W_t^*\right]}{E_{t-1}\left[d_t P_t^{*\theta} C_t^* S_t\right]}. \tag{1}$$

3.1.3 Exporter price setting in advance, local currency pricing

Consider now home firms who choose to serve the foreign market through exporting. Empirically, whether exports are producer cost priced (PCP) or local currency priced (LCP) depends on the particular bilateral relationship. I do not endogenize the choice here,[10] but rather take the choice as given and examine the implications. I find that the currency choice has important implications for the effects of uncertainty.

First I consider the case where exports, like multinational production, are LCP. Denote this price choice as $p_{F,LCP,t}$. The maximization problem of the firm is then:

$$\max_{p_{H,LCP,t}} E_{t-1}\left[d_t \left(S_t p_{H,LCP,t} y_{H,LCP,t} - \tau \frac{W_t}{\phi} y_{H,LCP,t}\right)\right].$$

Since $p_{H,LCP,t}$ is set in the foreign currency, this revenue is repatriated with the nominal exchange rate S_t. Real demand depends only on the relative price and foreign demand, $y_{H,LCP,t} =$

[9] For the purposes of this paper, I restrict firms to either serve the foreign market through MP or exporting, but not both. It can be shown that with export prices set in the local currency, firms will never wish to both export and produce abroad.

[10] See Gopinath et al. (2010), Bhattarai (2009), and Engel (2006) for examples of papers which endogenize this choice.

$\left(\frac{P_t^*}{p_{H,LCP,t}}\right)^\theta C_t^*$. Substituting this into the maximization problem and solving for the optimal price,

$$p_{H,LCP,t}(\phi) = \frac{\theta}{\theta-1}\frac{1}{\phi}\tau\frac{E_{t-1}\left[d_t P_t^{*\theta} C_t^* W_t\right]}{E_{t-1}\left[d_t P_t^{*\theta} C_t^* S_t\right]}. \tag{2}$$

Factor price equalization implies that $W_t = S_t W_t^*$. Thus, it is straightforward to see that for a given productivity ϕ, the relative price choice is simply $p_{F,MP,t}/p_{F,LCP,t} = \tau^{-1}$. That is, none of the expectations play a role in the optimal price choice between multinational production and an exporter who sets prices in the local currency. This result is intuitive in that with factor price equalization holding both in expectation and ex-post, firms should not set different prices except to account for transportation costs.

3.2 Export cutoff

Define $\hat{\phi}_{X,t}$ as the cutoff productivity at time t for a home firm looking to enter the foreign market. If a firm has a productivity above this level, it will either choose to export to the foreign market or set up a factory there. The marginal firm at the cutoff condition receives zero expected profit net of the fixed cost of exporting, f_X. That is,

$$E_{t-1}\left[d_t\left(\underbrace{S_t p_{H,LCP,t}(\hat{\phi}_{X,t}) y_{H,LCP,t}(\hat{\phi}_{X,t})}_{\text{revenue}} - \underbrace{\frac{W_t y_{H,LCP,t}(\hat{\phi}_{X,t})}{\hat{\phi}_{X,t}}\tau}_{\text{labor costs}}\right)\right] - E_{t-1}\left[d_t \underbrace{S_{t-1} P_t^* f_X}_{\text{fixed costs}}\right] = 0 \equiv \xi(\hat{\phi}_X), \tag{3}$$

where again d_t is the stochastic discount factor of the home firm, $p_{H,LCP,t}$ is the price of the good paid by foreign households (in the foreign currency), $y_{H,LCP,t}$ is the demand of the good at that price, and W_t is the home wage. Define $\xi(\phi)$ as the net profit from exporting for a firm with productivity ϕ.

3.3 Multinational production cutoff

Define $\hat{\phi}_{MP,t}$ as the cutoff productivity at time t above which a firm optimally chooses to serve the foreign market through multinational production rather than exporting. It is the productivity at which expected profits net of fixed costs are equal between the two methods of serving the foreign market. That is,

$$E_{t-1}\left[d_t\left(\underbrace{S_t p_{H,MP,t}(\hat{\phi}_{MP,t}) y_{H,MP,t}(\hat{\phi}_{MP,t})}_{\text{revenue}} - \underbrace{S_t \frac{W_t^* y_{H,MP,t}(\hat{\phi}_{MP,t})}{\hat{\phi}_{MP,t}}}_{\text{labor costs}}\right)\right] \\ - E_{t-1}\left[\underbrace{S_{t-1} P_t^* f_{MP}}_{\text{fixed costs}}\right] - \underbrace{\xi(\hat{\phi}_{MP,t})}_{\text{profit from exporting}} = 0, \quad (4)$$

where the first term is expected export profits of a firm with productivity $\hat{\phi}_{MP,t}$ and the second term is expected multinational profits of the same firm. With further assumptions about the nature of firm price setting, these cutoff expressions can be written in terms of the underlying exogenous variables.

3.4 Results

Consider now the case in which prices are set one period in advance, and both export and multinational prices are set in the foreign currency. In this case, the ratio of the export price relative to the multinational price charged by a firm with productivity ϕ is given by equations (1) and (2):

$$\frac{p_{H,LCP,t}}{p_{H,MP,t}} = \tau \frac{E_{t-1}[d_t P_t^{*\theta} C_t^* W_t]}{E_{t-1}[d_t P_t^{*\theta} C_t^* S_t W_t^*]}.$$

If factor price equalization holds, the expectations cancel and the firms charge the same price after accounting for trade costs. It can then be shown that the relative cutoff is simply:

$$\left(\frac{\hat{\phi}_{MP,t}}{\hat{\phi}_X}\right)^{\theta-1} = \frac{f_{MP} - f_X}{f_X\left(\tau^{\theta-1} - 1\right)}.$$

Thus, the relative extensive margin is unaffected by nominal uncertainty. The extensive margin is illustrated in Figure 1. Here, profits are shown on the vertical axis, and productivity (to the power $\theta - 1 > 0$) is shown in the horizontal axis. The dotted lines represent the initial (stochastic) steady state, and the solid (green) lines depict the change after an increase in foreign volatility.

Firms engage in domestic production if their expected profits exceed the fixed cost f; this is where the expected profit line crosses the x-axis. A foreign firm with productivity higher than $\hat{\phi}_D^*$ will produce in the foreign market. Similarly, a firm will export if its expected profits exceed the fixed cost f_X. Since exports are subject to a transportation cost, these profit lines have a smaller slope and even with the same fixed cost as domestic production, there would be a higher threshold $\hat{\phi}_X$ to export. Finally, very productive firms will find it optimal to switch to multinational production if the expected profit from producing abroad exceeds the expected profit from exporting; that is, the cutoff $\hat{\phi}_{MP}$ lies where the expected profits from exporting $E[\pi_X]$ and multinational production $E[\pi_{MP}]$ intersect.

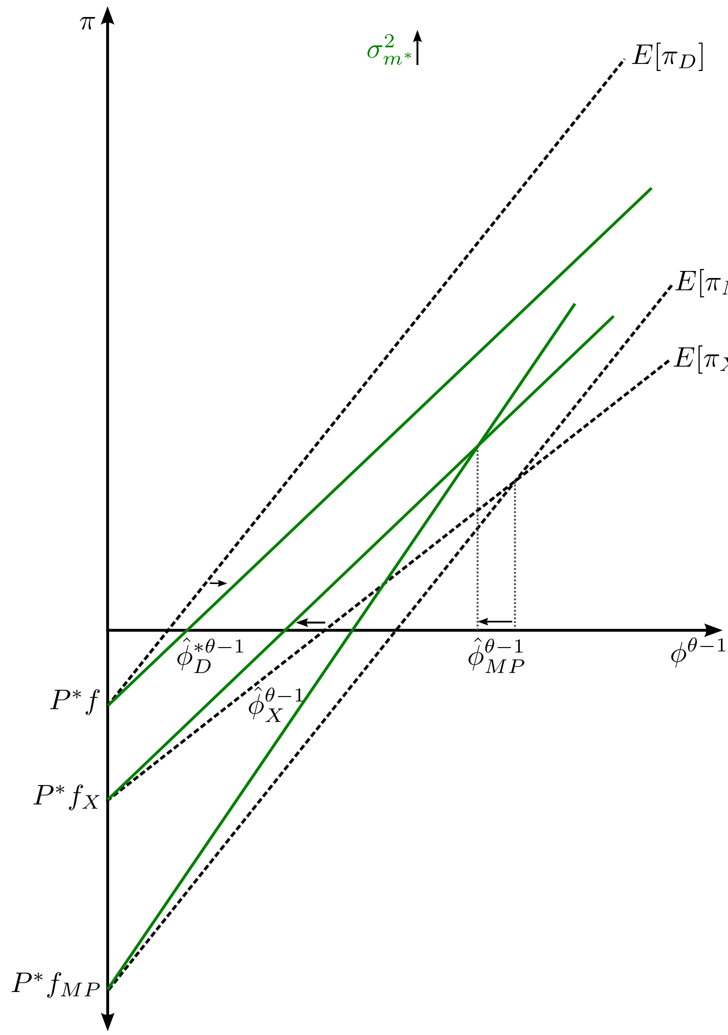
An increase in foreign volatility has a negative impact on the foreign producers, while it encourages both exports and multinational production. The intuition is that foreign volatility is good for home producers because a foreign monetary contraction coincides with a foreign currency appreciation, more than compensating the home producers. So both cutoffs fall. But what about actual trade flows and multinational sales? For that, I must be more explicit about the shape of the firm distribution. Proposition 1 demonstrates sufficient conditions under which the export and multinational sales changes are proportional.

Proposition 1 *If firm productivity is characterized by a Pareto distribution, exports are priced in the foreign currency, and factor price equalization holds, then the ratio of multinational sales to exports is unaffected by uncertainty.*

Proof. See appendix.

The basic intuition of the proof is that relative prices are unaffected by nominal volatility, then the relative sales of multinationals and exporters depends only on the mass of firms of each type and the ratio of average productivities. With a Pareto distribution, it can be shown that the ratio of average productivities and ratio of the mass of firms remain constant as volatility changes.

Figure 1: Domestic, export, and FDI cutoffs before (dotted) and after (solid) an increase in foreign nominal volatility



The dotted line and solid line depict the first and second steady states, respectively. The second steady state represents a higher foreign volatility.

3.5 A note on the flexible price case

It is useful to understand the model's implications under flexible prices for the extensive margin choice between multinational production and exporting. The only decision made in advance is that of whether and how to produce for the foreign market. The cutoff conditions are still a function of expected profits, which could be influenced by any number of shocks. The following proposition demonstrates formally that so long as factor price equalization holds, the relative extensive margin is unaffected by any uncertainty about future consumption, exchange rates, prices, etc.

Proposition 2 *With flexible prices and factor price equalization, the relative extensive margin between exports and multinational production is unaffected by uncertainty.*

Proof. With the export price $p_{H,X,t}(\phi) = \frac{1}{S_t}\frac{\theta}{\theta-1}\frac{W_t}{\phi}$, the export cutoff (3) becomes:

$$\hat{\phi}_{X,t}^{\theta-1} = \frac{E_{t-1}[d_t P_t^* S_{t-1} f_x]}{\tau^{1-\theta}\left(\left(\frac{\theta}{\theta-1}\right)^{1-\theta} - \left(\frac{\theta}{\theta-1}\right)^{-\theta}\right) E_{t-1}\left[d_t S_t^{\theta} P_t^{*\theta} C_t^* W_t^{1-\theta}\right]}.$$

With flexible prices, the multinational price is $p_{F,MP,t}(\phi) = \frac{\theta}{\theta-1}\frac{W_t^*}{\phi}$ and the multinational cutoff (4) becomes:

$$\hat{\phi}_{MP,t}^{\theta-1} = \frac{E_{t-1}[d_t P_t^* S_{t-1}(f_{MP} - f_X)]}{\left(\left(\frac{\theta}{\theta-1}\right)^{1-\theta} - \left(\frac{\theta}{\theta-1}\right)^{-\theta}\right)\left(E_{t-1}\left[d_t S_t P_t^{*\theta} C_t^* W_t^{*1-\theta}\right] - \tau^{1-\theta} E_{t-1}\left[d_t S_t^{\theta} P_t^{*\theta} C_t^* W_t^{1-\theta}\right]\right)}.$$

More informative is the relative cutoff expression:

$$\left(\frac{\hat{\phi}_{MP,t}}{\hat{\phi}_X}\right)^{\theta-1} = \frac{f_{MP} - f_X}{f_X\left(\tau^{\theta-1}\frac{E_{t-1}\left[d_t S_t P_t^{*\theta} C_t^* W_t^{*1-\theta}\right]}{E_{t-1}\left[d_t S_t^{\theta} P_t^{*\theta} C_t^* W_t^{1-\theta}\right]} - 1\right)}.$$

Here, we can see that the effects of uncertainty reduce down to a ratio $\frac{E_{t-1}\left[d_t S_t P_t^{*\theta} C_t^* W_t^{*1-\theta}\right]}{E_{t-1}\left[d_t S_t^{\theta} P_t^{*\theta} C_t^* W_t^{1-\theta}\right]}$. Note that if factor price equalization holds, i.e. $S_t W_t^* = W_t$, then this ratio equals 1. Then the relative cutoff expression becomes $\frac{f_{MP}-f_X}{f_x}(\tau^{\theta-1} - 1)^{-1}$, exactly that found by Helpman et al. (2004) in a deterministic setting. Thus, with flexible prices, any effect of uncertainty on the relative extensive margin requires factor price equalization not to hold. This is true regardless of the presence of other sectors with sticky prices and regardless of the underlying shock process.

3.6 Factor price equalization

Factor price equalization holds in the baseline model because of complete markets and labor entering linearly in the utility function, as noted by Devereux and Engel (1999). This leads to the first order conditions $W_t = P_t C_t^{\rho}$ and $W_t^* = P_t^* C_t^{*\rho}$. Because the real exchange rate is the ratio of marginal utilities of consumption, it follows that the nominal exchange rate $S_t = \frac{P_t C_t^{\rho}}{P_t^* C_t^{*\rho}}$, and thus $W_t = S_t W_t^*$.

One can relax the assumption about complete markets or the assumption about labor entering linearly. Relaxing incomplete markets will not provide very large deviations from factor price equalization. Labor entering with an exponent $1+\nu$ and $\nu > 0$, can break factor price equalization more substantially. Here, the first order conditions become $W_t = P_t C_t^{\rho} l_t^{\nu}$. Thus, as more labor is utilized for a given level of consumption, wages must rise to compensate households.

While this is certainly a reasonable assumption, it produces wage dynamics soundly rejected by the data. Maintaining the assumption of FPE, we have in logs $\hat{W}_t = \hat{S}_t + \hat{W}_t^*$. In the data, the wage-based real exchange rate (from relative unit labor costs) corresponds to $\frac{W_t}{S_t W_t^*}$, which is far from constant, and tracks the nominal exchange rate closely. That is, $\hat{W}_t \approx \hat{W_t}^*$. With non-linear labor, the model implies that given a home monetary expansion, home wages rise more than foreign wages expressed in the home currency. That is, $\hat{W}_t > \hat{S}_t + \hat{W}_t^*$. This makes nominal wages even more volatile, contrary to the data.

4 Model where exports are priced in the producer's currency

4.1 Exporter price setting in advance, producer cost pricing

Suppose instead that exporters set prices in their own currency. This is the predominant case for the U.S., where 97% of exports are priced in dollars (Gopinath and Rigobon, 2008). That is, $p_{H,PCP,t}$ is dollar-denominated, and changes to the nominal exchange rate S_t have complete pass-through to the foreign-currency price faced by households $p_{H,PCP,t}/S_t$.

The firm's price optimization then takes the following form:

$$\max_{p_{H,PCP,t}} E_{t-1}\left[d_t\left(p_{H,PCP,t}y_{H,PCP,t} - \tau\frac{W_t}{\phi}y_{H,PCP,t}\right)\right].$$

Note that here, output is:

$$y_{H,PCP,t} = \left(\frac{P_t^*}{p_{H,PCP,t}/S_t}\right)^{\theta} C_t^*.$$

Standard optimization leads to the following optimal price:

$$p_{H,PCP,t} = \frac{\theta}{\theta-1}\tau\frac{1}{\phi}\frac{E_{t-1}\left[d_t W_t S_t^{\theta} P_t^{*\theta} C_t^*\right]}{E_{t-1}\left[d_t S_t^{\theta} P_t^{*\theta} C_t^*\right]}. \tag{5}$$

The export cutoff condition becomes:

$$E_{t-1}\left[d_t\left(p_{H,PCP,t}(\hat{\phi}_X)y_{H,PCP,t}(\hat{\phi}_X) - \tau\frac{W_t}{\hat{\phi}_X}y_{H,PCP,t}(\hat{\phi}_X)\right)\right] = E_{t-1}[d_t S_{t-1} P_t^* f_x]. \tag{6}$$

where $y_{H,PCP,t} = \left(\frac{P_t^*}{p_{H,PCP,t}S_t^{-1}}\right)^{\theta} C_t^*$. (6) can be rewritten as:

$$E_{t-1}\left[d_t S_t^{\theta} P_t^{*\theta} C_t^*\left(p_{H,PCP,t}^{1-\theta} - \tau\frac{W_t}{\hat{\phi}_X}p_{H,PCP,t}^{-\theta}\right)\right] - E_{t-1}[d_t S_{t-1} P_t^* f_x] = 0 \equiv \xi(\hat{\phi}_X).$$

Where $\xi(\phi)$ is the net profit of an exporter for any productivity ϕ. Using this, the multinational cutoff can be written:

$$E_{t-1}\left[d_t\left(\underbrace{S_t p_{H,MP,t}(\hat{\phi}_{MP,t})y_{H,MP,t}(\hat{\phi}_{MP,t})}_{\text{revenue}} - \underbrace{S_t\frac{W_t^* y_{H,MP,t}(\hat{\phi}_{MP,t})}{\hat{\phi}_{MP,t}}}_{\text{labor costs}}\right)\right] - E_{t-1}\left[\underbrace{S_{t-1}P_t^* f_{MP}}_{\text{fixed costs}}\right] - \underbrace{\xi(\hat{\phi}_{MP,t})}_{\text{profit from exporting}} = 0.$$

4.2 A Numerical Illustration

With producer cost pricing, multinational revenue and export revenue are now affected differently by nominal volatility. Multinational revenue is a function only of demand C_t^*, since the price is set in advance in the foreign currency. Export revenue varies with the exchange rate as pass-through to export prices in the foreign currency is complete.

Since export prices now vary with the exchange rate, the price index P_t^* becomes uncertain at date $t-1$. This substantially complicates solving the model analytically, so I proceed numerically by discretizing the state space for the foreign money supply M^* and computing the stochastic steady state for various $\sigma_{m^*}^2$.

Table 1: Model parameters

β	0.96	Annual discount rate
ρ	2	Standard risk-aversion
θ	5	Elasticity of substitution
k	$\theta + 0.1$	Pareto shape parameter
τ	1.2	20% iceberg trade cost
$f_X = f$	0.035	Fixed cost of local firms and exporters
f_{MP}	1	60% of foreign sales from multinationals

To do this, I must calibrate the model parameters.[11] Table 1 outlines the parameters in the model. Most parameters are very standard; as is common in the trade literature, I use an elasticity of substitution between varieties of 5, in the middle of most estimates.[12] The Pareto shape parameter k governing the distribution of firm productivities is taken to be very close to the elasticity of substitution, as in Russ (2007). Iceberg trade costs of 20% are within the range of estimated tariffs and freight costs. This leaves the fixed costs. I set the fixed costs of domestic production and export to be the same, as the focus here is on multinational production.[13] I set the fixed costs of multinational production to be consistent with 60% of the value of foreign sales to come from multinational affiliates, consistent with the average of the data used in Section 5. As the variance of the foreign money supply grows, exporting becomes relatively more attractive compared to multinational production. Consider an unexpected foreign contraction. Demand C_t^* falls for both multinational firms and exporters, and the foreign exchange rate appreciates (S_t rises). This makes profits denominated in the home currency higher for both exporters and multinationals.[14] In addition, the exporter's price, set in the home currency, becomes relatively cheaper in foreign currency terms. This stimulates greater demand, and the home exporter's price is closer to its profit-maximizing point. This automatic adjustment of the price makes a PCP exporter relatively better off in the presence of higher foreign uncertainty. This effect tends to dominate regardless of

[11] Substantial experimentation with the model parameters reveals that the main qualitative results are not sensitive to the precise parameters chosen.

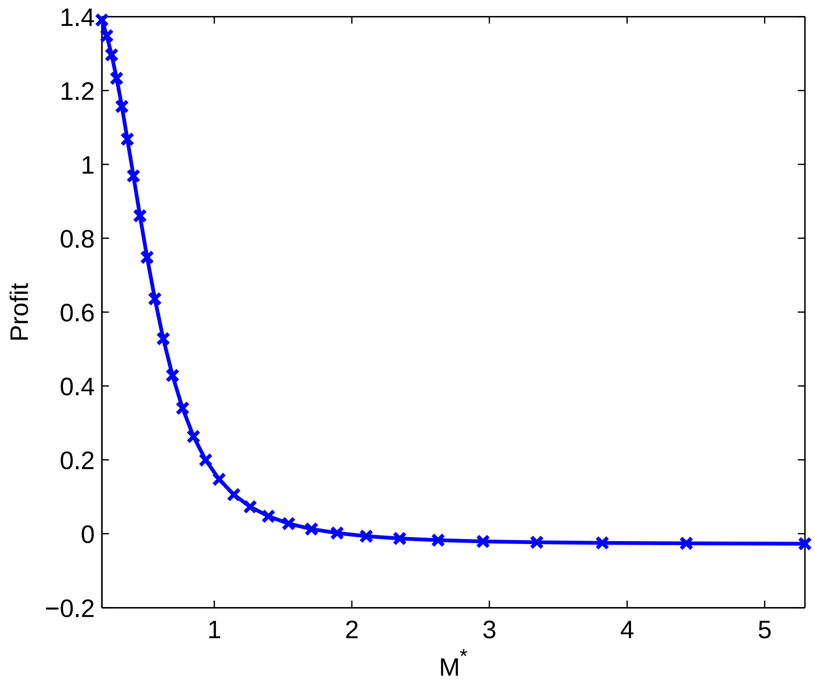
[12] See Ruhl (2008) for a survey.

[13] These fixed costs imply that 35% of potential entrants export and 90% produce domestically under no uncertainty.

[14] This is also the basic result from Russ (2007), showing that higher foreign volatility is relatively better for home firms over foreign firms in the foreign market.

the correlation between foreign demand C_t^* and the exchange rate S_t, say, from other sources of shocks. To better understand this, consider first Figure 2. It plots the profit of a home exporter

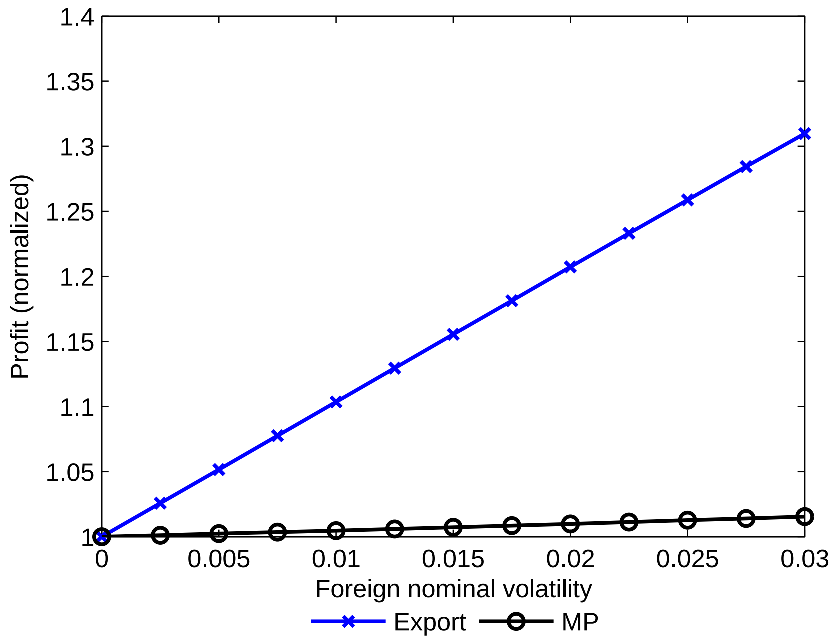
Figure 2: Convexity of the exporter profit function



against realizations of the foreign money supply M^*. Each point represents a value of the foreign money supply on the discretized grid. Starting from the median of about 1, the probability of moving one point left is equal to the probability of moving one point right. Clearly, exporter profit is highly convex in the foreign money supply. The exporter benefits dramatically more from foreign contractions than it suffers from foreign expansions.

As foreign nominal volatility rises, it increases the likelihood that the firm finds itself further away from the median point. Since the likelihood of a significant foreign contraction increases, this increases the expected profit of an exporter. A multinational does benefit from foreign volatility as well. Yet the multinational does not gain the advantage of having its price automatically lowered in foreign currency terms as a PCP exporter does. Figure 3 shows the relative impact of expected profit for a sample firm as volatility increases. Multinational profit does increase slightly, but it

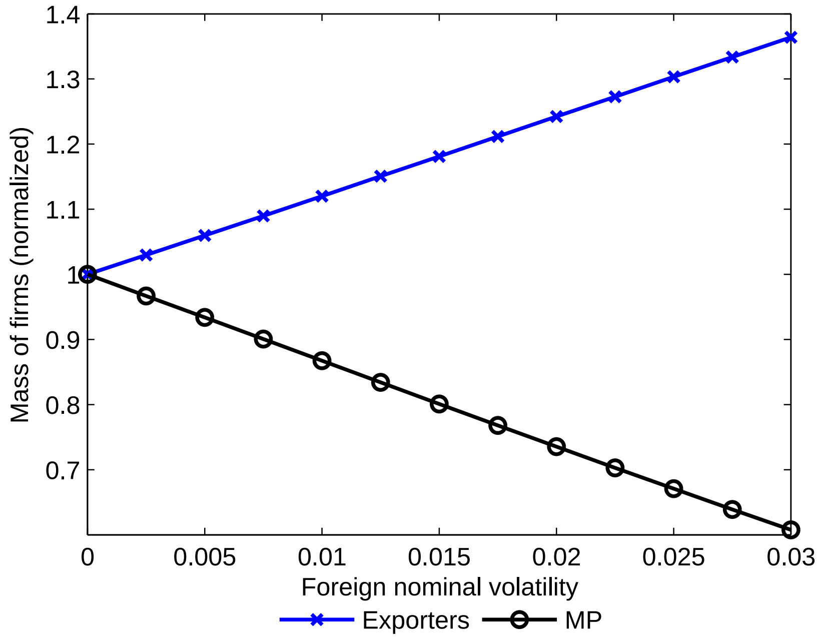
Figure 3: Expected profit for an example firm



is dwarfed by the dramatic increase in expected profit for an exporter. Expected profit is exactly what determines the extensive margin from (6). As expected profit of a potential exporter rises, it draws in firms from both margins: firms which would otherwise only produce domestically and firms which would otherwise be multinationals. Figure 4 shows the relative impact on the extensive margin for exporters and multinationals. As volatility rises, many multinationals become exporters, reducing their mass. Note that because there are many more exporters, a similar percentage gain in the mass of exporters represents a much larger mass of firms.

In terms of quantity, this translates to a relatively small drop in multinational sales; the lowest productivity multinational firms become exporters, so their total effect is relatively small. For exporters, on the other hand, these new firms are the most productive and translate to a large increase in trade. This can be seen in Figure 5. Finally, because the effects of volatility may work through additional unmodeled channels, I focus on the fraction of multinational sales as a portion of total foreign sales in Figure 6. In both value and quantity terms, the fraction of foreign sales

Figure 4: The extensive margin of exporters and multinationals



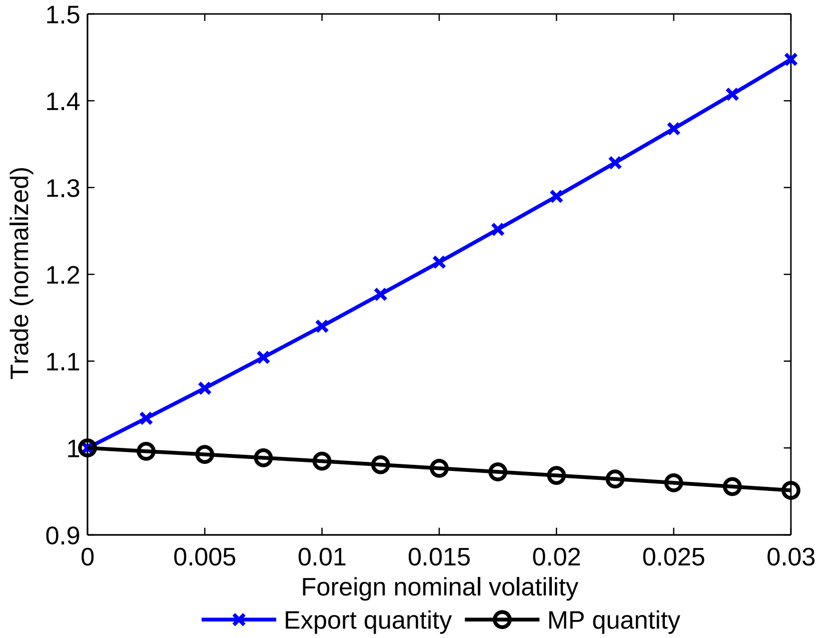
from multinationals falls as volatility rises. Given the current calibration, going from no volatility to a volatility of 0.03 leads to a drop in multinational sales from about 60% to below 50%.

5 Data

I move now to consider evidence based on U.S. exports and U.S. multinational foreign affiliate sales. I use multinational sales data from the BEA for 1999-2007 (the latest year currently available) and match it to export data from the U.S. International Trade Commission. This data exists at the sector, country, year level. Full details of the data used in the regressions are available in Tables 4 and 5 in the appendix.

It is important to keep in mind that both measures are in nominal U.S. dollars. For trade, the Bureau of Labor Statistics does not construct price indices for each export destination. Similarly, there are no multinational sales-specific price indices available by destination country. The analysis in the forthcoming sections will be in terms of nominal ratios, but these may not necessarily

Figure 5: Quantity sales by exporters and multinationals



correspond to the real goods quantity ratios.

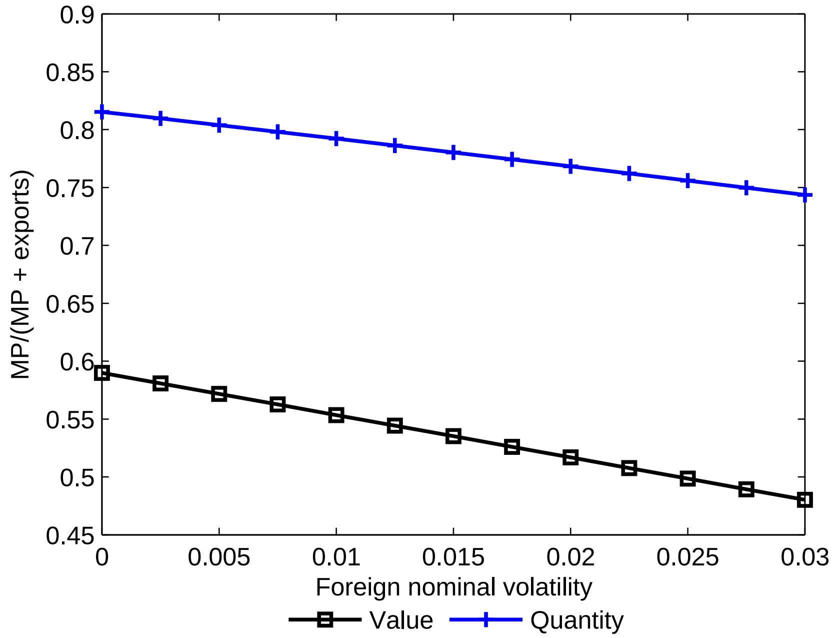
I exclude a small number of countries which experienced currency or debt crises during this time sample.[15] Robustness analysis in Section 5.2 shows that the main results of the preferred specification are unaffected by including them.

5.1 Results

There are several measures of volatility one might consider to proxy for the nominal volatility in the model. At its most basic, the model has implications for the money supply growth rate; yet this is a theoretical stand-in for many such nominal demand forces which an economy may face. Since the data on money supplies is lacking for some countries in the sample, it makes sense to consider a more widely available measure: consumer price inflation. In the model, the nominal volatility directly translates to inflation volatility. On the other hand, it also translates into exchange rate volatility; this may seem like the most logical volatility variable, yet because exchange rates are

[15] These countries are Argentina, Turkey, Venezuela, Brazil, and the Dominican Republic.

Figure 6: The fraction of total foreign sales from multinationals



influenced by a large number of other shocks, we will see that inflation can have a very different effect on multinational production compared to exchange rate volatility.

It is reasonable to think that there could be a large number of shocks affecting both exports and multinational sales; it makes sense, then, to consider exports and sales jointly and look for a relative effect. To that end, I estimate the following:

$$\frac{sales_{i,t}}{sales_{i,t}+EX_{i,t}} = \beta_0 + \beta_1\sigma(\Delta\ln(P_{i,t})) + \beta_2\sigma(\Delta\ln(\mathrm{S}_{i,t})) + \gamma Z_{i,t} + \epsilon_{i,t}. \tag{7}$$

where $sales$ is sales by foreign affiliates of U.S. multinationals in country i, mapped to the data as total foreign sales of U.S. affiliates. EX are total exports to country i. Both are in current U.S. dollars. Thus, the dependent variable is the fraction of multinational sales as a share of multinational sales and exports. The variable of interest on the right hand side is $\sigma(\Delta\ln(P_{i,t}))$, the volatility of the price level in country i for year t[16]. The volatility of the nominal exchange

[16]The CPI measures are monthly, and the standard deviation is taken for each year.

Table 2: The response of trade and multinational sales to inflation volatility

	(1)	(2)	(3)
Inflation Volatility	-15.79**	-15.42***	-16.14***
	(5.927)	(5.096)	(4.908)
Exchange Rate Volatility		2.156	1.903
		(1.492)	(1.271)
Inflation Level	-3.523	4.661	14.73**
	(7.906)	(6.106)	(5.953)
OECD		0.187***	0.150**
		(0.0483)	(0.0612)
US Border		-0.174***	-0.0170
		(0.0401)	(0.0642)
ln(real GDP per capita)			0.0326
			(0.0244)
ln(distance)			0.113**
			(0.0456)
Industry dummies	yes	yes	yes
Year dummies	yes	yes	yes
Observations	2,809	2,809	2,525
R-squared	0.294	0.382	0.397

Notes: The dependent variable is sales/(sales + exports). *** p<0.01, ** p<0.05, * p<0.1, standard errors clustered by country in parentheses

rate is $\sigma(\Delta \ln(S_{i,t}))$, Z consists of a number of country/time specific variables as controls, and $\epsilon_{i,t}$ is the regression residual. Given the limitations of cross-country regressions, β_1 is best considered a conditional correlation, controlling for other likely determinants of the dependent variable.

The results pooling available sectors, countries, and years together are presented in Table 2. Each regression has both industry and year dummies, which controls for changes in the overall business cycle and the particular characteristics of each industry.[17] There is a robust negative coefficient on inflation volatility. Economically, this means an increase in one standard deviation of inflation volatility decreases multinational sales as a fraction of total foreign sales by 5 percentage points, or about one-seventh of a standard deviation in the pooled ratios.

The regressions include a number of controls in columns 2 and 3. Whether the country is a member of the OECD (generally a developed country status) tends to have a positive impact on the ratio of multinational sales to exports; this is consistent with many explanations, including

[17]The results are very similar with industry-year dummies.

Table 3: Total multinational sales as a fraction of total multinational sales and exports, by industry

Industry	Inflation volatility	Exrate volatility	Obs.
Information	-9.36*	0.85**	329
Manufacturing (chemical)	-4.12	2.78	349
Manufacturing (computers)	-11.88	0.18	310
Manufacturing (electrical)	-32.77**	3.10	303
Manufacturing (food)	-29.46**	0.96	326
Manufacturing (machinery)	-14.27*	1.81	317
Manufacturing (metals)	-10.78	3.09	300
Manufacturing (transportation)	-32.29**	4.34	301
Mining	16.52	0.62	274

Notes: The dependent variable is sales/(sales + exports). Inflation level, U.S. border, OECD, year dummies included in all regressions. *** $p<0.01$, ** $p<0.05$, * $p<0.1$, clustered by country

that developed countries have good institutions which permit horizontal FDI to be more profitable. On the other hand, Mexico and Canada tend to have lower multinational sales relative to exports; this is consistent with the relatively low transportation costs and tariffs from being members of NAFTA. GDP per-capita and distance do not have a statistically significant effect, though the sign on distance is the expected one.

Given that the industry dummies do not control for a heterogeneous impact of inflation volatility by sector, I re-run the analysis for each sector individually in Table 3. Here, we see that information, electrical, food, machinery, and metals sectors all have negative and significant coefficients. Chemical manufacturing has a negative coefficient but it is relatively small and statistically insignificant. The outlier is mining, an industry which does not lend itself to horizontal FDI in many cases. Exchange rate volatility is positive and insignificant in all regressions except information.

5.2 Robustness

I subject the pooled results of Section 5.1 to a series of robustness checks. The results are shown in Table 6 in the appendix. Column 1 reports the results adding back in the crisis countries, showing that the results are not sensitive to those outliers. Column 2 includes a number of additional controls, including real GDP volatility with a significant, negative coefficient, and an array of gravity-equation variables: common language, former colony, currency union, and landlocked status. In this specification, none of these additional explanatory variables are statistically significant.

Column 3 performs the same exercise as column 2, but leaves the crisis countries in. Again, inflation volatility is significantly negative and of similar magnitude, but now real GDP volatility is not significant. Column 4 instead clusters the errors by industry rather than country, showing that the statistical significance of inflation volatility is not sensitive to this choice. Exchange rate volatility, on the other hand, is now significant and positive.

Columns 5 and 6 report similar regressions with a different dependent variable: the log of the sales/export ratio. This is the measure used by Ramondo et al. (2010) in the context of GDP volatility. Without the crisis countries, I find a positive and insignificant response of inflation volatility, and with the crisis countries the coefficient becomes negative and insignificant. Exchange rate volatility is positive and significant in both cases, while real GDP volatility is negative and insignificant.

Note that the log ratio puts substantial weight on observations with relatively small multinational sales or relatively small exports. In the data, there are a number of such observations that I plot in appendix Figure 7. Some of these observations in the tails are the result of either zero multinational sales or zero exports; I eliminate them in Figure 8, showing that a substantial proportion remain.[18] The log ratio by construction eliminates the extreme points while heavily weighting the near extreme points, making it less suitable for industry-level analysis with a large number of countries. This would only be compounded with more disaggregated data.

5.3 Discussion of exchange rate volatility

The empirical results in Section 5.1 support the model's prediction that increased nominal volatility as measured by inflation volatility should reduce the ratio of multinational sales as a fraction of total foreign sales. Yet the results for exchange rate volatility go in the opposite direction, if anything.

[18] If I run pooled regression (3) using only those observations with non-zero exports and non-zero multinational sales, I obtain a point estimate for the effects of inflation volatility on the fraction of multinational production relative to total foreign sales of -4.19 significant at the 10% level.

The model does imply that nominal volatility affects the firm's choice *through* the exchange rate, and as inflation volatility rises so should exchange rate volatility. This is not necessarily inconsistent with the empirical evidence, however.

Eichenbaum and Evans (1995) provide empirical evidence supporting the notion that a contractionary monetary policy shock appreciates the U.S. dollar relative to various foreign currencies.[19] While based on U.S. monetary policy, this evidence is consistent with the model's mechanism that a foreign monetary contraction will lead to a foreign nominal exchange rate appreciation.

Exchange rates are not driven entirely by any one shock, however. Another underlying source of exchange rate fluctuations could have the opposite effect on exporting or multinational firms' profits through another channel. Exchange rate volatility may also affect firms if the firm itself is risk averse.[20] Because exchange rate volatility is not robustly significant in the preferred specifications, I do not explicitly model the potential effects of risk aversion on this channel. My results do suggest, however, that one should not conflate the nominal volatility of the sort modeled in this paper with nominal exchange rate volatility.

6 Conclusion

International trade theory has recently made significant progress in modeling the endogenous choice of how to serve a foreign market. Yet the standard static considerations are only part of a firm's consideration; this paper contributes to this growing literature by considering how nominal uncertainty affects this choice. This is of particular policy relevance since inflation volatility is commonly seen as something that can be tamed by modern monetary policy.

I show how in a general equilibrium model where exports are priced in the producer's currency and multinational production is priced in the local currency, an increase in foreign nominal volatility decreases the fraction of foreign sales coming from multinational production. Using bilateral, multisector trade and multinational sales from the U.S., I find support for this result in the data.

The model predicts that if the country's exports are LCP, then volatility will not matter. As

[19] Landry (2009) provides more recent evidence.

[20] Examples of this include Cushman (1985) and Goldberg and Kolstad (1995).

more data becomes available about the activity of multinationals, this can be tested by examining the export and multinational behavior of other countries. Future work should also incorporate vertical production as well as horizontal production, to generate predictions which better match the available trade and multinational sales data. The data suggest that future empirical studies of the effects of volatility on trade or foreign investment should distinguish between exchange rate volatility in general and other forms of uncertainty such as inflation volatility.

References

Bhattarai, S. (2009) "Optimal Currency Denomination of Trade: Theory and Quantitative Exploration."

Cavallari, Lilia (2007) "A Macroeconomic Model of Entry with Exporters and Multinationals," *The B.E. Journal of Macroeconomics*, Vol. 7, No. 1.

——— (2008) "Macroeconomic Interdependence with Trade and Multinational Activities," *Review of International Economics*, Vol. 16, No. 3, pp. 537–558.

——— (2009) "Exports and foreign direct investments in an endogenous-entry model with real and nominal uncertainty," *Journal of Macroeconomics*, Vol. In Press, Corrected Proof.

Chari, V V, Patrick J Kehoe, and Ellen R McGrattan (2002) "Can sticky price models generate volatile and persistent real exchange rates?" *The Review of Economic Studies*, Vol. 69, No. 240, p. 533.

Cushman, David O. (1985) "Real Exchange Rate Risk, Expectations, and the Level of Direct Investment," *The Review of Economics and Statistics*, Vol. 67, No. 2, pp. 297–308.

Devereux, Michael B. and Charles Engel (1999) "The Optimal Choice of Exchange-Rate Regime: Price-Setting Rules and Internationalized Production," *National Bureau of Economic Research Working Paper Series*, Vol. No. 6992.

Eichenbaum, Martin and Charles L. Evans (1995) "Some Empirical Evidence on the Effects of Shocks to Monetary Policy on Exchange Rates," *The Quarterly Journal of Economics*, Vol. 110, No. 4, pp. 975–1009.

Engel, Charles (2006) "Equivalence Results for Optimal Pass-Through, Optimal Indexing to Exchange Rates, and Optimal Choice of Currency for Export Pricing," *Journal of the European Economic Association*, Vol. 4, No. 6, pp. 1249–1260.

Fillat, Jose and Stephania Garetto (2009) "Risk, Returns, and Multinational Production."

Giovannini, Alberto (1988) "Exchange rates and traded goods prices," *Journal of International Economics*, Vol. 24, No. 1-2, pp. 45–68.

Goldberg, Linda S. and Charles D. Kolstad (1995) "Foreign Direct Investment, Exchange Rate Variability and Demand Uncertainty," *International Economic Review*, Vol. 36, No. 4, pp. 855–873.

Gopinath, Gita and Roberto Rigobon (2008) "Sticky Borders*," *Quarterly Journal of Economics*, Vol. 123, No. 2, pp. 531–575.

Gopinath, Gita, Oleg Itskhoki, and Roberto Rigobon (2010) "Currency Choice and Exchange Rate Pass-Through," *American Economic Review*, Vol. 100, No. 1, pp. 304–336.

Helpman, Elhanan, Marc J. Melitz, and Stephen R. Yeaple (2004) "Export versus FDI with Heterogeneous Firms," *The American Economic Review*, Vol. 94, No. 1, pp. 300–316.

Irarrazabal, A. A and L. D Opromolla (2009) "A Theory of Entry and Exit into Exports Markets,"Technical report, Mimeo, New York University.

Landry, Anthony (2009) "State-dependent pricing, local-currency pricing, and exchange rate pass-through," *Journal of Economic Dynamics and Control*, Vol. In Press, Corrected Proof.

Obstfeld, Maurice and Kenneth Rogoff (1998) "Risk and Exchange Rates," *National Bureau of Economic Research Working Paper Series*, Vol. No. 6694.

Ramondo, N. and V. Rappoport (2009) "The Role of Multinational Production in a Risky Environment."

Ramondo, N., V. Rappoport, and K. J Ruhl (2010) "The Proximity-Concentration Tradeoff under Uncertainty."

Rose, Andrew (2005) "Which International Institutions Promote International Trade?" *Review of International Economics*, Vol. 13, No. 4, pp. 682–698.

Ruhl, K. (2008) "Solving the elasticity puzzle in international economics," *Mimeo.*

Russ, Katheryn (2007) "The endogeneity of the exchange rate as a determinant of FDI: A model of entry and multinational firms," *Journal of International Economics*, Vol. 71, pp. 344–372.

Schoenle, Raphael (2010) "International Menu Costs and Price Dynamics," *Mimeo, Princeton University.*

A Technical Appendix

A.1 Derivation of S_t

The representative household faces the following budget constraint, written in nominal home currency:

$$P_tC_t + \sum_{s^{t+1}} Q(s^{t+1}|s^t)B(s^{t+1}) + M_t = M_{t-1} + W_tL_t + B(s^t) + \Pi_t + T_t.$$

where Π_t are profits from domestic firms and T_t are lump-sum transfers of seigniorage revenues from the government. As standard in the literature, s^t denotes the state of the world (including the history up to time t), and is used to construct a complete set of securities $B(s^{t+1})$.

The first order conditions are then very standard,[21] with Lagrange multiplier λ_t :

$$\begin{aligned}
C_t : U_C(\cdot) &= \lambda_t P_t \\
L_t : U_L(\cdot) + \lambda_t W_t &= 0 \\
M_t : U_M(\cdot) + \beta E_t(\lambda_{t+1}) &= \lambda_t \\
B_{t+1} : Q(s^{t+1}|s^t)\lambda_t &= E_t(\beta\lambda_{t+1}).
\end{aligned}$$

[21]For notational convenience, I omit explicitly writing out the probability of transitioning from state s^t to s^{t+1}.

Using the first order condition for bond holdings, one obtains the expression for the stochastic discount factor:

$$\begin{aligned} Q(s^{t+1}|s^t)\lambda_t &= \beta E_t \lambda_{t+1} \\ Q(s^{t+1}|s^t) &= \beta \frac{P_t C_t^\rho}{P_{t+1} C_{t+1}^\rho} \equiv d_{t+1}. \end{aligned}$$

The utility function has real money balances in logs, yielding an exact log-linear solution as shown by Obstfeld and Rogoff (1998).

Starting with the M_t first order condition:

$$\begin{aligned} U_M + \beta E_t \lambda_{t+1} &= \lambda_t \\ \frac{\chi}{M_t} + \beta E_t \frac{1}{P_{t+1} C_{t+1}^\rho} &= \frac{1}{P_t} C_t^\rho \\ \frac{P_t C_t^\rho \chi}{M_t} + \beta E_t \frac{P_t C_t^\rho}{P_{t+1} C_{t+1}^\rho} &= 1 \\ \frac{P_t C_t^\rho}{M_t} &= 1 - E_t d_{t+1}. \end{aligned}$$

Following Obstfeld and Rogoff (1998), consider

$$\begin{aligned} 1 = \frac{\chi P_t C_t^\rho}{M_t} + E_t \left[\beta \frac{P_t C_t^\rho}{P_{t+1} C_{t+1}^\rho} \right] &= \frac{\chi P_t C_t^\rho}{M_t} + \beta \frac{\chi P_t C_t^\rho}{M_t} E_t \left[\frac{M_t}{P_{t+1} C_{t+1}^\rho} \right] \\ &= \frac{\chi P_t C_t^\rho}{M_t} + \beta \frac{\chi P_t C_t^\rho}{M_t} E_t \left[\frac{M_t}{M_{t+1}} \frac{M_{t+1}}{\chi P_{t+1} C_{t+1}^\rho} \right]. \end{aligned}$$

A candidate solution is one in which $\frac{\chi P_t C_t^\rho}{M_t}$ is a constant for all t. Let $\alpha \equiv E_t \left[\frac{M_t}{M_{t+1}} \right]$. Then,

$$\begin{aligned} 1 &= \frac{\chi P_t C_t^\rho}{M_t} + \beta E_t \left[\frac{M_t}{M_{t+1}} \right] \\ 1 - \beta\alpha \equiv E_t \left[\frac{M_t}{M_{t+1}} \right] &= E_{t-1} \left[\frac{M_{t-1}}{M_t} \right] \\ \Rightarrow \quad C_t^\rho &= \frac{M_t}{P_t} \frac{1 - \beta\alpha}{\chi}. \end{aligned}$$

The foreign budget constraint is analogous:

$$P_t^* C_t^* + \sum_{s^{t+1}} Q(s^{t+1}) B^*(s^{t+1}) \frac{1}{S_t} + M_t^* = M_{t-1}^* + W_t^* L_t^* + \Pi_t^* + T_t^* + B^*(s^t) \frac{1}{S_t}.$$

The equivalent expression for the same bond prices Q is then:

$$Q(s^{t+1}|s^t) = \frac{E_t \lambda_{t+1}^*}{\lambda_t^*} = E_t \left[\frac{U_{c,t+1}^*}{P_{t+1}^* S_{t+1}} \right] \frac{P_t^* S_t}{U_{c,t}^*}.$$

With complete markets, the exchange rate is solved by equating the price of state-contingent bonds $Q(s^{t+1}|s^t)$ and iterating backward. Chari et al. (2002) provide a detailed derivation of this. Iterating this backwards:

$$\begin{aligned}
E_t\left[\frac{1}{P_tC_t^\rho}\right]P_{t-1}C_{t-1}^\rho &= E_{t-1}\left[\frac{1}{C_t^{*\rho}P_t^*S_t}\right]S_{t-1}P_{t-1}^*{C_{t-1}^*}^\rho \\
E_{t-1}\left[\frac{P_0C_0^\rho}{P_tC_t^\rho}\right] &= S_0P_0^*C_0^*E_{t-1}\left[\frac{1}{S_tP_t^*C_t^{*\rho}}\right] \\
\frac{S_0P_0^*C_0^{*\rho}}{P_0C_0^\rho} &\equiv 1 \\
\Rightarrow \quad S_t &= \frac{P_tC_t^\rho}{P_t^*C_t^{*\rho}}.
\end{aligned}$$

With the expression for C_t^ρ, the exchange rate can be expressed as a function of exogenous variables:

$$S_t = \frac{M_t}{M_t^*}\frac{1-\beta\alpha}{1-\beta\alpha^*}.$$

A.2 Proof of proposition 1

The weighted-average exporter productivity is

$$\tilde{\phi}_X^{\theta-1} = \frac{1}{G(\hat{\phi}_{MP})-G(\hat{\phi}_X)}\int_{\hat{\phi}_X}^{\hat{\phi}_{MP}}\phi^{\theta-1}g(\phi)\,d\phi. \tag{8}$$

and the weighted-average multinational productivity is

$$\tilde{\phi}_{MP}^{\theta-1} = \frac{1}{1-G(\hat{\phi}_{MP})}\int_{\hat{\phi}_{MP}}^{\infty}\phi^{\theta-1}g(\phi)\,d\phi.$$

The representative exporter charges the following price:

$$\tilde{p}_{H,X,t}^* = \frac{\theta}{\theta-1}\frac{1}{\tilde{\phi}_X}\tau\frac{E_{t-1}[d_tW_tC_t^*]}{E_{t-1}[d_tS_tC_t^*]}.$$

Using factor price equalization, one can also express the representative multinational firm price:

$$\tilde{p}_{H,MP,t}^* = \frac{\theta}{\theta-1}\frac{1}{\tilde{\phi}_{MP}}\frac{E_{t-1}[d_tW_tC_t^*]}{E_{t-1}[d_tS_tC_t^*]}.$$

Thus, the relative price is simply

$$\frac{\tilde{p}_{H,MP,t}^*}{\tilde{p}_{H,X,t}^*} = \frac{\tilde{\phi}_X}{\tilde{\phi}_{MP}\tau}.$$

Since demand depends only on the price, the ratio of multinational production to exports is simply

$$\frac{N_{MP,t}\tilde{y}_{H,MP,t}^*}{N_{X,t}\tilde{y}_{H,X,t}^*} = \frac{N_{MP,t}}{N_{X,t}}\left(\frac{\tilde{\phi}_X}{\tilde{\phi}_{MP}\tau}\right)^{-\theta},$$

where $N_{MP,t}$ is the fraction of the unit mass of home firms which produce abroad, and $N_{X,t}$ is the fraction which export. To show that nominal uncertainty does not affect this intensive margin, it is necessary to demonstrate that the average productivities $\tilde{\phi}_X$ and $\tilde{\phi}_{MP}$ are themselves unaffected by nominal uncertainty. In addition, the ratio of firm masses must also be unaffected by nominal uncertainty.

To derive expressions for these average productivities, consider imposing the common assumption that firm productivities follow a Pareto distribution with parameter k. Previous work, including Helpman et al. (2004), has found that the Pareto distribution captures well the distribution of firm sizes seen in the data. Recall that if the minimum productivity of any firm is normalized to be 1, the PDF of the Pareto distribution is $g(\phi) = k\phi^{-k-1}$ and the corresponding CDF is $G(\phi) = 1 - \phi^k$.

Above we showed that $\hat{\phi}_{MP}/\hat{\phi}_X$ is a constant. Let γ_X be the value of this ratio. Now we seek to prove that if γ_X is constant, then $\tilde{\phi}_X/\tilde{\phi}_{MP}$ is also constant.

As is now common in the literature, it is straightforward to show that the average multinational productivity depends only on the elasticity of substitution θ, the shape parameter k, and the productivity cutoff $\hat{\phi}_{MP}$:

$$\tilde{\phi}_{MP}^{\theta-1} = \left(\frac{k}{k-\theta+1}\right)\hat{\phi}_{MP}^{\theta-1}.$$

Using the definition of the average productivity (8) above, one can also show that

$$\tilde{\phi}_X = \frac{1}{\hat{\phi}_X^{-k} - \hat{\phi}_{MP}^{-k}} \frac{k}{k-\theta+1}\left[\hat{\phi}_{MP}^{\theta-k-1} - \hat{\phi}_X^{\theta-k-1}\right].$$

Using $\hat{\phi}_{MP} = \gamma_X\hat{\phi}_X$ with $\gamma_X > 1$, one can show:

$$\tilde{\phi}_X^{\theta-1} = \frac{\gamma_X^{\theta-k-1} - 1}{1-\gamma_X^{-k}} \frac{k}{k-\theta+1}\hat{\phi}_X^{\theta-1}.$$

Since γ_X is a constant, this implies that the ratio

$$\frac{\tilde{\phi}_X}{\tilde{\phi}_{MP}} = \frac{\gamma_X^{\theta-k-1} - 1}{1-\gamma_X^{-k}}\left(\frac{\hat{\phi}_X}{\hat{\phi}_{MP}}\right)^{\theta-1}$$

is also constant with respect to nominal uncertainty.

Finally, consider the mass of firms engaged in multinational production. This is simply

$$N_{MP} = \hat{\phi}_{MP}^{-k}.$$

and

$$N_X = \hat{\phi}_X^{-k} - \hat{\phi}_{MP}^{-k}.$$

With $\hat{\phi}_{MP} = \gamma_X\hat{\phi}_X$, we have $N_X = \hat{\phi}_X^{-K}(1-\gamma_X^{-k})$ and thus

$$\frac{N_{MP}}{N_X} = \left(\frac{\hat{\phi}_{MP}}{\hat{\phi}_X}\right)^{-k}\frac{1}{1-\gamma^{-k}}.$$

That is, nominal uncertainty does not affect the relative extensive margin $\hat{\phi}_{MP}/\hat{\phi}_X$, or the relative mass of firms $N_{MP,t}/N_{X,t}$. Thus, it does not affect the relative intensive margin $\tilde{y}_{H,MP,t}/\tilde{y}_{H,X,t}$.

A.3 Numerical solution

The model with PCP exports no tractable analytical solutions for the stochastic steady state. Instead, I employ numerical techniques to characterize the equilibrium. The basic premise is to discretize the exogenous, stochastic variable (M^*), and solve the model such that the pricing, cutoff, and equilibrium conditions hold in every state s^t. That is, the expectations are solved by discretizing the exogenous process with quadrature methods. Since the export choice and pricing decisions are made one period in advance, the equilibrium need only be solved for period t given conditions in $t-1$.

M^* is discretized with Gaussian quadrature methods using 30 nodes. Then, using numerical search over $\hat{\phi}_H$, $\hat{\phi}_X$, $\hat{\phi}_{MP}$, p_H, $p_{H,PCP}$, $p_{H,X}$, I calculate the other endogenous variables.[22] The numerical algorithm iterates until the following equilibrium conditions hold:

1. The domestic cutoff condition
2. The exporter cutoff condition
3. The multinational production cutoff condition
4. The domestic price condition
5. The exporter price condition
6. The multinational production price condition

B Data appendix

B.1 Data description

Table 4 lists the sources of the variables used in the estimation procedure. Table 5 provide summary statistics for each variable.

[22] The model can be solved for one country without calculating the endogenous variables of the other country, saving substantial numerical search space.

Table 4: Data sources

Variable description	Source
Sales by majority-owned foreign affiliates of U.S. multinational firms	Bureau of Economic Analysis
Exports by major industry	USITC
Inflation ($\Delta \ln$ CPI), nominal exchange rate	IMF International Financial Statistics
Real GDP per capita, distance, common language, colony, currency union, landlocked	Rose (2005)

Table 5: Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
sales/(sales + exports)	3485	0.581	0.35	0	1
ln(sales/exports)	2962	1.095	2.53	-7.516	13.016
Inflation Volatility	3159	0.005	0.00	0.001	0.039
Inflation Level	3159	0.004	0.01	-0.003	0.044
Exchange Rate Volatility	3485	0.019	0.02	0	0.225
Landlocked	3225	0.064	0.25	0	1
Common Language	3225	0.336	0.47	0	1
Colony	3225	0.044	0.20	0	1
Currency Union	3225	0.018	0.13	0	1
Log Distance	3225	8.501	0.50	6.981	9.154
ln(real GDP per capita)	3458	9.009	1.25	5.883	10.936
Real GDP Volatility	3485	0.019	0.02	0.004	0.087
Crisis	3485	0.100	0.30	0	1
OECD	3485	0.446	0.50	0	1

Table 6: Robustness exercises of pooled regressions

	(1)	(2)	(3)	(4)	(5)	(6)
		sales/(sales + exports)			ln(sales/exports)	
Inflation Volatility	-17.09***	-12.64**	-14.71***	-12.64***	8.275	-9.913
	(3.533)	(5.604)	(3.645)	(3.628)	(27.25)	(27.55)
Exchange Rate Volatility	2.660*	1.074	2.251*	1.074***	17.99***	21.09***
	(1.426)	(0.923)	(1.288)	(0.303)	(6.338)	(5.422)
Real GDP Volatility		-6.811**	-0.904	-6.811**	-27.04	-7.971
		(3.289)	(1.546)	(2.355)	(20.48)	(8.837)
Inflation Level	-0.424	8.396	2.258	8.396*	18.74	-53.56***
	(4.088)	(5.489)	(4.542)	(4.489)	(43.23)	(17.45)
OECD	0.151***	0.0896	0.0635	0.0896**	0.503	0.223
	(0.0464)	(0.0786)	(0.0742)	(0.0360)	(0.462)	(0.412)
US Border	-0.155***	-0.0289	-0.00770	-0.0289	-1.797***	-1.752***
	(0.0384)	(0.111)	(0.110)	(0.106)	(0.566)	(0.547)
ln (real GDP per capita)		0.0286	0.0314	0.0286	0.0851	0.0752
		(0.0254)	(0.0238)	(0.0207)	(0.124)	(0.128)
ln (distance)		0.0851	0.0775	0.0851	-0.372	-0.513
		(0.0667)	(0.0689)	(0.0471)	(0.372)	(0.364)
Common Language		0.0270	-0.0213	0.0270	0.157	-0.0367
		(0.0572)	(0.0628)	(0.0213)	(0.311)	(0.314)
Former Colony		0.0339	0.107	0.0339	0.0595	0.380
		(0.0656)	(0.0768)	(0.0448)	(0.333)	(0.418)
Currency Union		-0.0282	-0.153**	-0.0282	-1.064**	-1.773***
		(0.0671)	(0.0614)	(0.0494)	(0.408)	(0.352)
Landlocked		0.0515	0.0597	0.0515	0.248	0.373
		(0.0573)	(0.0624)	(0.0542)	(0.336)	(0.403)
Observations	3,159	2,525	2,875	2,525	2,162	2,458
R-squared	0.379	0.426	0.408	0.426	0.564	0.540
Industry dummies	yes	yes	yes	yes	yes	yes
Year dummies	yes	yes	yes	yes	yes	yes
Drop crisis countries	no	yes	no	yes	yes	no
Clustered by	country	country	country	industry	country	country

Notes: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Figure 7: The distribution of multinational sales as a fraction of total foreign sales.

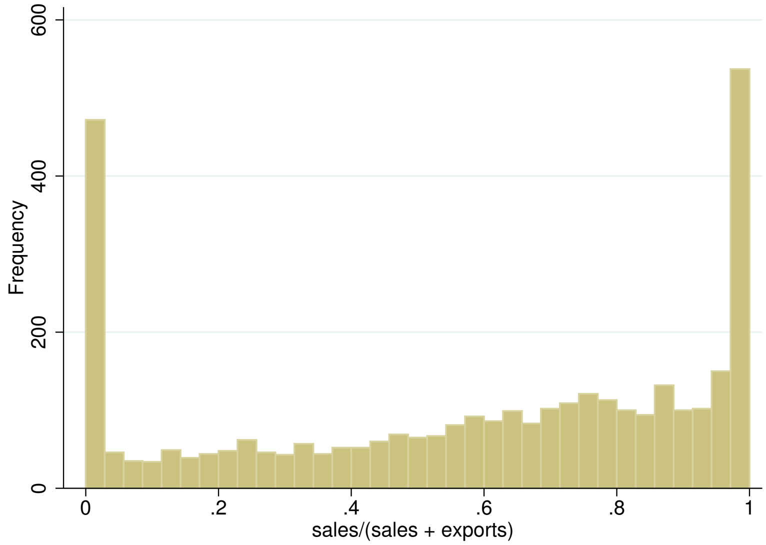


Figure 8: The distribution of multinational sales as a fraction of total foreign sales, for only observations with non-zero sales and non-zero exports