Exports versus Multinational Production under Nominal Uncertainty

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Abstract

This paper examines how nominal uncertainty affects the choice firms face to serve a foreign market through exports or to produce abroad as a multinational. I develop a two-country, stochastic general equilibrium model in which firms make production and pricing decisions in advance, and I consider its implications for the relative attractiveness of exporting and multinational production. I find that when multinational sales are priced in the local currency while exports are priced in the producer currency, destination volatility benefits exporters: during a foreign nominal contraction, the foreign exchange rate appreciates, causing exports to be relatively cheaper. Exporters gain non-linearly through demand, making profit convex in prices. As foreign volatility rises, the model implies that the home country should serve the foreign country relatively more through exports. I take this implication to bilateral 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 higher inflation volatility is associated with a significantly lower ratio of multinational sales to total foreign sales.

Keywords: Multinational Production, International Trade, Nominal Uncertainty, Proximity-Concentration

JEL classifications: F12, F23, F41

*First version: October, 2010. Contact: logantlewis@ltlewis.net. The views in this paper are solely the responsibility of the author and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or of any other person associated with the Federal Reserve System. I especially thank Andrei Levchenko, Jagadeesh Sivadasan, Linda Tesar, and Jing Zhang for their comments, suggestions, and encouragement. I also thank Çağatay Bircan, Sebastien Bradley, Alan Deardorff, Veronica Rappoport, Katheryn Russ, and seminar participants at various institutions. I gratefully acknowledge the support of the Robert V. Roosa Dissertation Fellowship. All errors are mine.

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 (MP) 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 local (foreign) currency, this creates an 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 local currency, nominal uncertainty does not affect the choice of how to serve the destination market. If, as in U.S. data, exports are instead priced in the producer currency, then exporting becomes relatively more attractive for destinations with higher volatility. 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. The foreign nominal contraction leads to a foreign appreciation, causing the exporter's price to automatically fall in terms of the foreign currency. This makes expected profits of exporters more convex as foreign volatility rises.

Recent work demonstrates the importance of nominal uncertainty for international transactions. Among the most volatile aggregate conditions faced by firms is the nominal exchange rate. While nominal exchange rates are largely disconnected from other observable macroeconomic variables, Faust and Rogers (2003) demonstrate that monetary policy shocks account for roughly one-third of the volatility of exchange rates. Thus, the model described here can be thought of as one which works through the exchange rate without explaining all of its volatility seen in the data. Furthermore, nominal volatility is more directly influenced by monetary policy than various forms of real volatility, and therefore it is important to understand its implications on the attractiveness of trade and multinational production.

Nominal exchange rate volatility matters only if nominal prices do not adjust. 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 U.S. dollars. By contrast, production abroad is likely to be denominated in the local currency. This distinction in the currency of pricing between multinational production and exports is crucial for understanding how firms react to differences in nominal uncertainty in the model.

The analysis is based on the canonical Helpman, Melitz and Yeaple (2004) framework of trade and multinational production, extended to a stochastic environment. Firms are heterogeneous in productivity, and they face higher fixed costs to produce abroad than to export. Firms with high productivity find it 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 via demand. This in turn affects the extensive margin of firm participation in each market. I first consider the case of foreign firms, who price both their exports and multinational production in the local (home) currency. Here, nominal uncertainty affects neither the extensive nor intensive margin of exporting relative to MP. Then I consider the U.S. (home) case, where exports are priced in the producer (home) currency and MP is priced in the local (foreign) currency. In this case, exporter profits are convex in foreign nominal volatility. This in turn implies that as volatility rises, multinational production as a fraction of total foreign sales (MP plus exports) falls in the model.

I also briefly discuss an alternative model in which nominal wages instead of prices are set in advance. The basic intuition carries through. Optimal prices are markups over marginal cost, and a home exporter's marginal cost in foreign currency terms varies with the exchange rate, while a multinational's does not. Thus, volatility will benefit exporters through the convex profit function, and the model predicts that the fraction of multinational sales in total foreign sales should fall as volatility rises.

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 multinational sales relative to exports. Separating the regressions for each major sector, I find that the coefficient on volatility is significant for information, chemical, electrical, food, and transportation manufacturing. Other manufacturing sectors have the expected sign, with mining having the smallest insignificant coefficient. 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.

Exchange rate volatility itself tends not to be statistically significant. When controlling for inflation volatility, exchange rate volatility tends to have a small, negative, and insignificant coefficient. Exchange rates move as the result of many shocks, and it is difficult to generate realistic exchange rate movements from the kinds of shocks typically included in DSGE models (Chari, Kehoe and McGrattan 2002). The mechanism in my model only requires that exchange rate volatility caused by the underlying monetary volatility goes in the model direction; that is, a foreign nominal contraction leads to a foreign exchange rate appreciation. Exchange rate volatility from other sources may be handled differently by firms, with risk aversion leading to hedging motives, as an example.[2] The empirical results suggest that it is important to find more direct measures of underlying shocks, and they may have different effects on trade and MP than "pure" exchange rate shocks.

[2]That said, Wei (1999) argues there is little evidence that exchange rate risk is hedged well.

This paper contributes to a recent and growing literature on the effects of various forms of uncertainty on international entry. Perhaps the most closely related paper is Ramondo, Rappoport and Ruhl (2013), who model real uncertainty. Their mechanism works via changes in relative costs between exporters and multinationals. The mechanism in this paper is distinct and complementary: it works through changes in export prices relative to multinational prices caused by fluctuations in the nominal exchange rate, when the prices are set in different currencies. They also test U.S. export and multinational sales data against volatility, in their case GDP volatility. Another closely related paper is Fillat and Garetto (2012), who model real uncertainty in the presence of sunk costs, fixed costs, and persistent shocks in partial equilibrium. This combination creates option value considerations in addition to the expected profit mechanism. Their focus is on the differences in earnings yields and returns between the two types of firms.

Fundamentally, both the mechanism in this paper and that in Ramondo et al. (2013) depend on the convexity of the profit function, where an increase in volatility leads to an increase in expected profit, all else equal. The benefit risk-neutral firms receive from increased volatility appears to be an under-appreciated consequence of standard aggregators like CES. Giovannini (1988) made this point for generic profit functions with sticky prices and exchange rate volatility in the context of exports, in partial equilibrium. Engel (2006) generalized these results further with a focus on the optimal currency choice of exports. This is in contrast to other partial equilibrium work such as Goldberg and Kolstad (1995), who examine the production-location decision with both real and nominal shocks; their main results are driven by firms having some degree of risk aversion.

In modeling nominal uncertainty, this paper is most closely related to Russ (2007), who 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.

The rest of the paper is organized as follows: Section 2 presents the overall model environment. Section 3 details how foreign firms serve the home market. Section 4 describes how home firms serve the foreign market and briefly describes the sticky wage alternative model. Section 5 introduces the data and estimation strategy for testing the model. Section 6 concludes.

2 Model setup

Consider an economy with two countries, home and foreign (denoted by an asterisk). Each is inhabited by a representative household which maximizes utility over consumption, labor (leisure), and real money holdings. Households trade a complete set of state-contingent bonds; thus, the

[3]In addition, Cavallari (2010) 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).

model focuses on the implications of uncertainty on firms. The uncertainty takes the form of an exogenous, stochastic money growth rate.

Firms face fixed costs for producing domestically, exporting, and serving foreign markets via multinational production. Multinationals avoid transportation costs and pay higher fixed costs, while exporters face smaller fixed costs but pay per-unit transportation 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 tractable while being consistent with pricing data, prices are set one period in advance. Trade consists of state-contingent bonds as well as varieties produced by monopolistically competitive firms, and these firms have heterogeneous productivities based on a permanent fixed draw from a productivity distribution. Labor is the only input of production.

In the following sections I lay out in more detail the key components of the model, reserving some details for the appendix.

2.1 Households

Each country is occupied by a representative household which maximizes the expected discounted stream of utility $U(\cdot)$, choosing aggregate consumption C_t, labor supplied L_t, bond holdings $B(s^{t+1})$, and real money balances M_t/P_t; s^t denotes the state of the world and its history up to time t. For tractability, assume that utility is separable and of the form:

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

The home household faces a standard budget constraint which leads to familiar first order conditions, shown in the appendix.

The foreign household has an analogous problem, and the real and nominal exchange rates are solved by equating the price of state-contingent bonds Q and iterating backwards (Chari et al. 2002). The nominal exchange rate, defined so that an increase represents a home depreciation, can be expressed as a function entirely of exogenous variables and parameters (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 supply 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 the 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 real money balance first order condition. 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 $y(i)$ through CES aggregation, with a common elasticity of substitution θ:

$$C_t = \left[\int_\Omega y_t(i)^{(\theta-1)/\theta} \, di \right]^{\theta/(\theta-1)}.$$

This implies very standard demand equations for each variety sold at price p:

$$y_t(i) = \left(\frac{P_t}{p_t(i)} \right)^\theta C_t. \tag{2}$$

While there is no explicit home-bias in preferences over varieties in this setup, transportation costs and fixed costs will yield lower trade relative to a frictionless economy. In addition, complete markets and labor entering linearly in the utility function imply that wages between the two countries are equalized ($W_t = S_t W_t^*$). Section 4.6 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]

The comparative statics considered in this paper are changes in the volatility of the foreign money supply, $\sigma_{m^*}^2$. Since the paper is focused on stochastic steady states rather than short-run dynamics following changes in the money supply, it makes little theoretical difference to model a money supply growth rate rule as opposed to a more realistic alternative (e.g. shocks to a Taylor rule).

[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.

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

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

2.3 Firms serving the local market

Each country has a potential unit mass of firms.[7] These firms use one input of production, labor $l(i)$, and their specific technology $\phi(i)$ to produce a variety $y_t(i) = \phi(i)l_t(i)$. To produce for their local market, firms must pay a per-period fixed cost f and set their prices in advance of the realization of the money supply. Firms differ in their productivities ϕ, which completely characterizes the rest of their decisions. Thus, I omit the variety i designation going forward.

Firms set prices for their local market by solving the following optimization problem:

$$\max_{p_t(\phi)} E_{t-1}\left[d_t(p_t(\phi)y_t(\phi) - W_t l_t(\phi))\right],$$

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. The optimal price choice is then:

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

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 analytically simplifying the expressions for the foreign country.

The cutoff of firms serving their own market is the productivity $\hat{\phi}$ above which expected flow profits exceed the fixed cost:

$$E_{t-1}\left[d_t\left(\underbrace{p_t(\hat{\phi}_t)y_t(\hat{\phi}_t)}_{\text{revenue}} - \underbrace{\frac{W_t y_t(\hat{\phi}_t)}{\hat{\phi}_t}}_{\text{labor costs}}\right)\right] - E_{t-1}\left[d_t \underbrace{P_t f}_{\text{fixed costs}}\right] = 0.$$

Once again, the foreign country has analogous conditions for firms serving its local market.

3 Foreign firms serving the home market

Recent empirical evidence by Gopinath and Rigobon (2008) shows that 90% of U.S. imports are priced in dollars. This currency choice is the result of a variety of macroeconomic factors, some of which are the subject of recent work.[8] I abstract from this choice and impose it as an assumption for tractability.

[7] This is a normalization following Russ (2007). The fixed cost is parameterized such that not all potential firms enter the local markets, and the free entry condition holds.

[8] See, e.g., Engel (2006), Gopinath, Itskhoki and Rigobon (2010), Bhattarai (2009), and Eichengreen (2011). Devereux and Engel (2001) discuss the effects of local currency pricing and producer currency pricing on the optimality of floating versus flexible exchange rate regimes in the context of multinational production.

Foreign multinationals operating in the home market will also price in the home currency, providing symmetry in the pricing decisions of a foreign exporter and multinational. I consider each pricing decision in turn.[9]

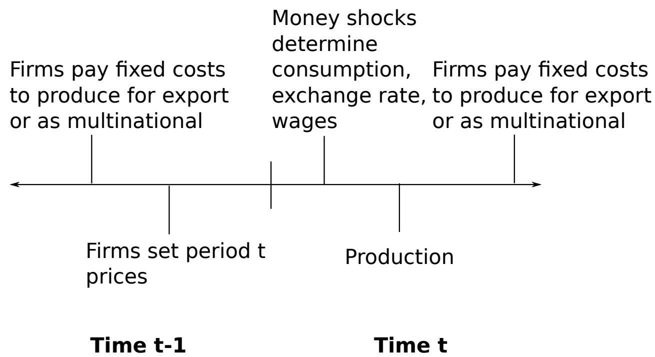

Figure 1: The timing for firms in the model

The timing for all firms in the model is depicted in Figure 1. Firms make both their production and pricing decisions one period in advance. In other words, both the decision of whether and how to serve foreign markets and what price to set are made before the nominal shocks are realized.

3.1 Foreign exporter price setting

Consider foreign firms who choose to serve the home market through exports, and denote this price choice $p^*_{X,t}$. These firms face per-unit iceberg transportation costs τ and per-period fixed costs f_X paid in advance. The maximization problem of the firm, omitting firm subscripts, is then:

$$\max_{p^*_{X,t}} \xi^*_X(\phi) = E_{t-1}\left[d^*_t\left(\tfrac{1}{S_t}p^*_{X,t}y^*_{X,t} - \tau\frac{W^*_t}{\phi}y^*_{X,t}\right)\right]. \tag{3}$$

Since $p_{X,t}$ is set in the home currency, this revenue is repatriated with the nominal exchange rate $1/S_t$. Substituting the demand condition (2) into the maximization problem and solving for the optimal price, one obtains:

$$p^*_{X,t}(\phi) = \frac{\theta}{\theta-1}\frac{1}{\phi}\tau\frac{E_{t-1}\left[d^*_t P^\theta_t C_t W^*_t\right]}{E_{t-1}\left[d^*_t P^\theta_t C_t \frac{1}{S_t}\right]}. \tag{4}$$

[9]For a discussion of the implications of flexible prices, see Appendix A.3.

3.2 Foreign multinational price setting

Now consider foreign firms that choose to serve the home market via multinational production.[10] As mentioned in the previous section, these multinationals set their prices in advance in the home currency, known as local currency pricing. The maximization problem takes the form:

$$\max_{p^*_{MP,t}} E_{t-1}\left[d^*_t \tfrac{1}{S_t}\left(p^*_{MP,t} y^*_{MP,t} - \frac{W_t}{\phi} y^*_{MP,t}\right)\right].$$

Note the lack of transportation cost τ and the labor cost from home workers W_t. This yields the following optimal price choice:

$$p^*_{MP,t}(\phi) = \frac{\theta}{\theta-1}\frac{1}{\phi}\frac{E_{t-1}\left[d^*_t P^\theta_t C_t \frac{1}{S_t} W_t\right]}{E_{t-1}\left[d^*_t P^\theta_t C_t \frac{1}{S_t}\right]}. \tag{5}$$

As discussed in Section 4.6, factor price equalization holds in the model. Here, this implies that the ratio of prices charged by a firm choosing between exporting and MP is simply $p^*_{MP,t}/p^*_{X,t} = 1/\tau$. That is, none of the expectations play a role in the optimal price choice between MP and exports. This result is intuitive: with factor price equalization holding both in expectation and ex-post, firms should not set different prices except to account for transportation costs.

3.3 Foreign export cutoff

Let $\hat{\phi}^*_{X,t}$ be the productivity at time t above which a foreign firm will enter the home market. Such a firm will either choose to export or operate in the home market as a multinational. The marginal firm with productivity $\hat{\phi}^*_{X,t}$ receives zero expected profit net of the fixed cost of exporting f_X. That is,

$$E_{t-1}\left[d^*_t\left(\underbrace{\frac{1}{S_t} p^*_{X,t}(\hat{\phi}^*_{X,t}) y^*_{X,t}(\hat{\phi}^*_{X,t})}_{\text{revenue}} - \underbrace{\frac{W^*_t y^*_{X,t}(\hat{\phi}^*_{X,t})}{\hat{\phi}^*_{X,t}}\tau}_{\text{labor costs}}\right)\right] - E_{t-1}\left[d^*_t \underbrace{\frac{1}{S_{t-1}} P_t f_X}_{\text{fixed costs}}\right] = 0, \tag{6}$$

where again d^*_t is the stochastic discount factor of the foreign firm, $p^*_{X,t}$ is the price of the good paid by home households (in the home currency), $y^*_{X,t}$ is the demand of the good at that price, and W^*_t is the foreign wage. Define $\xi^*_X(\phi)$ as the flow profit from exporting for a firm with productivity ϕ.

[10] An alternative framework would allow firms to pay both the export and multinational fixed costs, then choose where to actually produce the good based on the realization of shocks. It can be shown that in the foreign firm case in this paper, this strategy is never optimal. I assume that home firms in Section 4 cannot switch their production location after shocks are realized.

3.4 Foreign multinational cutoff

Now let $\hat{\phi}^*_{MP,t}$ be the cutoff productivity at time t above which a foreign firm optimally chooses to serve the home market through multinational production. It is the productivity at which expected profits net of fixed costs are equal between the two methods of serving the foreign market. This can be expressed as:

$$E_{t-1}\left[d_t^*\frac{1}{S_t}\left(\underbrace{p^*_{MP,t}(\hat{\phi}^*_{MP,t})y^*_{MP,t}(\hat{\phi}^*_{MP,t})}_{\text{revenue}} - \underbrace{\frac{W_t y^*_{MP,t}(\hat{\phi}^*_{MP,t})}{\hat{\phi}^*_{MP,t}}}_{\text{labor costs}}\right)\right]$$
$$- E_{t-1}\left[d_t^* \underbrace{\frac{1}{S_{t-1}}P_t(f_{MP}-f_X)}_{\text{fixed costs}}\right] - \underbrace{\xi^*_X(\hat{\phi}^*_{MP_t})}_{\text{profit from exporting}} = 0, \quad (7)$$

where the first two terms are the expected profit from MP net of fixed costs. The third term is the expected flow profit from exporting for a firm with productivity $\hat{\phi}^*_{MP,t}$.

3.5 Results

Given the pricing structure where both MP and export prices are set in the home currency, recall that $p^*_{MP,t}/p^*_{X,t} = 1/\tau$, and the home price index P_t is set entirely in advance and is thus non-stochastic. This yields analytically tractable expressions of the the home side of the economy in terms of the home money supply. It can be shown that the relative cutoff is simply:

$$\left(\frac{\hat{\phi}^*_{MP}}{\hat{\phi}^*_X}\right)^{\theta-1} = \frac{f_{MP}-f_X}{f_X\left(\tau^{\theta-1}-1\right)}. \quad (8)$$

Thus, the relative extensive margin is unaffected by nominal uncertainty. The only determinants of the cutoff ratio are exactly those found in Helpman et al. (2004).

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 home currency, and factor price equalization holds, then the ratio of foreign multinational sales to exports is unaffected by uncertainty.*

Proof. See appendix.

The basic intuition of the proof is that if 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.[11] 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. Without factor price equalization (discussed further in Section 4.6), foreign exporters would face exchange rate shocks on their costs relative to their local prices. This would cause exporters to set their prices in part as a function of $E_{t-1}[S_t^{-1}]$, which increases with home volatility.

4 Home firms serving the foreign market

Since most of U.S. imports and exports are priced in dollars, I model this asymmetrical pattern by imposing that home firms exporting to the foreign market set their price in their own currency. While I do not model the currency choice explicitly, we will see that exporters will benefit from having their goods priced in their own currency. In an online appendix, I discuss more general conditions under which producer currency pricing (PCP) is optimal. There is less direct evidence regarding U.S. multinational price setting abroad; I treat them as identical to their foreign competitors, pricing in the foreign currency. In the case of Canada, Cao, Dong and Tomlin (2012) analyze producer price data and find that all but a "few" (p. 22) products in their sample produced and sold within Canada price in Canadian dollars.

This asymmetry in the currency of pricing, and the resulting asymmetric effects of nominal uncertainty, is an important difference between the model in this paper and models of real uncertainty such as Ramondo et al. (2013). In Section 3, nominal uncertainty did not affect the *relative* choice of exporting versus multinational production. Factor price equalization eliminated differences on the cost side (essentially the focus of real models), and setting prices in the same currency eliminated differences on the price-setting side. In this section, factor price equalization will still hold. Since home exporters price in their own currency, however, exporters will gain a pricing advantage relative to being a multinational.

[11] In a world of sunk costs and persistent shock processes, the export vs. multinational production decision involves option values in addition to expected discounted profits. See Fillat and Garetto (2012) for a model incorporating sunk costs and persistent real shocks.

4.1 Home exporter price setting

Analogously to the foreign exporter, home exporters set prices in their own currency to maximize expected discounted flow profits:[12]

$$\max_{p_{X,t}} \xi_X(\phi) \equiv E_{t-1}\left[d_t\left(p_{X,t}y_{X,t} - \frac{W_t}{\phi}y_{X,t}\right)\right].$$

Now, demand for the exported home good is:

$$y_{X,t}(\phi) = \left(\frac{P_t^*}{p_{X,t}S_t^{-1}}\right)^{\theta} C_t^*, \tag{9}$$

and the optimal price charged by exporters is:

$$p_{X,t}(\phi) = \frac{\theta}{\theta-1}\frac{\tau}{\phi}\frac{E_{t-1}[d_t S_t^{\theta} P_t^{*\theta} C_t^* W_t]}{E_{t-1}[d_t S_t^{\theta} P_t^{*\theta} C_t^*]}.$$

Recall that $W_t = P_t C_t^{\rho} = M_t \frac{(1-\beta\alpha)}{\chi}$. In this paper, I abstract from home volatility, so $M_t = 1\ \forall t$ and $\alpha = 1$. Thus, the home nominal wage is simply $W_t = \frac{(1-\beta)}{\chi}$, and the home exporter price is simply:

$$p_{X,t}(\phi) = \frac{\theta}{\theta-1}\frac{1-\beta}{\chi}\frac{\tau}{\phi}. \tag{10}$$

That is, expressed in the home currency, the home price is not affected by foreign volatility. In the foreign currency, the effective price is:

$$\frac{p_{X,t}(\phi)}{S_t} = \frac{\theta}{\theta-1}\frac{\tau}{\chi\phi}\left(M_t^*(1-\beta\alpha^*)\right)^{-1},$$

so it moves inversely with the foreign money supply contemporaneously via the exchange rate.

4.2 Home multinational price setting

Also analogously to the foreign multinational, home multinationals set prices to maximize expected discounted flow profits:

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

[12] Firms here are risk-neutral: they maximize a linear expression of profits, as opposed to explicit concavity used in the previous literature, e.g. Goldberg and Kolstad (1995). These profits are adjusted by the stochastic discount factor of their owners, which are households in this model. Without home volatility, the stochastic discount factor $d_t = \beta\frac{P_{t-1}C_{t-1}^{\rho}}{P_t C_t^{\rho}} = \beta$, so it plays no role for home firms.

yielding an similar expression to (5), specifically $p_{MP,t}(\phi) = \frac{\theta}{\theta-1}\frac{1}{\phi}\frac{E_{t-1}[d_t P_t^{*\theta} C_t^* S_t W_t^*]}{E_{t-1}[d_t P_t^{*\theta} C_t^* S_t]}$. Note that just as in the case of home exporters, these firms maximize discounted profits denominated in their own currency, repatriated at time t.[13] Unlike in the foreign multinational case, however, the price index P_t^* is not fully determined in advance of period t. The price index can be expressed as:

$$P_t^{*1-\theta} = N^* p_t^*(\tilde{\phi}^*)^{1-\theta} + N_x S_t^{\theta-1} p_{X,t}(\tilde{\phi}_X^*)^{1-\theta} + N_{MP} p_{MP,t}(\tilde{\phi}_{MP})^{1-\theta}, \tag{11}$$

where N^* is the mass of foreign firms producing in the foreign market, N_X is the mass of home firms exporting to the foreign market, and N_{MP} is the mass of home firms producing in the foreign market as a multinational; $\tilde{\phi}$ represents the weighted average productivity of the representative foreign firm, home exporter, and home multinational. So while each price is set in advance, the exporter price term varies with the exchange rate, making P_t^* stochastic and non-linear in M_t^*.

To understand how the multinational price varies with foreign volatility, we can express the price entirely in terms of the foreign money supply and price level:

$$p_{MP,t}(\phi) = \frac{\theta}{\theta-1}\frac{1}{\theta}\frac{1-\beta\alpha^*}{\chi}\frac{E_{t-1}\left[M_t^{*1/\rho} P_t^{*\theta-1/\rho}\right]}{E_{t-1}\left[M_t^{*1/\rho-1} P_t^{*\theta-1/\rho}\right]}. \tag{12}$$

Let $\Xi_1 \equiv \frac{E_{t-1}\left[M_t^{*1/\rho} P_t^{*\theta-1/\rho}\right]}{E_{t-1}\left[M_t^{*1/\rho-1} P_t^{*\theta-1/\rho}\right]}$. I show in the appendix that (for reasonable calibrations) an approximation to Ξ_1 does not vary substantially with $\sigma_{m^*}^2$, and verify it numerically with the calibration used in Section 4.5. Note that because $\Xi_1 \approx E_{t-1}[M_t^*]$, away from a stochastic steady state (where $M_{t-1} = 1$), the multinational price will track movements in the foreign money supply with a one period lag. So while P_t^* only moves contemporaneously from the export term, the domestic and multinational price terms respond with a one period lag. In this way, the model simulated dynamically has inflation, which is a function of the volatility of the foreign money supply.

Primarily, $p_{MP,t}$ falls as $\sigma_{m^*}^2$ rises because of the $1-\beta\alpha^*$ term (recall that $\alpha^* = e^{\sigma_{m^*}^2}$). Expressed in the home currency, $S_t p_{MP,t} = \frac{M_t}{M_t^*}\frac{1-\beta}{1-\beta\alpha^*} p_{MP,t}$ rises as foreign volatility increases, for a given productivity level ϕ. Average exporter multinational prices will be a function of both this intensive price choice and the extensive margin cutoffs, discussed next.

4.3 Cutoff conditions and the extensive margin

To understand how volatility affects the extensive margins, first consider the home exporter cutoff condition. Going forward, I omit time subscripts on the productivity cutoffs for brevity. This is the productivity level $\hat{\phi}_X$ at which a home firm is indifferent between exporting and not exporting

[13] This is not a strong assumption, so long as multinationals and exporters can similarly re-time the repatriation of their profits.

given the fixed cost:

$$E_{t-1}\left[d_t\left(p_{X,t}(\hat{\phi}_{X,t})y_{X,t}(\hat{\phi}_{X,t})-\tau\frac{W_t}{\hat{\phi}_{X,t}}y_{X,t}(\hat{\phi}_{X,t})\right)\right]=E_{t-1}[d_tS_{t-1}P_t^*f_X], \tag{13}$$

or expressed more succinctly using the notation introduced above, flow profit $\xi_X(\hat{\phi}_X)=E_{t-1}[d_tS_{t-1}P_t^*f_X]$.[14] Using (10) as well as substituting for the aggregate variables, flow profit $\xi_X(\hat{\phi}_X)$ can be expressed as:

$$\xi_X(\hat{\phi}_X)=\hat{\phi}_X^{\theta-1}\beta(1-\beta)(1-\beta\alpha^*)^{1/\rho-\theta}\tau^{1-\theta}\left(\left(\frac{\theta}{\theta-1}\right)^{1-\theta}-\left(\frac{\theta}{\theta-1}\right)^{-\theta}\right)E_{t-1}\left[P_t^{*\theta-1/\rho}M_t^{*1/\rho-\theta}\right]. \tag{14}$$

Foreign monetary volatility affects two terms in this expression: $(1-\beta\alpha^*)^{1/\rho-\theta}$ is increasing in $\sigma^2_{m^*}$, while $E_{t-1}\left[P_t^{*\theta-1/\rho}M_t^{*1/\rho-\theta}\right]$ is ambiguous. Complicating this expression is an expectation of P_t^*, which is a function not only of the intensive margin but the extensive margin. I show numerically in Section 4.5 that total export profits (net of fixed costs) are increasing in $\sigma^2_{m^*}$.

That said, the *relative* choice between exports and multinational production is a function of the ratio of the productivity cutoffs, which will conveniently eliminate the level effects of the P_t^* term. To see this, consider the productivity level $\hat{\phi}_{MP}$ at which a firm is indifferent between being a multinational and exporting:

$$\xi_{MP}(\hat{\phi}_{MP})-\xi_X(\hat{\phi}_{MP})=E_{t-1}\left[d_tS_{t-1}P_t^*(f_{MP}-f_X)\right], \tag{15}$$

where $\xi_{MP}(\hat{\phi}_{MP})=E_{t-1}\left[d_tS_t\left(p_{MP,t}(\hat{\phi}_{MP})y_{MP,t}(\hat{\phi}_{MP})-\frac{W_t^*}{\hat{\phi}_{MP,t}}y_{MP,t}(\hat{\phi}_{MP})\right)\right]$. By substituting in the multinational price and aggregate expressions, this can be expressed as:

$$\xi_{MP}(\hat{\phi}_{MP})=\hat{\phi}_{MP}^{\theta-1}\beta(1-\beta)(1-\beta\alpha^*)^{1/\rho-\theta}E_{t-1}\left[\left(\left(\frac{\theta}{\theta-1}\Xi_1\right)^{1-\theta}-\left(\frac{\theta}{\theta-1}\Xi_1\right)^{-\theta}M_t^*\right)M_t^{*1/\rho-1}P_t^{*\theta-1/\rho}\right]. \tag{16}$$

Note that the $(1-\beta\alpha^*)^{1/\rho-\theta}$ term is identical to the term in the ξ_X expression (14). Here we have a third term which is technically a function of both foreign volatility and the foreign money supply, $\Xi_2\equiv\left(\frac{\theta}{\theta-1}\Xi_1\right)^{1-\theta}-\left(\frac{\theta}{\theta-1}\Xi_1\right)^{-\theta}M_t^*$. Recall that Ξ_1 varies little as foreign volatility rises; while Ξ_2 has second-order covariance with the $M_t^{*1/\rho-1}P_t^{*\theta-1/\rho}$ term, quantitatively it is very minor. Since $E_{t-1}[\Xi_1]\approx E_{t-1}[M_t^*]$, we have that $E_{t-1}[\Xi_2]\approx\left(\frac{\theta}{\theta-1}\right)^{1-\theta}-\left(\frac{\theta}{\theta-1}\right)^{-\theta}$, the term found in (14). Going forward analytically, I will use this approximation. In the numerical analysis of Section 4.5,

[14] Note that $S_{t-1}=\frac{1-\beta}{1-\beta\alpha^*}\neq 1$ if $t-1$ is a stochastic steady state where $M_{t-1}^*=1$

I compute the exact solution. Fundamentally, these terms arise because the multinational price is a function of *expected* foreign wages, and profits are a function of *actual* foreign wages. For an exporter, $W_t = P_t C_t^{\rho} = (1-\beta)/\chi$, so this is not an issue.

The remaining expectation terms are crucially different and form the basis of how export profits change relative to multinational profits as foreign volatility increases. Underlying this difference is that the exchange rate S_t automatically affects the export price and, through the demand equation (9), makes export profits convex in the exchange rate. That is, export flow profit (14) has a $M_t^{*1/\rho-\theta}$ term and multinational flow profit (16) has a $M_t^{*1/\rho-1}$ term.

From (13) and (15), the relative cutoff can be expressed as:

$$\left(\frac{\hat{\phi}_X}{\hat{\phi}_{MP}}\right)^{\theta-1} \approx \frac{f_X}{f_{MP}-f_X}\left(\tau^{\theta-1}\frac{E_{t-1}\left[M_t^{*1/\rho-1}P_t^{*\theta-1/\rho}\right]}{E_{t-1}\left[M_t^{*1/\rho-\theta}P_t^{*\theta-1/\rho}\right]}-1\right) \tag{17}$$

where the approximation here is the result of canceling the Ξ_2 term with its export counterpart, discussed above. Thus, the relative extensive margin of exports versus multinational production is a function of the fixed costs and transportation costs in the same way as (8) and Helpman et al. (2004). Foreign volatility affects the expectation terms, discussed further in the appendix. Given plausible assumptions about the covariance of M_t^* and P_t^*, this ratio falls as foreign volatility rises. That is, $\hat{\phi}_X$ falls relative to $\hat{\phi}_{MP}$.

4.4 Sales ratios

The ratio of multinational volume to export volume is $(N_{MP}y_{MP}(\tilde{\phi}_{MP}))/(N_X y_X(\tilde{\phi}_X))$, where N_{MP} is the mass of multinationals, y_{MP} is the representative firm's volume, $\tilde{\phi}_{MP}$ is its productivity, and likewise for the export terms. First, consider the ratio of firm masses. Let $\gamma_X \equiv \hat{\phi}_{MP}/\hat{\phi}_X > 1$ be the ratio of cutoff productivities, a simple transformation of (17). With a Pareto distribution of firm productivities (with parameter k) and the potential unit-mass normalization of firms, the ratio of firms is a function of the CDFs and one obtains:

$$\frac{N_{MP}}{N_X} = \frac{1}{\gamma_X^k - 1}.$$

As foreign volatility $\sigma_{m^*}^2$ rises, γ_X rises, and thus N_{MP}/N_X falls, which we will see numerically in the next section.

The ratio of volumes is a function of the prices and the exchange rate:

$$\frac{y_{MP}(\tilde{\phi}_{MP})}{y_X(\tilde{\phi}_X)} = S_t^{-\theta}\left(\frac{p_X(\tilde{\phi}_X)}{p_{MP}(\tilde{\phi}_{MP})}\right)^{\theta}.$$

Using the (10) and (12), we have:

$$\frac{y_{MP}(\tilde{\phi}_{MP})}{y_X(\tilde{\phi}_X)} = \frac{1}{M_t^{*-\theta}} \Xi_1^{-\theta} \tau^{\theta} \left(\frac{\tilde{\phi}_{MP}}{\tilde{\phi}_X} \right)^{\theta}.$$

where the only term not known at time $t-1$ is the realization of the foreign money supply (via the exchange rate). This is the same convexity effect that generates the expected profit advantage that home exporters have. Note that $E_{t-1}\left[M_t^{*-\theta}\right] = E_{t-1}[M_t^*]^{-\theta} exp(\theta(\theta+1)\sigma_{m^*}^2/2)$ is increasing in foreign volatility, as is $E_{t-1}\left[M_t^{*\theta}\right] = E_{t-1}[M_t^*]^{\theta} exp(\theta(\theta-1)\sigma_{m^*}^2/2)$. This implies a difference between the expectation of the ratio of volume and the ratio of the expectations of volume, discussed below.[15]

Next, consider the relative average productivity term. We have that:

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

which is also increasing in γ_X. This is because γ_X rises as the productivity cutoff of the multinational rises relative to the export cutoff, making the representative multinational relative more productive than the representative exporter. So while there are fewer multinationals, they sell more on average as foreign volatility rises. Thus, it is important to consider both the intensive margin and the extensive margin together:

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

which is decreasing in γ_X, and thus decreasing in foreign volatility. Note that as $k+1-\theta \to 0$, the term goes to infinity (and its slope with respect to γ_X goes to zero). Therefore, the closer the calibration of $k+1$ is to θ, the less the extensive margin matters.[16]

Without destination-specific import and multinational price indices, the appropriate measure to compare to the data is not volume but value, expressed in the home currency. Once again using (10) and (12), we have $S_t p_{MP}(\tilde{\phi}_{MP})/p_X(\tilde{\phi}_X) = (M_t^* \tau)^{-1}(\tilde{\phi}_X/\tilde{\phi}_{MP})\Xi_1$. So the nominal ratio is:

$$\frac{S_t p_{MP}(\tilde{\phi}_{MP})}{p_X(\tilde{\phi}_X)} \frac{N_{MP}}{N_X} \frac{y_{MP}(\tilde{\phi}_{MP})}{y_X(\tilde{\phi}_X)} = M_t^{*\theta-1} \left(\frac{\tau}{\Xi_1} \right)^{\theta-1} \frac{1}{\gamma_X^{k+1-\theta} - 1}, \tag{18}$$

which is decreasing in γ_X faster than the real ratio.

[15]Taking the natural logarithm inside in the expectation also matters, and is relevant for the theoretical and empirical specification analyzed by Ramondo et al. (2013). In logs, the mean preserving spread of the money supply process implies that this $M_t^{*\theta}$ term is decreasing as foreign volatility increases.

[16]This is emphasized by di Giovanni and Levchenko (2013).

Furthermore, the nominal ratio is itself hard to interpret in levels. Given the large number of zero values and near zero values for multinational sales or exports in the data (discussed further in Section 5.4), I use multinational sales as a fraction of total foreign sales. Because of the M_t^* term, this is not a simple transformation of the expectation of (18).[17]

4.5 A numerical illustration

To understand the quantitative effects of volatility, I proceed numerically. I discretize the state space for the foreign money supply M^* and compute the stochastic steady state for various $\sigma^2_{m^*}$.

Table 1: Model parameters

β	0.96	Annual discount rate
χ	1	Utility of real money balances
ρ	2	Standard risk-aversion
θ	5	Elasticity of substitution
k	4.25	Pareto shape parameter
τ	1.2	20% iceberg trade cost
f	0.01	Fixed cost of local firms
f_X	0.024	Fixed cost of exporters
f_{MP}	30	Fixed cost of multinationals

To do this, I must calibrate the model parameters. Table 1 outlines the parameters in the model. Most are standard. As is common in the trade literature, I use an elasticity of substitution between varieties of 5, in the middle of most estimates.[18] The Pareto shape parameter k governing the distribution of firms is calibrated to domestic firm sales such that $k/(\theta-1) \approx 1.06$, found by Axtell (2001) and Luttmer (2007). Iceberg trade costs τ of 20% are within the range of estimated tariffs and freight costs. This leaves the fixed costs. I set the fixed cost of domestic production such that mass of operating firms is within $(0, 1)$[19] and the export fixed cost such that about 18% of domestic firms export under no uncertainty, consistent with Bernard, Jensen, Redding and Schott (2007) for U.S. manufacturing firms. The fixed cost for multinationals is set very high relative to domestic and export costs, which given the Pareto calibration still implies that 80% of sales in the foreign market are from multinationals.[20]

[17] The expectation of (18) is actually increasing in foreign volatility, while the expectation of the log ratio and the expectation of the fraction used in the following sections are decreasing in foreign volatility.

[18] See Ruhl (2008) for a survey. This elasticity determines the degree of expenditure switching between home and foreign varieties, and it plays an important role in determining the magnitude of the advantage that exporters receive by pricing in their own currency.

[19] The mass of firms operating domestically has little bearing on the overall effect of volatility on exporters and multinational producers.

[20] Given the calibration of the Pareto shape parameter k, the right tail of the firm sales distribution is very large.

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.[21] 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 an exporter that prices in the producer currency relatively better off in the presence of higher foreign volatility. Changes in foreign volatility affect both the foreign price level and demand, faced equally by both exporters and multinationals. The fundamental difference in terms of the relative attractiveness is that exporters gain from the inherent price volatility.

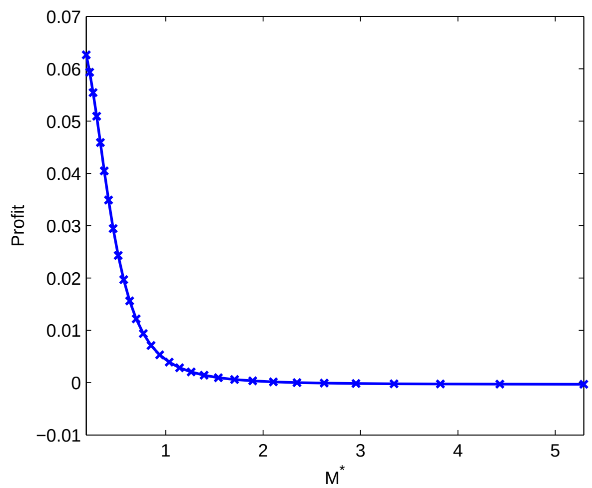

Figure 2: Convexity of the exporter profit function

To better understand this, consider first Figure 2. It plots the profit of a home exporter against realizations of the foreign money supply M^* on a discretized grid. Starting from the median of 1, the probability of moving one point left is equal to the probability of moving one point right. Clearly, exporter profit is convex in the foreign money supply. The exporter benefits more from foreign contractions than it suffers from foreign expansions, all else equal.

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

It is not feasible to calibrate the multinational fixed cost high enough to be consistent with the 60% value of foreign sales from multinational affiliates seen in Section 5.

[21] This effect on multinationals is a central result from Russ (2007), showing that higher foreign volatility is relatively better for home firms over foreign firms in the foreign market (and that home volatility is the opposite). I will show later that the presence of exporters can make foreign volatility lower the expected profit of multinationals instead.

increases the expected profit of an exporter, all else equal.

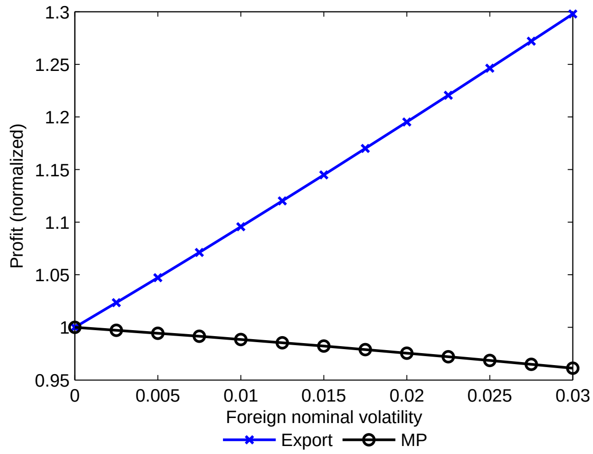

Figure 3: Expected profit for an example firm

A multinational does not have this pricing advantage. Figure 3 shows the relative impact of (normalized) expected profit for a sample high-productivity firm as volatility ($\sigma^2_{m^*}$) increases. Multinational profit actually falls here, as expected revenue falls more than expected costs with increased volatility. Russ (2007) shows that in a world with only multinationals and no exporters, multinationals should benefit from foreign volatility. Here, that effect is offset by the additional general equilibrium forces caused by exporting. While there are no direct competition effects in the model, changes in the composition of firms serving the foreign market and average pass-through of these volatile exchange rate shocks affect the foreign price level. The entrance of new exporters, for example, can lower the foreign price level P^*_t and reduce multinational profits. On net, these effects are sufficient to overcome the advantage that multinationals would receive if there were no exporters.

The relative benefit exporters receive in profit is exactly what determines the extensive margins in (17). 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. That is, the exporter cutoff $\hat{\phi}_X$ is falling, and firms which previously produced only for the home market become exporters.

In terms of quantity, this translates to a relatively small drop in multinational sales; only the lowest productivity multinational firms become exporters, so their total effect is relatively small.

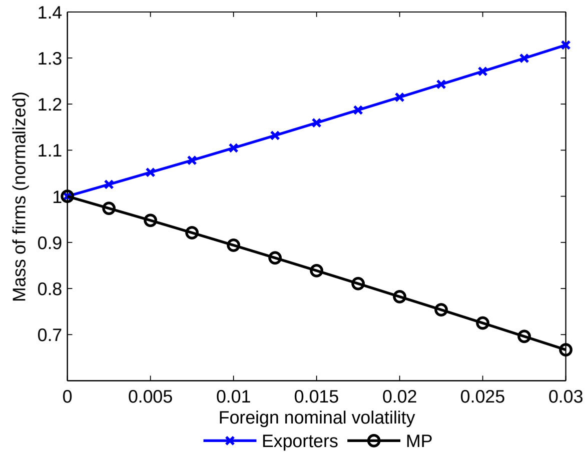

Figure 4: The extensive margin of exporters and multinationals

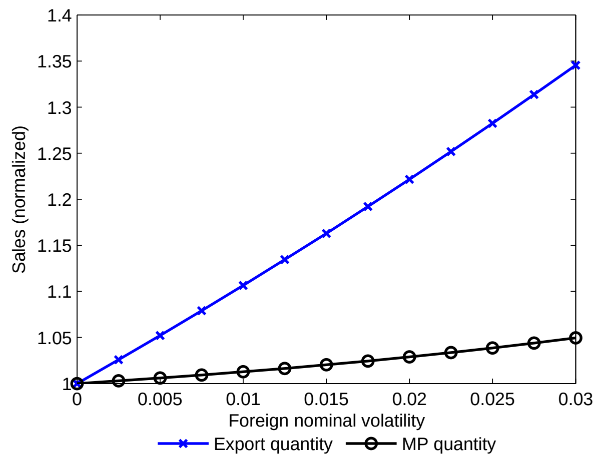

Figure 5: Quantity sales by exporters and multinationals

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 volatility may affect trade and multinational sales jointly through additional unmodeled channels, I focus on the (expected) 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 from multinationals falls as volatility rises.[22] Given the current calibration, going from no volatility to a variance of 0.03 leads to a drop in multinational sales from about 80% to 75%.

[22]Recall from Section 4.4 that as the Pareto distribution calibration $k/(\theta - 1) \to 1$, the slope of the quantity line becomes less steep, as changes in the extensive margin have less of an effect on aggregate sales.

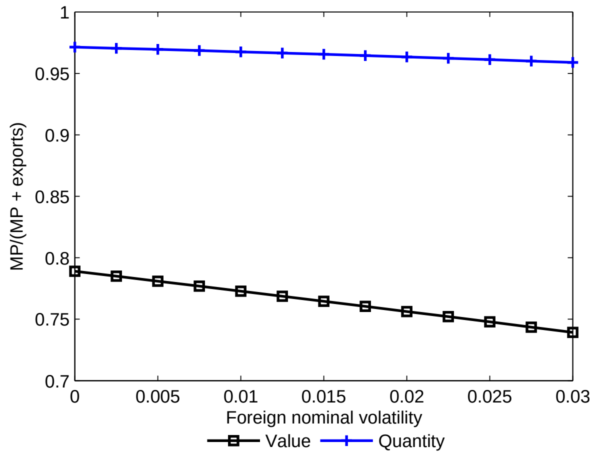

Figure 6: The fraction of total foreign sales from multinationals

4.6 A note on factor price equalization

Factor price equalization holds in the baseline model because markets are complete and labor enters linearly in the utility function, as noted by Devereux and Engel (2001). 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 $W_t = S_t W_t^*$. Factor price equalization shuts down any channel stemming from differences in production costs across countries. There are no country-specific productivity shocks, and a firm's productivity is the same whether it chooses to produce in the home or foreign country. This is in contrast to Ramondo et al. (2013), whose results effectively stem from differences in relative costs.

One can relax the assumption about complete markets or the assumption about labor entering linearly. Relaxing complete markets will not provide very large deviations from factor price equalization, as the exchange rate will follow roughly similar dynamics (Chari et al. 2002). Labor entering with an exponent $1 + \eta$ and $\eta > 0$ can break factor price equalization more substantially. Here, the first order conditions become $W_t = P_t C_t^{\rho} l_t^{\eta}$. Thus, as more labor is needed 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. If factor price equalization holds, in log-deviations we have $\hat{W}_t = \hat{S}_t + \hat{W}_t^*$. 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 a home monetary expansion causes home wages to rise more than foreign wages expressed in the home currency. That is, $\hat{W}_t > \hat{S}_t + \hat{W}_t^*$. This means nominal wages would be even more volatile, contrary to the data. Factor price equalization is also broken in a model of sticky wages, which I will discuss next.

4.7 Sticky wages

A common alternative to sticky prices is sticky nominal wages. Such a model has special appeal in an international environment, where nominal wages in each country are fairly stable and the nominal exchange rate is quite volatile.

In an online appendix, I lay out a sticky wage version of the benchmark model. Unlike the sticky price model, the two countries are symmetric. Still, the basic intuition of the home country side of the sticky price model carries through. While prices are flexible, optimal prices are simply a markup over marginal costs. With wages set in advance, the only portion of price setting not known in advance is the exchange rate. Multinationals, with labor in the destination country, will not have exchange rate changes affect their marginal costs. Exporters do, however, as their nominal wage must be converted into destination currency terms. Because profits are convex in prices, this price volatility benefits exporters. The model implies the same comparative static as the home firms in the benchmark model: higher volatility should lead to a lower fraction of foreign sales from multinationals. Quantitatively, the results of the sticky wage model are significantly stronger than the sticky price model, as expected foreign wages (denominated in the home currency) rise relative to home wages as foreign volatility rises.

5 Data

In this section, I consider evidence based on U.S. exports and U.S. multinational foreign affiliate sales. The United States is the ideal platform for comparison to the model: the overwhelming producer currency pricing for exports is somewhat unusual, as the dollar plays a large role in international trade due to its status as a reserve currency.[23] To the extent that exporters are priced in the local currency rather than the producer's currency, Proposition 1 shows that the model implies no net effect on the attractiveness between exports and multinational production. I use publicly available multinational sales data from the BEA for 1999-2007 and match it to export data from the U.S. International Trade Commission. These data exist at the sector, country, year level. Full details of the data used in the regressions are available in Tables 5 and 6 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. Thus, the analysis in the forthcoming sections will be in terms of nominal ratios.

[23]For example, Cravino (2014) documents that most Chilean exports are priced in dollars rather than pesos, regardless of destination. Gopinath and Rigobon (2008) also show that most U.S. imports are priced in dollars, implying that at least some exports from other major countries are priced in dollars rather than their own currencies.

The full list of countries with relevant summary statistics can be found in Appendix B.2. In robustness exercises, I exclude a small number of countries which experienced currency or debt crises during the sample period, as defined by Laeven and Valencia (2008).[24]

5.1 Estimation strategy

There are several potential measures of volatility 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 that an economy may face. In addition, the data on money supplies is lacking for some countries in the sample, so it makes sense to consider a more widely available measure: consumer price inflation. In the model, 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 measure, yet because exchange rates are influenced by shocks largely disconnected from other macro aggregates, we will see that inflation volatility can have a very different effect on exports relative to multinational sales compared to exchange rate volatility.

I estimate the following:

$$\frac{sales_{i,t}}{sales_{i,t} + exports_{i,t}} = \beta_0 + \beta_1\sigma^2(\Delta \ln(P_{i,t})) + \beta_2\sigma^2(\Delta \ln(\mathrm{S}_{i,t})) + \gamma Z_{i,t} + \epsilon_{i,t}. \tag{19}$$

where *sales* are sales by foreign affiliates of U.S. multinationals in country i, mapped to the data as total foreign sales of U.S. affiliates. *exports* 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.[25] This eliminates any channels that jointly affect both exports and multinational sales.

The variable of interest on the right hand side is $\sigma^2(\Delta \ln(P_{i,t}))$, the volatility of the price level in country i for year t.[26] The volatility of the nominal exchange rate is $\sigma^2(\Delta \ln(S_{i,t}))$, Z consists of a number of country/time specific variables as controls, and $\epsilon_{i,t}$ is the regression residual.

5.2 Results

The results pooling available sectors, countries, and years together are presented in Table 2. Each regression has industry-year dummies, controlling for changes in the overall business cycle and the particular characteristics of each industry. There is a robust negative coefficient on inflation

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

[25] Brainard (1997) used a similar fraction as the dependent variable.

[26] The CPI measures are monthly, and the variance is taken for each year. The results are generally robust to using lagged values, shown in Section 5.4. Longer horizons (e.g. variance of quarterly changes over a multi-year window) for the volatility tend to have the same sign but lose statistical significance. Exchange rate volatility is constructed similarly.

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

	(1)	(2)	(3)
Inflation volatility	-395.4**	-404.8**	-827.5***
	(157.6)	(152.8)	(170.0)
Exchange rate volatility	-0.256	-0.259	-0.590**
	(0.740)	(0.645)	(0.290)
Inflation level	-0.0531	-0.0744	0.859***
	(0.365)	(0.491)	(0.208)
OECD	0.195***	0.191***	0.235***
	(0.0461)	(0.0615)	(0.0602)
U.S. border	-0.176***	-0.0693	-0.0454
	(0.0369)	(0.0896)	(0.0876)
ln (real GDP per capita)		-0.0399	-0.0763**
		(0.0353)	(0.0295)
ln (distance)		0.0548	0.0844
		(0.0717)	(0.0660)
Rule of law index		0.0694	0.118**
		(0.0511)	(0.0493)
Crisis		0.117	
		(0.102)	
Observations	3,127	3,127	2,717
R-squared	0.377	0.392	0.432
Industry-year dummies	yes	yes	yes
Crisis countries	yes	yes	no

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

volatility. The estimate in column 1 implies that moving one standard deviation to the right in the distribution of inflation volatility is associated with a 4.3 percentage point reduction in multinational sales as a fraction of total foreign sales. Exchange rate volatility is negative and insignificant, and the inflation level is also insignificant. Membership in the OECD is strongly significant, implying a nearly 20 percentage point increase in the ratio. This is consistent with many explanations, including that developed countries have good institutions which permit horizontal FDI to be more profitable. Canada and Mexico (bordering the U.S.) are significantly associated with a relatively lower multinational sales ratio, reflecting lower tariff and transportation costs.

Column 2 includes additional controls. Distance is insignificant in these specifications, though of the expected sign; countries farther from the U.S. are served relatively more with multinational sales. A dummy for the countries which experienced a crisis during the sample is insignificant; if such countries represented a significant expropriation risk, we would expect this to be negative and significant. Column 3 drops the crisis countries, which doubles the magnitude of inflation volatility and improves the explanatory power of several variables. Real GDP per capita is now negative and significant, perhaps capturing institutional quality. The more-direct World Bank World Governance Indicators rule of law index is actually positive and significant.

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

Industry	Inflation volatility	Exrate volatility	Obs.
Information	-566.4**	14.3	359
Manufacturing (chemical)	-240.0**	0.2	385
Manufacturing (computers)	-128.5	-0.4	351
Manufacturing (electrical)	-661.9*	-0.2	328
Manufacturing (food)	-948.4**	-2.1**	365
Manufacturing (machinery)	-192.4	-0.0	353
Manufacturing (metals)	-299.9	-0.3	325
Manufacturing (transportation)	-773.7**	-0.1	340
Mining	-123.7	1.0	321

Notes: The dependent variable is sales/(sales + exports) and the sample includes crisis countries. Inflation level, U.S. border, OECD, real GDP per capita, distance, rule of law index, and year dummies included in all regressions. *** p<0.01, ** p<0.05, * p<0.1, clustered by country

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, chemical, electrical, food, and transportation sectors all have negative and significant coefficients. Computers, metals and machinery manufacturing have smaller, insignificant negative coefficients. Mining is also notably different, as this is an industry which has more flexible prices and does not generally lend itself to horizontal FDI. Exchange rate volatility is of mixed sign and insignificant in all regressions except food, which is negative.

5.3 Discussion of exchange rate volatility

The empirical results in Section 5.2 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. When both inflation and exchange rate volatility are included, exchange rate volatility tends to be insignificant. 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 data.

Eichenbaum and Evans (1995) and Landry (2010) provide empirical evidence supporting the notion that a contractionary monetary policy shock appreciates the U.S. dollar relative to various foreign currencies. While based on U.S. monetary policy, this evidence is consistent with the model's mechanism that a monetary contraction will lead to a nominal exchange rate appreciation.

Exchange rates are not driven 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.[27] Exchange rate volatility may also affect firms if the firm itself is risk averse.[28] 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.

5.4 Robustness

I subject the pooled results of Section 5.2 to a series of robustness checks. The results are shown in Table 4. Column 1 reports the baseline regression with the addition of other common gravity explanatory variables like a common language, former colony, and landlocked status. None of these are significant. I also add real GDP volatility, measured as the standard deviation of annual log changes in GDP growth over 1980-2009; this is similar in spirit to Ramondo et al. (2013), and captures real, more medium-term volatility. Their model implies that GDP volatility should have a negative effect on the log ratio of multinational sales to exports (discussed below). Using the fraction of sales as the dependent variable, this measure of GDP volatility is positive and insignificant in most specifications.

Columns 2 and 3 separately include inflation volatility and exchange rate volatility. Overall, inflation volatility has a correlation coefficient of 0.17 with exchange rate volatility, and the estimates are essentially identical when each is included separately. Columns 4 and 5 report the same coefficients as the baseline but different clustered standard errors. The fourth column clusters by industry instead of country, which not surprisingly reduces the standard error of country-level variables like exchange rate volatility, real GDP volatility, real income, etc. A more strict clustering is shown in column 5, where the euro-zone countries are in a single cluster; the standard errors look very similar to the first column.

Columns 6 and 7 use lagged values of the volatility measure. The former uses only lagged volatilities, and the latter includes both the contemporaneous volatility and the lagged volatility. In both cases, inflation volatility is negative and significant, similar in magnitude to the benchmark estimates.

Finally, column 8 reports similar regressions with a different dependent variable: the log of the sales/export ratio. This is the measure used by Ramondo et al. (2013) in the context of GDP volatility. I find a positive and insignificant response of inflation volatility. Exchange rate volatility is positive and significant, while real GDP volatility is positive and insignificant.

[27] Russ (2012), for example, finds that nominal interest rates and nominal exchange rates are correlated differently with multinational firm profits.

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

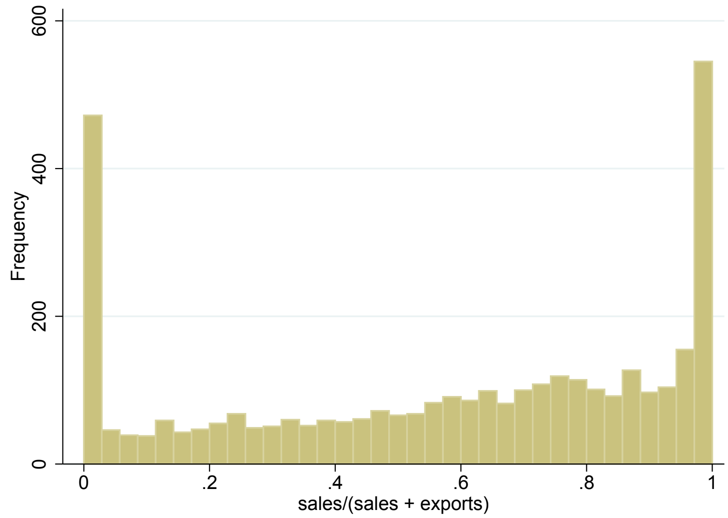

Figure 7: The distribution of multinational sales as a fraction of total foreign sales.

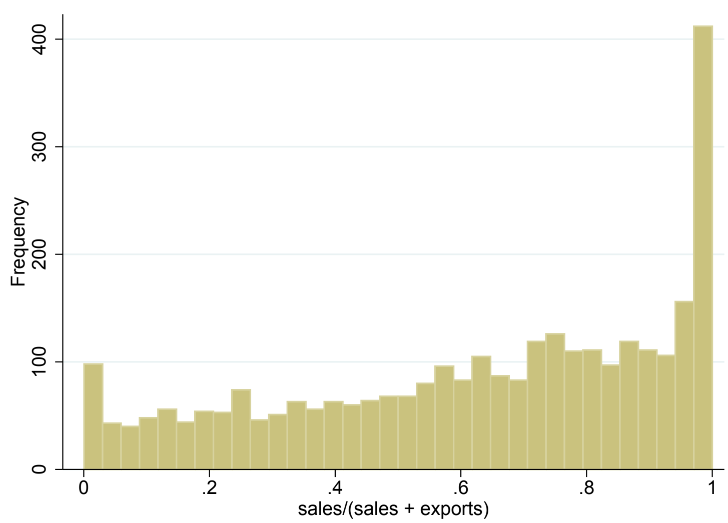

Figure 8: The distribution of multinational sales as a fraction of total foreign sales, for only observations with non-zero sales and non-zero exports

The log ratio puts substantial weight on observations with relatively small multinational sales or relatively small exports, depending on which is in the denominator. This makes it less suitable for industry-level analysis with a large number of countries. In the data, there are a number of such observations, plotted in 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. These issues would only be compounded with more disaggregated data.

6 Conclusion

International trade theory has recently made significant progress in modeling the endogenous choice of how to serve a foreign market. Yet standard considerations such as transportation costs and fixed costs are only part of a firm's choice; 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, multi-sector 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 priced in the local currency, then volatility will not matter. On the other hand, sticky wages imply that volatility always matters. As more data become available about the activity of multinationals, these models should 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 volatility such as inflation volatility.

Table 4: Robustness exercises of pooled regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				sales/(sales + exports)				ln(sales/exports)
Inflation volatility	-351.3**	-352.5**		-351.3***	-351.3**		-475.4***	679.7
	(170.7)	(174.0)		(91.64)	(172.9)		(167.0)	(1,194)
Exchange rate volatility	-0.106		-0.633	-0.106	-0.106		32.49***	29.00**
	(0.747)		(0.551)	(0.341)	(0.749)		(9.144)	(12.71)
Inflation volatility$_{t-1}$						-328.7**	-199.2**	
						(122.5)	(84.63)	
Exchange rate volatility$_{t-1}$						-0.411	-0.162	
						(0.687)	(0.774)	
GDP volatility	35.79	35.79	40.42*	35.79**	35.79	40.82*	32.84	79.89
	(22.60)	(22.60)	(23.11)	(12.94)	(23.12)	(23.95)	(23.10)	(113.9)
Inflation level	-0.0652	-0.0644	-0.382	-0.0652	-0.0652	-0.346	-0.298	-3.929
	(0.440)	(0.440)	(0.304)	(0.162)	(0.437)	(0.351)	(0.452)	(2.483)
OECD	0.200**	0.200**	0.198**	0.200***	0.200**	0.213**	0.213**	0.665
	(0.0840)	(0.0836)	(0.0865)	(0.0438)	(0.0829)	(0.0889)	(0.0848)	(0.467)
U.S. border	-0.0652	-0.0650	-0.0542	-0.0652	-0.0652	-0.0833	-0.0956	-1.712***
	(0.112)	(0.112)	(0.114)	(0.107)	(0.120)	(0.120)	(0.119)	(0.597)
ln (real GDP per capita)	-0.0534	-0.0534	-0.0572	-0.0534***	-0.0534	-0.0553	-0.0584	-0.339
	(0.0368)	(0.0368)	(0.0378)	(0.0147)	(0.0389)	(0.0393)	(0.0369)	(0.220)
ln (distance)	0.0434	0.0435	0.0399	0.0434	0.0434	0.0390	0.0357	-0.549
	(0.0716)	(0.0715)	(0.0727)	(0.0488)	(0.0694)	(0.0738)	(0.0733)	(0.458)
Rule of law index	0.0901	0.0903	0.0995	0.0901**	0.0901	0.0813	0.0761	0.513
	(0.0585)	(0.0585)	(0.0605)	(0.0323)	(0.0571)	(0.0611)	(0.0584)	(0.340)
Common language	-0.0316	-0.0318	-0.0466	-0.0316	-0.0316	-0.0275	-0.00652	-0.346
	(0.0659)	(0.0655)	(0.0693)	(0.0193)	(0.0657)	(0.0726)	(0.0696)	(0.379)
Colony	0.108	0.108	0.123*	0.108**	0.108	0.102	0.0845	0.555
	(0.0692)	(0.0690)	(0.0708)	(0.0362)	(0.0754)	(0.0744)	(0.0748)	(0.460)
Landlocked	-0.0129	-0.0130	-0.0189	-0.0129	-0.0129	-0.0107	-0.00813	0.276
	(0.0674)	(0.0674)	(0.0705)	(0.0232)	(0.0637)	(0.0684)	(0.0649)	(0.292)
Observations	3,127	3,127	3,127	3,127	3,127	2,653	2,653	2,695
R-squared	0.396	0.396	0.389	0.396	0.396	0.394	0.408	0.531
Industry-year dummies	yes	yes	yes	yes	yes	yes	yes	yes
Crisis countries	yes	yes	yes	yes	yes	yes	yes	yes
Clustered by	country	country	country	industry	group euro	country	country	country

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

A Technical appendix

A.1 Derivation of S_t

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

$$P(s^t)C(s^t) + \sum_{s^{t+1}} Q(s^{t+1}|s^t)B(s^{t+1}) + M(s^t) = M(s^{t-1}) + W(s^t)L(s^t) + B(s^t) + \Pi(s^t) + T(s^t).$$

where $\Pi(s^t)$ are profits from domestic firms and $T(s^t)$ 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, with Lagrange multiplier $\lambda(s^t)$:

$$\begin{aligned}
C(s^t) &: U_C(\cdot) = \lambda(s^t)P(s^t), \\
L(s^t) &: U_L(\cdot) + \lambda(s^t)W(s^t) = 0, \\
M(s^t) &: U_M(\cdot) + \beta \sum_{s^{t+1}} \lambda_{t+1} = \lambda(s^t), \\
B(s^{t+1}|s^t) &: Q(s^{t+1}|s^t) = \pi(s^{t+1}|s^t)\beta\frac{\lambda(s^{t+1})}{\lambda(s^t)}.
\end{aligned}$$

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 $M(s^t)$ first order condition:

$$\begin{aligned}
& U_M + \beta \sum_{s^{t+1}} \pi(s^{t+1}|s^t)\lambda(s^{t+1}) = \lambda(s^t), \\
\Rightarrow \quad & \frac{\chi}{M(s^t)} + \beta \sum_{s^{t+1}} \pi(s^{t+1}|s^t)\frac{1}{P(s^{t+1})C(s^{t+1})^\rho} = \frac{1}{P(s^t)C(s^t)^\rho}, \\
\Rightarrow \quad & \frac{P(s^t)C(s^t)^\rho \chi}{M_t} + \beta \sum_{s^{t+1}} \pi(s^{t+1}|s^t)\frac{P(s^t)C(s^t)^\rho}{P(s^{t+1})C(s^{t+1})^\rho} = 1,
\end{aligned}$$

Following Obstfeld and Rogoff (1998), consider

$$
\begin{aligned}
1 &= \frac{\chi P(s^t)C(s^t)^\rho}{M(s^t)} + \sum_{s^{t+1}} \pi(s^{t+1}|s^t) \left[\beta \frac{P(s^t)C(s^t)^\rho}{P(s^{t+1})C(s^{t+1})^\rho}\right] \\
&= \frac{\chi P(s^t)C(s^t)^\rho}{M(s^t)} + \beta \frac{\chi P(s^t)C(s^t)^\rho}{M(s^t)} \sum_{s^{t+1}} \pi(s^{t+1}|s^t) \left[\frac{M(s^t)}{P(s^{t+1})C(s^{t+1})^\rho}\right] \\
&= \frac{\chi P(s^t)C(s^t)^\rho}{M(s^t)} + \beta \frac{\chi P(s^t)C(s^t)^\rho}{M(s^t)} \sum_{s^{t+1}} \pi(s^{t+1}|s^t) \left[\frac{M(s^t)}{M(s^{t+1})} \frac{M(s^{t+1})}{\chi P(s^{t+1})C(s^{t+1})^\rho}\right].
\end{aligned}
$$

A candidate solution is one in which $\frac{\chi P(s^t)C(s^t)^\rho}{M(s^t)}$ is a constant for all t. Let $\alpha \equiv \sum_{s^{t+1}} \pi(s^{t+1}|s^t) \left[\frac{M(s^t)}{M(s^{t+1})}\right] = \sum_{s^t} \pi(s^t|s^{t-1}) \left[\frac{M(s^{t-1})}{M(s^t)}\right]$. Then,

$$
\begin{aligned}
1 &= \frac{\chi P(s^t)C(s^t)^\rho}{M(s^t)} + \beta \sum_{s^{t+1}} \pi(s^{t+1}|s^t) \left[\frac{M(s^t)}{M(s^{t+1})}\right], \\
\Rightarrow \quad C(s^t)^\rho &= \frac{M(s^t)}{P(s^t)} \frac{1-\beta\alpha}{\chi}.
\end{aligned}
$$

The foreign budget constraint is analogous:

$$
P^*(s^t)C^*(s^t) + \sum_{s^{t+1}} Q(s^{t+1})B^*(s^{t+1}) \frac{1}{S(s^t)} + M^*(s^t) = M^*(s^{t-1}) + W^*(s^t)L^*(s^t) + \Pi^*(s^t) + T^*(s^t) + B^*(s^t) \frac{1}{S(s^t)}.
$$

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

$$
Q(s^{t+1}|s^t) = \pi(s^{t+1}|s^t)\beta \frac{P^*(s^t)C^*(s^t)^\rho}{P^*(s^{t+1})C^*(s^{t+1})^\rho} \frac{S(s^t)}{S(s^{t+1})}
$$

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 backwards:

$$
\begin{aligned}
\frac{P^*(s^t)C^*(s^t)^\rho}{P^*(s^{t+1})C^*(s^{t+1})^\rho} \frac{S(s^t)}{S(s^{t+1})} &= \frac{P(s^t)C(s^t)^\rho}{P(s^{t+1})C(s^{t+1})^\rho}, \\
\Rightarrow \quad \frac{P^*(s^0)C^*(s^0)^\rho}{P^*(s^1)C^*(s^1)^\rho} \frac{S(s^0)}{S(s^1)} &= \frac{P(s^0)C(s^0)^\rho}{P(s^1)C(s^1)^\rho}.
\end{aligned}
$$

Let $S(s^0)\frac{P^*(s^0)C^*(s^0)^\rho}{P(s^0)C(s^0)^\rho} \equiv 1$, then:

$$\begin{aligned} S(s^1) &= \frac{P(s^1)C(s^1)^\rho}{P^*(s^1)C^*(s^1)^\rho} \\ \Rightarrow \quad S(s^t) &= \frac{P(s^t)C(s^t)^\rho}{P^*(s^t)C^*(s^t)^\rho}. \end{aligned}$$

This is the standard result that the (nominal) exchange rate equals the ratio of the marginal utilities of consumption adjusted by the nominal price indices. With the expression for $C(s^t)^\rho$, the exchange rate can be expressed as a function of exogenous variables:

$$S(s^t) = \frac{M(s^t)}{M(s^t)^*}\frac{1-\beta\alpha}{1-\beta\alpha^*}.$$

With s^t notation only important for this result, uncertainty can be expressed for the rest of the analysis in terms of subscripts and expectations.

A.2 Proof of proposition 1

The weighted-average exporter productivity is

$$\tilde{\phi}_X^{*\theta-1} = \frac{1}{G(\hat{\phi}_{MP}^*) - G(\hat{\phi}_X^*)} \int_{\hat{\phi}_X^*}^{\hat{\phi}_{MP}^*} \phi^{\theta-1} g(\phi)\, d\phi, \tag{20}$$

and the weighted-average multinational productivity is

$$\tilde{\phi}_{MP}^{*\theta-1} = \frac{1}{1 - G(\hat{\phi}_{MP}^*)} \int_{\hat{\phi}_{MP}^*}^{\infty} \phi^{\theta-1} g(\phi)\, d\phi. \tag{21}$$

From (4), the representative exporter charges the following price, noting that P_t^θ is non-stochastic:

$$p_{X,t}^*(\tilde{\phi}_X^*) = \frac{\theta}{\theta-1}\frac{1}{\tilde{\phi}_X^*}\tau\frac{E_{t-1}[d_t^* W_t^* C_t]}{E_{t-1}[d_t^* \frac{1}{S_t} C_t]}.$$

Using factor price equalization ($W_t^* S_t = W_t$), one can also express the representative multinational firm price:

$$p_{MP,t}^*(\tilde{\phi}_{MP}^*) = \frac{\theta}{\theta-1}\frac{1}{\tilde{\phi}_{MP}^*}\frac{E_{t-1}[d_t^* W_t^* C_t]}{E_{t-1}[d_t^* \frac{1}{S_t} C_t]}.$$

Thus, the relative price is simply

$$\frac{p_{MP,t}^*(\tilde{\phi}_{MP}^*)}{p_{X,t}^*(\tilde{\phi}_X^*)} = \frac{\tilde{\phi}_X^*}{\tilde{\phi}_{MP}^*\tau}.$$

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

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

where $N^*_{MP,t}$ is the fraction of the unit mass of foreign firms which produce in the home country, and $N^*_{X,t}$ is the fraction that 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), found that the Pareto distribution captures well the firm size distribution 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 $G(\phi) = 1 - \phi^{-k}$.

In the main text we had that $\hat{\phi}^*_{MP}/\hat{\phi}^*_X$ is a constant. Let $\gamma^*_X \equiv \hat{\phi}^*_{MP}/\hat{\phi}^*_X$. Now we seek to prove that if γ^*_X is constant, then $\tilde{\phi}^*_{MP}/\tilde{\phi}^*_X$ 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 $\hat{\phi}^*_{MP}$:

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

Using the definition of the average productivity (20) above, one can also show that:

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

The ratio is then:

$$\left(\frac{\tilde{\phi}^*_{MP}}{\tilde{\phi}^*_X} \right)^{\theta-1} = \left(\frac{\gamma^{*k-1}_X}{\gamma^{*k+1-\theta}_X - 1} \right)^{\frac{\theta}{\theta-1}}. \tag{22}$$

Since $\gamma^*_X > 1$ is constant, this ratio is also constant with respect to nominal uncertainty.

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

$$N^*_{MP} = \hat{\phi}^{*-k}_{MP},$$

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:

$$\frac{N_{MP}^*}{N_X^*} = \frac{1}{\gamma_X^{*k} - 1}. \tag{23}$$

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 $y_{MP,t}^*(\tilde{\phi}_{MP}^*)/y_{X,t}^*(\tilde{\phi}_X^*)$.

A.3 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 formally demonstrates 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 $p_{X,t}(\phi) = \frac{1}{S_t}\frac{\theta}{\theta-1}\frac{W_t}{\phi}$, the export cutoff 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 $p_{MP,t}(\phi) = \frac{\theta}{\theta-1}\frac{W_t^*}{\phi}$ and the multinational cutoff becomes:

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

The relative cutoff expression is more informative:

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

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 underlying shock process.

A.4 Derivation of P_t^*

The zero profit condition of goods aggregation implies:

$$P_t^* C_t^* - \int_{\Omega^*} p_t^*(i) y_t^*(i)\, di - \int_{\Omega_X} \frac{1}{S_t} p_{X,t}(i) y_{X,t}(i)\, di - \int_{\Omega_{MP}} p_{MP,t}(i) y_{MP,t}(i)\, di = 0.$$

Substituting the appropriate versions of (2) for the quantities, we obtain:

$$\begin{aligned} P_t^* C_t^* &= \int_{\Omega^*} p_t^*(i)^{1-\theta} P_t^{*\theta} C_t^*\, di + \int_{\Omega_X} S_t^{\theta-1} p_{X,t}^{1-\theta} P_t^{*\theta} C_t^*\, di + \int_{\Omega_{MP}} p_{MP,t}(i)^{1-\theta} P_t^{*\theta} C_t^*\, di, \\ \Rightarrow \quad P_t^{*1-\theta} &= \int_{\Omega^*} p_t(i)^{*1-\theta}\, di + \int_{\Omega_X} S_t^{\theta-1} p_{X,t}(i)^{1-\theta}\, di + \int_{\Omega_{MP}} p_{MP,t}(i)^{1-\theta}\, di. \end{aligned}$$

Note that the only term unknown at date $t-1$ is the exchange rate S_t. Using the analogous expressions to (20) and (21) for the weighted-average productivities and keeping in mind that the mass of potential entrants is normalized within $(0,1)$, we obtain equation (11).

A.5 Discussion of Ξ_1

Recall that $\Xi_1 \equiv \frac{E_{t-1}\left[M_t^{*1/\rho} P_t^{*\theta-1/\rho}\right]}{E_{t-1}\left[M_t^{*1/\rho-1} P_t^{*\theta-1/\rho}\right]}$. M_t^* is log-normal by construction, and at time t, P_t^* varies only with the exchange rate $S_t = \frac{M_t}{M_t^*}\frac{1-\beta}{1-\beta\alpha^*}$. Thus, P_t^* is a shifted log-normal, due to the presence of the domestic and multinational price terms. I treat P_t^* as approximately log-normal, which allows for analytical expressions of Ξ_1. Numerical simulations indicate that these approximations are reasonable.

By the properties of log-normal random variables, we have:

$$\frac{E_{t-1}\left[M_t^{*1/\rho} P_t^{*\theta-1/\rho}\right]}{E_{t-1}\left[M_t^{*1/\rho-1} P_t^{*\theta-1/\rho}\right]} \approx E_{t-1}[M_t^*] exp((1/\rho-1)\sigma_{m^*}^2 + (\theta-1/\rho))\sigma_{m^*p^*})$$

where σ_{mp} is the covariance between $m^* = \ln M^*$ and $p^* = \ln P^*$. The first term is negative but less than 1 in absolute value for $\rho > 1$, and the second coefficient is positive. To approximate this covariance, we need a closed-form expression for P_t^*. Consider a first-order approximation of P_t^*

around the non-stochastic steady state $\bar{P}^{*}$:

$$\hat{P}_t^* \approx \bar{P}^{*(1-\theta)/\theta} \bar{N}_X \frac{\theta}{\theta - 1} \frac{1}{\bar{\tilde{\phi}}_X} \tau \frac{1-\beta}{\chi} \hat{M}_t *,$$

that is, after domestic and multinational prices are set in $t-1$, the foreign aggregate price index fluctuates based on the degree to which home exports form part of the price index (N_X).

An approximation for the covariance is then:

$$\sigma_{m^*p^*} \approx \hat{P}_t^* \hat{M}_t^* = \bar{P}^{*(1-\theta)/\theta} \bar{N}_X \frac{\theta}{\theta - 1} \frac{1}{\bar{\tilde{\phi}}_X} \tau \frac{1-\beta}{\chi} \sigma_{m^*}^2. \tag{24}$$

So we have:

$$\frac{E_{t-1}\left[M_t^{*1/\rho} P_t^{*\theta - 1/\rho}\right]}{E_{t-1}\left[M_t^{*1/\rho - 1} P_t^{*\theta - 1/\rho}\right]} \approx E_{t-1}[M_t^*] exp \left[\left(\left(\frac{1}{\rho} - 1 \right) + \left(\theta - \frac{1}{\rho} \right) \left(\bar{P}^{*(1-\theta)/\theta} \bar{N}_X \frac{\theta}{\theta - 1} \frac{1}{\bar{\tilde{\phi}}_X} \tau \frac{1-\beta}{\chi} \right) \right) \sigma_{m^*}^2 \right].$$

In the benchmark calibration, $\rho = 2$ so the first term is -0.5, and the second term is about 0.34. In the numerical exercise, $\sigma_{m^*}^2 \in [0, 0.03]$, so both the approximate and exact numerical solutions for Ξ_1 are very close to 1 ($E_{t-1}[M_t^*] = 1$ if $M_{t-1}^* = 1$). Quantitatively, it can be ignored when considering the comparative statics.

A.6 Discussion of relative cutoff

Again making the assumption that P_t^* is approximately log-normal, we have by the properties of log-normals:

$$\begin{aligned}
\frac{E_{t-1}\left[M_t^{*1/\rho - 1} P_t^{*\theta - 1/\rho}\right]}{E_{t-1}\left[M_t^{*1/\rho - \theta} P_t^{*\theta - 1/\rho}\right]} =& E_{t-1}[M_t^*]^{\theta - 1} exp \Bigg(\frac{(1/\rho - 1)(1/\rho - 2)}{2} \sigma_{m^*}^2 + (1/\rho - 1)(\theta - 1/\rho)\sigma_{m^*p^*} - \\
& \frac{(1/\rho - \theta)(1/\rho - \theta - 1)}{2} \sigma_{m^*}^2 - (1/\rho - \theta)(\theta - 1/\rho)\sigma_{m^*p^*} \Bigg) \\
& = exp \Bigg((-\theta^2/2 - \theta/2 + \theta/\rho - 1/\rho + 1)\sigma_{m^*}^2 + (\theta - 1)(\theta - 1/\rho)\sigma_{m^*p^*}^2 \Bigg).
\end{aligned}$$

With $\rho = 2$, the first term is negative provided $\theta > 1$. The second term is positive, though $\sigma_{m^*p^*}^2$ is small. Section A.5 shows that this covariance depends on the degree to which exports affect the foreign price level. For $\rho = 2$, this expression is decreasing in $\sigma^2 m^*$ so long as $\sigma_{m^*p^*}/\sigma_{m^*}^2 < 1/2(\theta + 1)/(\theta - 1/2)$. For $\theta = 5$, this is 2/3. In practice, the approximation (24) gives $\sigma_{m^*p^*}/\sigma_{m^*}^2 \approx 0.08$ for the benchmark calibration.

A.7 Numerical solution

I employ numerical techniques to characterize the equilibrium described in Section 4. The basic procedure is to discretize the exogenous, stochastic variable (M^*), and solve the model such that the pricing, cutoff, and equilibrium conditions hold in every state of the economy. 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. This is more than sufficient to both accurately match values for which exact solutions are available and such that increasing the number of nodes has an insignificant quantitative effect. Then, using numerical search over $\hat{\phi}^*$, $\hat{\phi}_X$, $\hat{\phi}_{MP}$, p, p_X, p_{MP}, I calculate the other endogenous variables. The numerical algorithm iterates until the following equilibrium conditions hold:

1. The foreign firm cutoff condition:

$$E_{t-1}\left[d_t^* P_t^{*\theta} C_t^* \left(p_t^*(\hat{\phi}_t^*)^{1-\theta} - \frac{1}{\hat{\phi}_t^*} W_t^* p_t^*(\hat{\phi}_t^*)^{-\theta}\right)\right] - E_{t-1}\left[d_t^* P_t^* f\right] = 0.$$

2. The home exporter profit condition, expressed in foreign terms (note that $d_t = \frac{S_{t-1}}{S_t} d_t^*$ and $S_{t-1} = \frac{1-\beta\alpha}{1-\beta\alpha^*}$):

$$E_{t-1}\left[d_t^* S_t^{\theta-1} P_t^{*\theta} C_t^* \left(p_{X,t}(\hat{\phi}_{X,t})^{1-\theta} - \frac{1}{\hat{\phi}_{X,t}} W_t^* S_t \tau p_{X,t}(\hat{\phi}_{X,t})^{-\theta}\right)\right] - E_{t-1}\left[d_t^* \frac{S_{t-1}}{S_t} P_t^* f_X\right] = 0.$$

3. The home multinational production cutoff condition:

$$E_{t-1}\left[d_t^* P_t^{*\theta} C_t^* \left(p_{MP,t}(\hat{\phi}_{MP,t})^{1-\theta} - \frac{1}{\hat{\phi}_{MP,t}} W_t^* p_{MP,t}(\hat{\phi}_{MP,t})^{-\theta}\right)\right] - E_{t-1}\left[d_t^* S_t^{\theta-1} P_t^{*\theta} C_t^* \left(p_{X,t}(\hat{\phi}_{MP,t})^{1-\theta} - \frac{1}{\hat{\phi}_{MP,t}} W_t^* S_t \tau p_{X,t}(\hat{\phi}_{MP,t})^{-\theta}\right)\right] - E_{t-1}\left[d_t^* \frac{S_{t-1}}{S_t} P_t^* (f_{MP} - f_X)\right] = 0.$$

4. The foreign price condition:

$$p_t^*(\tilde{\phi}) = \frac{\theta}{\theta-1} \frac{1}{\tilde{\phi}} \frac{E_{t-1}\left[d_t^* P_t^{*\theta} C_t^* W_t^*\right]}{E_{t-1}\left[d_t^* P_t^{*\theta} C_t^*\right]}.$$

5. The exporter price condition:

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

6. The multinational production price condition:

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

B Data appendix

B.1 Data description

Table 5 lists the sources of the variables used in the estimation procedure. Table 6 provides summary statistics for each variable. The full country list is: Argentina, Austria, Belgium, Brazil, Canada, Colombia, Costa Rica, Czech Republic, Denmark, the Dominican Republic, Egypt, Finland, France, Germany, Greece, Honduras, Hong Kong, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Malaysia, Mexico, Netherlands, Nigeria, Norway, Panama, Peru, Philippines, Poland, Portugal, Russia, Saudi Arabia, Singapore, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, United Kingdom, Venezuela. The crisis countries are: Argentina, Turkey, Venezuela, Brazil, and the Dominican Republic.

Table 5: 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
Distance, common language, colony, land-locked	Rose (2005)
Rule of law	World Bank World Governance Indicators (WGI)
Real GDP per capita	World Bank World Development Indicators (WDI)

B.2 Summary statistics

Table 6: Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
sales/(sales + exports)	3565	0.57	0.35	0.00	1.00
ln (sales/exports)	3050	1.03	2.54	−7.52	13.02
CPI volatility*1000	3127	0.04	0.11	0.00	1.49
Inflation level	3127	0.05	0.07	−0.04	0.62
Exrate volatility*1000	3453	0.94	7.43	0.00	152.52
GDP volatility*1000	3502	0.69	2.63	0.00	50.56
OECD	3565	0.46	0.50	0.00	1.00
U.S. border	3565	0.04	0.20	0.00	1.00
ln (real GDP per capita)	3499	9.06	1.26	5.88	11.19
ln (dist)	3502	8.51	0.49	6.98	9.15
Rule of law	3565	0.69	0.96	−1.66	1.96
Common language	3502	0.33	0.47	0.00	1.00
Colony	3502	0.04	0.20	0.00	1.00
Landlocked	3502	0.09	0.29	0.00	1.00
Crisis	3565	0.12	0.32	0.00	1.00

Table 7: Average statistics by country

Name	sales/(sales + exports)	CPI volatility * 100	Exrate volatility * 100
Argentina	0.6672	0.0089	0.2243
Australia	0.7407	0.0000	0.0595
Austria	0.7543	0.0005	0.0470
Belgium	0.6296	0.0008	0.0487
Brazil	0.7842	0.0019	0.2259
Canada	0.5577	0.0013	0.0268
Colombia	0.5492	0.0027	0.0552
Costa Rica	0.4151	0.0023	0.0009
Czech Republic	0.8402	0.0022	0.0740
Denmark	0.7010	0.0014	0.0388
Dominican Republic	0.0639	0.0268	0.2102
Egypt	0.4432	0.0016	0.0506
Finland	0.5747	0.0011	0.0497
France	0.8035	0.0007	0.0480
Germany	0.8563	0.0011	0.0468
Greece	0.5009	0.0124	0.0495
Honduras	0.1560	0.0012	0.0016
Hong Kong	0.4262	0.0026	0.0001
Hungary	0.8390	0.0031	0.0617
India	0.6325	0.0050	0.0090
Indonesia	0.5736	0.0085	0.1990
Ireland	0.6742	0.0017	0.0482
Israel	0.3886	0.0023	0.0290
Italy	0.7824	0.0001	0.0477
Japan	0.4093	0.0008	0.0499
Korea: Republic of	0.3638	0.0019	0.0321
Luxembourg	0.2025	0.0052	0.0513
Malaysia	0.5876	0.0007	0.0024
Mexico	0.5193	0.0011	0.0263
Netherlands	0.7243	0.0022	0.0477
Nigeria	0.2112	0.0387	1.8358
Norway	0.6802	0.0026	0.0558
Peru	0.4137	0.0010	0.0087
Philippines	0.5420	0.0035	0.0219
Poland	0.7737	0.0016	0.0702
Portugal	0.7065	0.0014	0.0480
Russia	0.5557	0.0069	0.0164
Saudi Arabia	0.1753	0.0007	0.0000
Singapore	0.5834	0.0019	0.0112
South Africa	0.6518	0.0017	0.1265
Spain	0.8383	0.0023	0.0496
Sweden	0.7029	0.0016	0.0547
Switzerland	0.6776	0.0014	0.0519
Thailand	0.6432	0.0015	0.0219
Turkey	0.4465	0.0149	0.2091
United Kingdom	0.8338	0.0012	0.0324
Venezuela	0.5477	0.0068	0.1794

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Exports versus Multinational Production under Nominal Uncertainty

Additional appendix not for publication

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C Optimal Currency Choice

In the benchmark model analyzed in Section 4, exporters benefit from the foreign volatility, and domestic volatility is effectively shut down. In this section, I discuss the optimality of the producer currency price (PCP) choice for exporters and more general conditions under which it holds. This draws heavily on the currency choice literature. Engel (2006) analytically derives the optimal currency choice under a second-order approximation of profit maximization for general demand and cost functions. To translate these lessons into the benchmark model of this paper, I consider whether home exporters would optimally choose PCP, while multinationals are restricted to local currency pricing (LCP). Given factor price equalization, cost motives for preferring one mode of serving the foreign market over another are shut down. If PCP is the optimal price choice, then expected profits will necessarily be lower if a multinational can only engage in (LCP). As volatility rises, this difference becomes more acute, and the relative attractiveness of exporting rises. In this sense, the model in Section 4 embeds a currency choice, but that choice is made alongside the choice of how to serve the foreign market.

Let $\tilde{\theta}_X = -\frac{\partial y}{\partial p_X}\frac{p_X}{y}$ be the effective elasticity of demand faced by the exporter. Then let $\tilde{\epsilon}_X = \frac{\partial \tilde{\theta}_X}{\partial p_X}\frac{p_x}{\tilde{\theta}_X}$ be the elasticity of the elasticity, or the "super-elasticity" of demand. Engel (2006, p. 1256) shows that an exporter will choose PCP when:[29]

$$\tilde{\epsilon} b_{P^*S} + (\tilde{\theta}_X - 1) b_{WS} < \frac{\tilde{\theta} - 1 - \tilde{\epsilon}}{2}, \tag{25}$$

where b_{P^*S} represents the coefficient on the projection of the log of the aggregate foreign price index ($\ln P^*$) on the log of the exchange rate ($\ln S$), and b_{WS} likewise for the log of home wages.

First, consider a partial equilibrium environment in which the only stochastic variable is the exchange rate. Then the left hand side of (25) is zero. With CES demand, $\tilde{\epsilon} = 0$ and $\tilde{\theta} = \theta > 1$, a constant, and the condition always holds, making PCP the optimal currency choice. That said, there is still significant room for $\tilde{\epsilon} > 0$, which Gopinath et al. (2010) explore further.

In the case of linear demand, $\frac{\partial y}{\partial p} = -\mu$, a constant.[30] Then $\tilde{\theta} = \frac{\mu p_X}{y}$, and $\tilde{\epsilon} = \tilde{\theta} + 1$. This implies that the right hand side of (25) is $\frac{\tilde{\theta}-1-\tilde{\epsilon}}{2} = -2 < 0$. That is, if the left hand side is zero

[29] Engel (2006) generalizes this further to allow for the cost function to be non-linear and some costs to be paid in each market, elements from which I abstract to focus on the demand function.

[30] LCP is also generally optimal if demand is linear in relative prices, such that $\frac{\partial y}{\partial p} = \frac{-\mu}{P^*}$.

(partial equilibrium) or greater than -2 (weak general equilibrium effects), then LCP is optimal. In general, we would expect b_{P^*S} to be negative but small: a foreign monetary expansion will cause a foreign depreciation (S falls), and imported goods priced in the home currency will become more expensive (the overall price index P^* rises slightly). Without home volatility, wages $W_t = \frac{1-\beta}{\chi}$ are fixed, and thus $b_{WS} = 0$.

D Sticky Wage Model

In this section, I lay out an alternative model to the benchmark sticky price model considered in the paper. Instead of sticky nominal prices, nominal wages are sticky. The labor market consists of monopolistically competitive households which supply labor, along the lines of Chari et al. (2002). This labor is aggregated in a competitive market, leaving the heterogeneous firms producing varieties in the model to face an aggregate wage W_t in the home market and W_t^* in the foreign market.

D.1 Households

Utility is now indexed by household j and takes the form:

$$U_j(C_{j,t}, L_{j,t}, M_{j,t}) = \frac{C_{j,t}^{1-\rho}}{1-\rho} - \kappa l_{j,t} + \chi \ln \frac{M_{j,t}}{P_t}.$$

It can be shown that marginal utilities across households are equal up to a constant, assumed to be unity. With marginal utilities equalized, the households act exactly as a representative household for the consumption, money, and bond first order conditions.

Define ν as the elasticity of substitution between varieties of labor.[31] The composite unit of labor is then:

$$L_t = \left[\int l_{j,t}^{\frac{\nu-1}{\nu}} \, dj \right]^{\frac{\nu}{\nu-1}}. \tag{26}$$

Demand for each household's labor variety is then a matter of profit maximization or cost minimization:

$$\max W_t L_t - \int w_{j,t} l_{j,t} \, dj,$$

subject to (26), where W_t is the aggregate wage and $w_{j,t}$ is the wage paid to household j. This leads to a standard CES demand condition for labor as a function of the relative wage and total

[31]This is the only additional parameter to calibrate relative to the benchmark model. I keep all other parameters as in Table 1 and set $\nu = 7.7$ following Chari et al. (2002).

labor demand:

$$l_{j,t} = \left(\frac{W_t}{w_{j,t}}\right)^{\nu} L_t. \tag{27}$$

The zero profit condition provides the definition of the wage index:

$$W_t = \left[\int w_{j,t}^{1-\nu}\, dj\right]^{\frac{1}{1-\nu}}.$$

The budget constraint for each household is now (omitting s^t wherever possible):

$$P_{j,t}C_{j,t} + \sum_{s^{t+1}} Q(s^{t+1}|s^t)B_j(s^{t+1}) + M_{j,t} = M_{j,t-1} + w_{j,t}l_{j,t} + B_j(s^t) + \Pi_{j,t} + T_{j,t}. \tag{28}$$

Substituting (27) into (28) and taking the derivative with respect to $w_{j,t}$,[32] one obtains:

$$w_{j,t} = \frac{\nu}{\nu - 1}\frac{\kappa E_{t-1}[L_t]}{E_{t-1}\left[\frac{L_t}{P_t C_t^{\rho}}\right]} \tag{29}$$

The other household first order conditions provide the same expressions for C_t and S_t shown in the paper.

$$C_t^{\rho} = \frac{M_t}{P_t}\frac{1-\beta\alpha}{\chi},\ \alpha \equiv E_t\left[\frac{M_t}{M_{t+1}}\right].$$

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

D.2 Firms

With flexible prices and CES demand, firm prices are fixed markups over marginal costs. That is,

$$p_t(\phi) = \frac{\theta}{\theta-1}\frac{W_t}{\phi}, \qquad p_t^*(\phi) = \frac{\theta}{\theta-1}\frac{W_t^*}{\phi},$$

$$p_{X,t}(\phi) = \frac{\theta}{\theta-1}\tau\frac{W_t}{S_t\phi}, \qquad p_{X,t}^*(\phi) = \frac{\theta}{\theta-1}\tau\frac{S_tW_t^*}{\phi},$$

$$p_{MP,t}(\phi) = \frac{\theta}{\theta-1}\frac{W_t^*}{\phi}, \qquad p_{MP,t}^*(\phi) = \frac{\theta}{\theta-1}\frac{W_t}{\phi}.$$

Note that $p_t, p_{X,t}^*$, and $p_{MP,t}^*$ are denominated in the home currency while $p_t^*, p_{X,t}$, and $p_{MP,t}$ are denominated in the foreign currency.

As before, we assume that a firm either serves a foreign market through exports or through

[32] Households set their wage in advance and agree to supply whatever quantity of labor in the next period is demanded at that wage. Note that all households will set the same wage.

multinational production. Unlike the sticky price model in the paper, this model is symmetric between countries. Consider foreign firms looking to serve the home market. A firm on the margin between exporting and not exporting satisfies:

$$\xi^*(\hat{\phi}_{X,t}) \equiv E_{t-1}\left[d_t^*\left(\frac{1}{S_t}p^*_{X,t}(\hat{\phi}^*_{X,t})y^*_{X_t}(\hat{\phi}^*_{X,t}) - \frac{W_t^*}{\hat{\phi}^*_{X,t}}\tau y^*_{X,t}(\hat{\phi}^*_{X,t})\right)\right] = E_{t-1}\left[d_t^*\frac{1}{S_{t-1}}P_t f_X\right],$$

where $y^*_{X,t}(\phi) = \left(\frac{P_t}{p^*_{X,t}(\phi)}\right)^\theta C_t$. This leads to the following expression for the cutoff productivity, keeping in mind that now the wage W_t^* is known at time $t-1$.

$$\hat{\phi}^{*\theta-1}_{X,t} = \frac{\frac{f_X}{S_{t-1}}E_{t-1}\left[d_t^* P_t\right]}{\left(\left(\frac{\theta}{\theta-1}\right)^{1-\theta} - \left(\frac{\theta}{\theta-1}\right)^{-\theta}\right)\tau^{1-\theta}W_t^{*1-\theta}E_{t-1}\left[d_t^* P_t^\theta C_t S_t^{-\theta}\right]}. \tag{30}$$

The multinational cutoff is derived analogously to that in the baseline model, as the cutoff point at which a firm is indifferent between serving a market via multinational production and via exporting. That is,

$$E_{t-1}\left[d_t^*\frac{1}{S_t}\left(p^*_{MP,t}(\hat{\phi}^*_{MP,t})y^*_{MP,t}(\hat{\phi}^*_{MP,t}) - \frac{W_t y^*_{MP,t}(\hat{\phi}^*_{MP,t})}{\hat{\phi}^*_{MP,t}}\right)\right] - E_{t-1}\left[d_t^*\frac{1}{S_{t-1}}P_t(f_{MP}-f_X)\right] - \xi^*(\hat{\phi}^*_{MP_t}) = 0.$$

Again solving for $\hat{\phi}^*_{MP}$ in terms of aggregate variables, one obtains:

$$\hat{\phi}^{*\theta-1}_{MP,t} = \frac{\frac{f_{MP}-f_X}{S_{t-1}}E_{t-1}\left[d_t^* P_t\right]}{\left(\left(\frac{\theta}{\theta-1}\right)^{1-\theta} - \left(\frac{\theta}{\theta-1}\right)^{-\theta}\right)\left(W_t^{1-\theta}E_{t-1}\left[d_t^* S_t^{-1}P_t^\theta C_t\right] - W_t^{*1-\theta}\tau^{1-\theta}E_{t-1}\left[d_t^* S_t^{-\theta}P_t^\theta C_t\right]\right)}. \tag{31}$$

The ratio of (30) and (31) can be simplified to the following:

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

Thus, the extensive margin between being an exporter and a multinational depends on how volatility affects the relative wage W^*/W and a stochastic term largely driven by the exchange rate. I proceed as in the baseline model by analyzing the equilibrium numerically.

D.3 Closing and solving the model

Solving the model requires expressions for (1) the domestic cutoff conditions, (2) cutoffs for home firms serving the foreign market, (3) labor demand by firms.

The domestic cutoff conditions are straightforward:

$$E_{t-1}\left[d_t\left(p_t(\hat{\phi}_t)y_t(\hat{\phi}_t)-\frac{W_t}{\hat{\phi}_t}y_t(\hat{\phi}_t)\right)\right]=E_{t-1}\left[d_tP_tf\right].$$

Substituting out for prices and demand, one obtains:

$$\hat{\phi}_t^{\theta-1}=\frac{fE_{t-1}\left[d_tP_t\right]}{\left(\left(\frac{\theta}{\theta-1}\right)^{1-\theta}-\left(\frac{\theta}{\theta-1}\right)^{-\theta}\right)W_t^{1-\theta}E_{t-1}\left[d_tP_t^{\theta}C_t\right]}$$

Since all wages charged by households will be identical, (29) describes the aggregate wage W_t in the home country. Since it depends on expected labor, however, we must now explicitly solve for labor demand by firms. For the home country, this is:

$$L_t=N_t\frac{\tilde{y}_t}{\tilde{\phi}_t}+N_{X,t}\frac{\tilde{y}_{X,t}}{\tilde{\phi}_{X,t}}+N^*_{MP,t}\frac{\tilde{y}^*_{MP,t}}{\tilde{\phi}^*_{MP,t}}$$

where $\tilde{y}$ and $\tilde{\phi}$ denote the sales-weighted average firm output and productivity. The foreign expressions are analogous.

D.4 Results

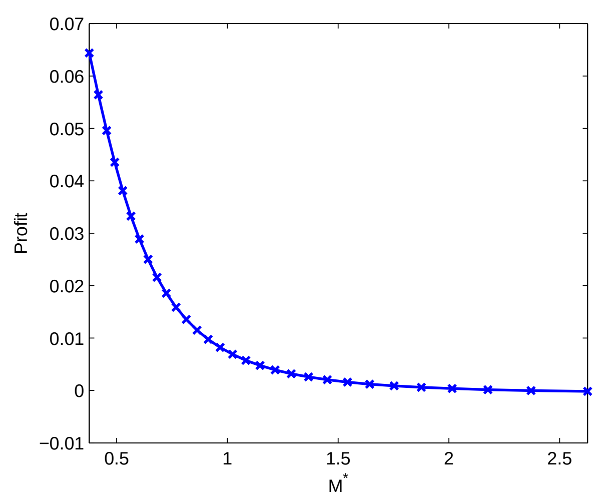

Figure 9: Convexity of the exporter profit function in the sticky-wage model

Figure 9 shows the sticky wage analogue to Figure 2, the convexity of the exporter's profit function for realizations of M^*. As before, a foreign contraction is better for home profits than a foreign expansion is worse.

The intuition is straightforward. Optimal prices are simple markups over marginal cost, converted to the foreign currency. Nominal wages are set in advance, so the only way that prices will change is through the exchange rate. Home exporters pay home wages, and so changes to the exchange rate pass through fully to the foreign market. Home multinationals, on the other hand, pay foreign wages, and so exchange rate changes have no effect on multinational prices. Thus, sticky wages in effect lead to exporters having complete pass through and multinationals having no pass through; this is the same condition for the home country in the benchmark sticky price model. Thus, it is not surprising that the same basic comparative statics should hold.

We can see this in Figures 10 and 11, which are the sticky-wage versions of Figures 4 and 6. Note that in this parameterization, the sticky wage model implies a stronger effect on the nominal ratio than the sticky price model.[33] The sticky wage results are stronger in part because the expected wage ratio $E_{t-1}[S_t]W_t^*/W_t$ rises as foreign volatility rises, shown in Figure 12.

[33]Once again, the real quantity ratio is only very slightly negative, the result of the parameterization of the productivity distribution which reduces the aggregate effect of the extensive margin.

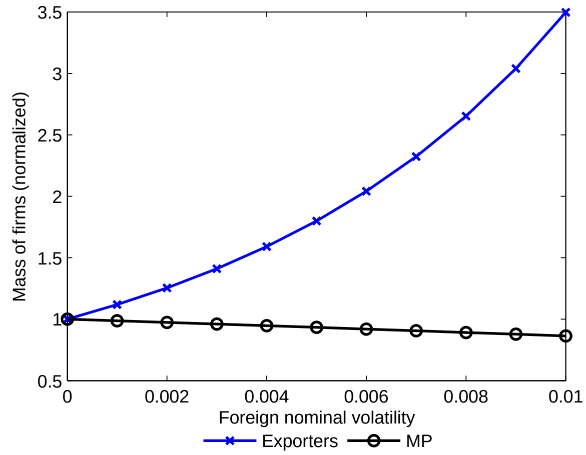

Figure 10: The extensive margin of exporters and multinationals

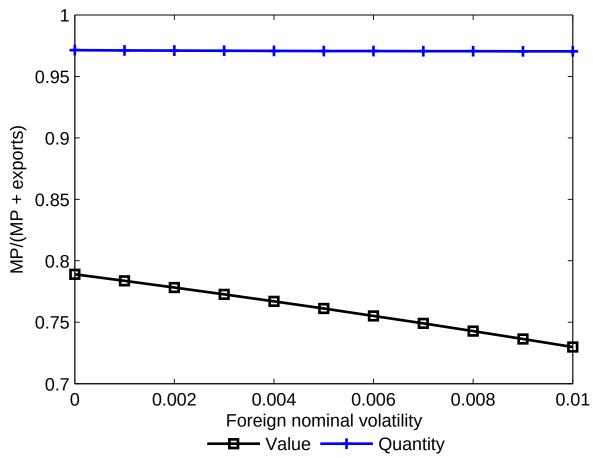

Figure 11: The fraction of total foreign sales from multinationals

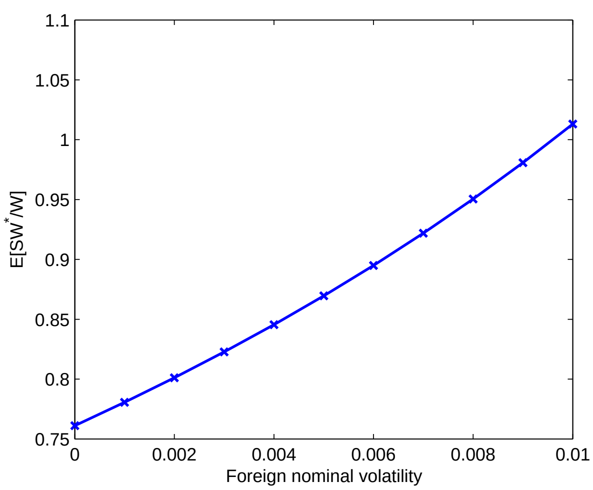

Figure 12: The expected relative foreign wage to home wage.