The Currency Denomination of Trade and Price Discrimination: The Euro after European Union Expansion

Mark David Witte

College of Charleston

Abstract

If a country's imports are invoiced in a foreign currency then the import prices paid by consumers, and the importing country's inflation rate, are vulnerable to exchange rate movements. Using a unique multiple market model I exam a representative firm's currency denomination decision when selling to different countries. The simulation studies the impact of EU expansion on the currency denomination of trade. Results suggest that when preferences are similar across countries EU expansion decreases the likelihood of price discrimination and could decrease the use of the euro as an invoicing currency in the original EU's imports.

December 2007

JEL Classification: F14, F31

Keywords: currency invoicing, exchange rate, inflation, EU expansion, price discrimination

Mark David Witte, 5 Liberty Street, Department of Economics and Finance, Charleston, SC 29401.
Email: wittem@cofc.edu

The Currency Denomination of Trade and Price Discrimination: The Euro after European Union Expansion

Abstract
If a country's imports are invoiced in a foreign currency then the import prices paid by consumers, and the importing country's inflation rate, are vulnerable to exchange rate movements. Using a unique multiple market model I exam a representative firm's currency denomination decision when selling to different countries. The simulation studies the impact of EU expansion on the currency denomination of trade. Results suggest that when preferences are similar across countries EU expansion decreases the likelihood of price discrimination and could decrease the use of the euro as an invoicing currency in the original EU's imports.

Introduction

Previous research on the currency denomination of trade has studied a representative firm's choice of invoicing currency when the firm sells to *only* one foreign market without any domestic buyers[1]. As trading firms tend to have multiple export markets its necessary to develop a model in which a representative firm sells to buyers in multiple countries. With a multiple market structure it's possible to examine the consequences of EU expansion on the currency denomination decision of an individual representative firm who sells to buyers in multiple countries: a non-EU country, a potential EU-expansion country and an original EU country. The simulation herein estimates the exporting firm's optimal currency denomination decisions before and after the EU-expansion country adopts the euro.

In each simulation, various exogenous parameters are randomly assigned to each of the 5,000 representative firms modeled. These randomly assigned parameters determine the firm's market, cost and demand. No particular simulation is designed to typify any particular industry or any particular firm; instead, the randomly assigned

[1] Excellent works include Bachetta and van Wincoop (2005), Friberg (1998) and Goldberg and Tille (2006).

parameters are designed to depict all potential trading firms to determine how those various exogenous parameters may affect the firm's optimal currency of denomination.

Why does the currency denomination of trade matter? If a country's imports are priced in a foreign currency then any movements in the volatile exchange rate will instantly be reflected in the sticky prices of the imports. In addition, if a country is *highly* dependent on imports denominated in a foreign currency then the import prices (and the volatile exchange rate) will have a greater effect on the importing country's inflation rate. Recent research by Gopinath, Itskhoki and Rigobon (2007) has found persistent, heightened price sensitivity to exchange rates when trade isn't denominated in the importing country's currency. Goldberg and Tille (2007) has shown that an importing country is more vulnerable to the macroeconomic shocks of other countries if their imported goods are denominated in a foreign currency.

The most important finding in this paper is that the expansion of the European Union may decrease the likelihood of price discrimination across countries; and thus decrease the use of the euro as an invoicing currency in the original EU's imports. Pre-expansion, when the three countries have three different currencies, the representative firm may invoice their prices in different currencies for different countries in order to minimize exchange rate risk. The various currencies provide a ready-made incentive for the exporting firm to price discriminate. However, post-expansion, when there are only two currencies (and one exchange rate), if preferences are similar across countries then there is less reason for the representative firm to price discriminate across countries. With no price discrimination, the representative firm must choose either their own currency or the euro to denominate their single price in all markets; decreasing the

likelihood that any individual country will see their imports denominated in their own currency. Because this paper includes a novel multiple market structure it is possible for the representative firm to price discriminate and thus the result herein is unique to the literature on the currency denomination of trade.

Simulation

The simulation in this paper borrows heavily from concepts and results found in previous literature. This includes the importance of elasticity of demand and marginal cost from Bachetta and van Wincoop (2005), the impact of forward currency contracts and exchange rate volatility from Friberg (1998), the effect of exchange rate transaction costs outlined in Black (1991), the inflation effects given in Taylor (2000) and the impact of the competition's price outlined by Goldberg and Tille (2006).

In this simulation, a representative firm must choose its currency invoicing strategy in three separate countries: a non-EU country which is home to the representative firm, a potential EU-expansion country and an original EU country. In addition, the firm must also choose the degree of price discrimination. The firm can elect to set one price for all three countries or one price for two countries and a second price for the third country or three prices with each country having a different price. Finally, the firm must choose how often to adjust their price(s). Because the euro is often used as a vehicle currency, the euro is a potential currency of denomination for all countries. The exporting firm's currency is also a potential currency of denomination for all markets. However, the currency of the EU-expansion country may only be used in the EU-expansion country and the representative firm's home country as it is unlikely to be used

as a vehicle currency in the euro zone. The representative firm's choices regarding currency of denomination and price discrimination are outlined in Table 1.

Table 1

Currency denomination strategies of the representative firm

	Currency Denomination in non-EU country	Currency Denomination in EU-expansion country	Currency Denomination in EU country	Degree of Price Discrimination
Scenario 1	euro	euro	euro	none
Scenario 2	non-EU currency	non-EU currency	non-EU currency	none
Scenario 3	non-EU currency	non-EU currency	euro	2 unique prices
Scenario 4	non-EU currency	euro	euro	2 unique prices
Scenario 5	EU-expansion currency	EU-expansion currency	euro	2 unique prices
Scenario 6	non-EU currency	euro	non-EU currency	2 unique prices
Scenario 7	euro	EU-expansion currency	euro	2 unique prices
Scenario 8	non-EU currency	EU-expansion currency	euro	3 unique prices
Scenario 9	euro	euro	euro	3 unique prices
Scenario 10	non-EU currency	non-EU currency	non-EU currency	3 unique prices
Scenario 11	non-EU currency	non-EU currency	euro	3 unique prices
Scenario 12	non-EU currency	euro	euro	3 unique prices
Scenario 13	EU-expansion currency	EU-expansion currency	euro	3 unique prices
Scenario 14	non-EU currency	euro	non-EU currency	3 unique prices
Scenario 15	euro	EU-expansion currency	euro	3 unique prices

5,000 simulations will be run each with its own independent representative firm. Various exogenous characteristics of the firm's market, cost and demand are randomly assigned in the simulation. The firm then optimizes its price, currency of denomination, degree of price discrimination and frequency of price adjustment based on those randomly assigned exogenous variables so that we can study how those exogenous variables may affect the firm's currency invoicing decision. The simulations are not intended to characterize any particular industry; instead, the simulations are designed to provide a realistic depiction of all potential firms that may be engaged in international trade.

For each country, *noEU* (the non-EU country), *EUex* (the potential expansion country) and *EU* (the original EU country), the firm's product has the following demand that determines the quantity (*Q*) sold by the firm in each respective market at time *t*:

$$Q_{noEU,t} = M_{noEU}\left(100 - b_{noEU}\left(\frac{p^{noEU}_{noEU,t}}{P_{noEU,t}}\right)\right) \qquad Q_{EUex,t} = M_{EUex}\left(100 - b_{EUex}\left(\frac{p^{EUex}_{EUex,t}}{P_{exEU,t}}\right)\right)$$

$$Q_{EU,t} = M_{EU}\left(100 - b_{EU}\left(\frac{p^{EU}_{EU,t}}{P_{EU,t}}\right)\right) \qquad (1)$$

M denotes the size of the firm's market in each respective country and *b* denotes a parameter that helps determine the elasticity of demand for the firm's product in each respective country. The elasticity parameter (*b*) varies in the three different countries; however, if *b* is similar across countries then consumers in the three countries share similar preferences. The potential degree of difference in demand elasticity or preferences across countries is randomly assigned in the simulation and will be highlighted as an important factor in the next section.

The reference price for the representative firm is *P*; this denotes the aggregate price set by the firm's potential competitors[2]. The reference prices follow a random walk and are allowed to be different across countries but are constrained by a weak law of one price.

The representative firm could choose to invoice their price in any of the three currencies as denoted by the superscript of $p^{noEU}_{noEU,t}$ in which the subscript denotes the country in which the price is set. For example, $p^{EU}_{EUex,t}$ denotes that the firm's price in the EU-expansion country is denominated in the euro. If the firm were to decide to set its

[2] This is similar to the relative price setup in Goldberg and Tille (2006).

price in some currency other than the importing country's currency then buyers in the importing country would have to pay a transaction cost of τ_{EU}, if the buyers are exchanging euros, or τ_{noEU}, if the buyers are exchanging the EU-expansion country's currency for the non-EU country's currency. Thus for buyers in the EU-expansion country their effective price in their own currency is given by $p^{EU}_{EUex,t}(1+\tau_{EU})e_{\frac{EUex}{EU},t}$: in which the exchange rate between the EU-expansion country and the EU is $e_{\frac{EUex}{EU},t}$.

The firm's marginal cost is given by a sticky wage, w_t, which grows at a random inflation rate adjusting only after cumulative inflation reaches a threshold level. The representative firm's total cost at time *t* given below:

$$TotalCost_t = w_t\left(Q_{noEU,t} + Q_{EUex,t} + Q_{EU,t}\right) \qquad (2)$$

The representative firm must choose between the various currency denomination and price discrimination scenarios outlined in Table 1. For example, if the firm were to choose Scenario 8 and uses the buyer's currency in all three countries then the firm's risk-discounted profit at time *t* would be as follows:

$$\pi_{8,t} = \left(p^{noEU}_{noEU,t} Q_{noEU,t} + p^{EUex}_{EUex,t} f_{\frac{noEU}{EUex},t-1}(1-\tau_{noEU})Q_{EUex,t} + p^{EU}_{EU,t} f_{\frac{noEU}{EU},t-1}(1-\tau_{EU})Q_{EU,t} - TotalCost_t \right)^{\alpha} \qquad (3)$$

The firm is risk averse with the degree of risk aversion given by the parameter α. In this simulation the forward rate is efficient, with the expected exchange rate in the next period equal to the current period's forward rate. As shown in Friberg (1998), a risk averse firm will always choose to hedge their revenue flow by using an efficient forward rate.

The representative firm must also choose how often to change its prices with *K* denominating the number of months in which the firm's prices are fixed. If the firm elects to change its price then the profit of that period is reduced by (1-*F*) for each different price, in which *F* denotes the firm's menu cost. For example, if the firm elects Scenario 8 then the sum of the firm's profits for all time periods in which the firm's prices are fixed is given below.

$$Sum\pi_{8,t+1} = (1-F)^3 E_t \pi_{8,t+1} + E_t \sum_{s=t+2}^{K+t} \pi_{8,s} \qquad (4)$$

Because the representative firm is setting three different prices the firm must pay the menu cost three times in the period that the firm adjusts its prices.

In the simulation, which is further detailed in the Appendix, the firm simultaneously optimizes when choosing their currency of denomination/price discrimination scenario and their frequency of price adjustment, *K*. The respective firm chooses the combination of currency of denomination, price discrimination and frequency of price adjustment that gives the firm the highest risk-discounted profit in the simulation. The simulation will be run for 5,000 different representative firms to create a large number of observations to study.

In order to determine the potential currency invoicing changes brought on by expansion of the EU, two different simulations will be run. In the first simulation the three countries each have their own currency; in the second simulation the EU-expansion country joins the European Union and adopts the euro. Between the first and second simulation, all exogenous parameters regarding the firm's market, cost and demand are unchanged, the only change is the EU-expansion country's currency.

Results

Table 2 reports the currency denomination shares of the 5,000 representative firms simulated in the three countries both pre-expansion and post-expansion. In both the non-EU country and the EU-expansion country the share of representative firms invoicing in the importing country increases. Meanwhile in the original EU country, invoicing in the euro drops from 58.8% to 53.2% of firms. What accounts for the drop in euro invoicing in the original EU country's imports? Do the exogenous factors of the model affect the representative firm's currency invoicing decision differently post-expansion?

Table 2

Currency denomination shares

		Pre-EU expansion	Post-EU expansion
Non-EU country	Non-EU country's currency	67.0%	72.0%
	EU-expansion country's currency	15.9%	-
	Euro	17.1%	28.0%
EU-expansion country	Non-EU country's currency	26.4%	29.5%
	EU-expansion country's currency	40.0%	-
	Euro	33.6%	70.5%
Original EU country	Non-EU country's currency	41.2%	46.8%
	EU-expansion country's currency	-	-
	Euro	58.8%	53.2%

To answer these questions, I make use of a two-stage probit least squares estimation method with corrected standard errors for simultaneous equations models in which one of the endogenous variables is continuous and the other endogenous variable is dichotomous[3]. In this case, the dichotomous decision is whether or not the firm will invoice their price in the importing country's currency and the continuous decision is the frequency of price adjustment. Because the firm makes these two decisions

[3] Technical details are described in Maddala (1983).

simultaneously the following pair of regression equations takes simultaneity into account by creating instruments for the two dependent variables.

$$K_i = X_{1i}\beta_1 + \gamma_1 I_{CurrDen,i} + \varepsilon_{K,i}$$
$$I_{CurrDen,i} = X_{2i}\beta_2 + \gamma_2 K_i + \varepsilon_{CD,i} \quad (5)$$

K_i is the representative firm's optimal frequency of price adjustment. $I_{CurrDen,i}$ is a dummy variable which is equal to 1 when the representative firm invoices in the currency of the importing country. X_{1i} and X_{2i} represent the various exogenous variables that are randomly determined in the simulation for each representative firm. This estimation is conducted four times: one, for the original EU country pre-expansion, two, for the original EU country post-Expansion, three, for the EU-expansion country pre-expansion and four, for the EU-expansion country post-expansion. Results are reported in Table 3.

As shown the sign and significance of the RHS exogenous variables differ pre-expansion and post-expansion. *None of the exogenous variables have changed after EU-expansion, only their effect on the representative firm's currency invoicing decision has changed.*

The change in the coefficient on the potential difference in demand elasticity between countries is similar for both the EU country and the EU-expansion country. *The potential difference in demand elasticity between countries is an exogenously assigned parameter from the simulation that determines the variance of the elasticity of demand between countries; a small number means that the elasticity of demand will vary less across countries reflecting the similar preferences of buyers across countries.*

Table 3

Results from Eq. 5

	Original EU country		EU-expansion country	
	Pre-Expansion	**Post-Expansion**	**Pre-Expansion**	**Post-Expansion**
Independent Variable	**Invoice in Euro**	**Invoice in Euro**	**Invoice in EU-expansion country's currency**	**Invoice in Euro**
Transaction cost of exchanging euro	-4.172 *(8.382)*	-24.57** *(7.817)*	24.75** *(8.007)*	-16.55** *(8.336)*
Transaction cost of exchanging EU-expansion currency	16.03** *(6.846)*		-69.41** *(6.624)*	
Average wage inflation of exporting firm	-4.252 *(10.70)*	-11.48 *(9.621)*	22.42** *(10.25)*	0.031 *(10.21)*
Menu cost of exporting firm	3.848* *(2.122)*	-1.000 *(1.877)*	-1.228 *(2.071)*	1.943 *(1.987)*
Percentage of firm's market in EU-expansion country	-1.234** *(0.426)*	-0.629 *(0.394)*	1.653** *(0.418)*	1.540** *(0.416)*
Percentage of firm's market in original EU country	-0.838 *(0.537)*	0.240 *(0.478)*	1.492** *(0.526)*	0.151 *(0.504)*
Size of all markets	0.605** *(0.138)*	0.343** *(0.125)*	-0.207 *(0.135)*	0.274** *(0.131)*
Elasticity Parameter b_{EU} OR b_{EUex}	0.007 *(0.011)*	0.038** *(0.011)*	0.033** *(0.011)*	0.055** *(0.012)*
Potential difference in demand elasticity between countries	**-0.025** ***(0.034)***	**0.089**** ***(0.032)***	**-0.013** ***(0.033)***	**0.075**** ***(0.033)***
Average reference price volatility	-3.684 *(3.624)*	4.219 *(3.496)*	-4.960 *(3.486)*	-3.100 *(3.700)*
Risk aversion of exporting firm	-1.128* *(0.669)*	0.046 *(0.618)*	-0.851 *(0.640)*	1.440** *(0.657)*
Original marginal cost of exporting firm	0.000 *(0.011)*	-0.001 *(0.011)*	0.025** *(0.011)*	-0.014 *(0.011)*
Failure of the law of one price (%)	1.285** *(0.223)*	1.017** *(0.206)*	-0.108 *(0.213)*	0.722** *(0.219)*
Instrument for frequency of price adjustment	-0.0446 *(0.0328)*	0.0191 *(0.0276)*	-0.0893** *(0.0322)*	-0.0683** *(0.0291)*
Constant	1.428 *(0.930)*	-1.008 *(0.829)*	1.145 *(0.906)*	-1.119 *(0.879)*

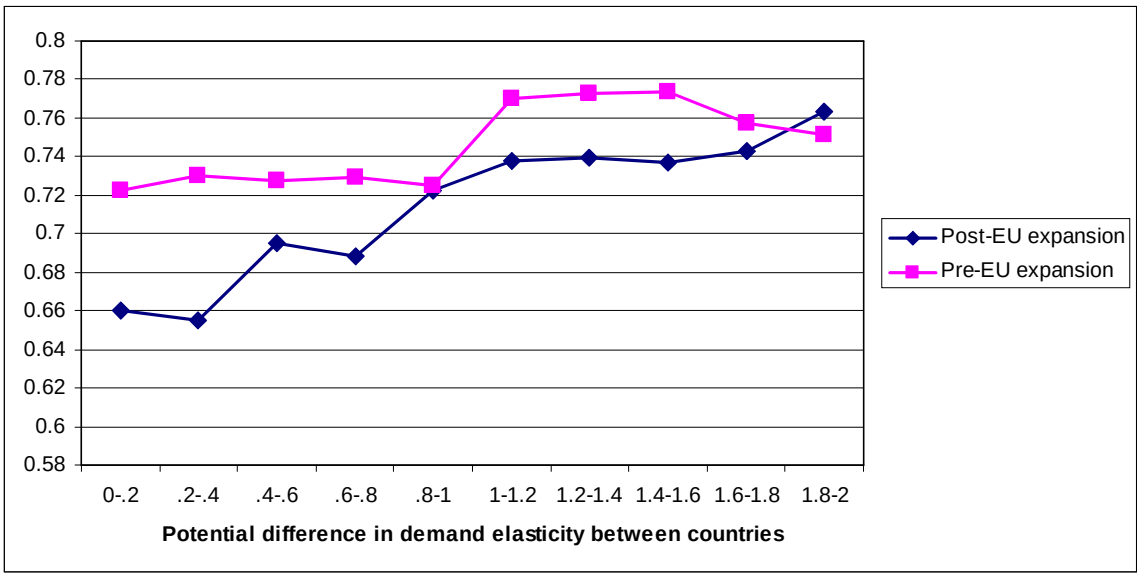
Note: Corrected standard errors are given in parenthesis. Significance at the 5% and 10% level is denoted by ** and * respectively.

Pre-expansion, the coefficient is insignificant and negative for both countries; post-expansion the coefficient is significant and positive. This suggests that before the expansion, the difference in preferences across countries had little impact on the firm's currency denomination decision. After the expansion, however, if buyer's preferences are similar in different countries then the firm is much less likely to denominate their price in the currency of the importing country.

Why would a representative firm not use the importing countries currency if the preferences are similar across countries? The answer lies in price discrimination. *When preferences are similar across countries there's little incentive to price discriminate across countries.* This is reflected in Figure 1.

Figure 1

Percentage of representative firms using price discrimination



When the potential difference in demand elasticity across countries is small, the representative firms are less likely to price discriminate post-expansion relative to pre-expansion. Before the EU expansion, the use of different currencies in the three countries provided the representative firm a ready-made reason to price discriminate as price

discrimination would allow the firm to better accommodate three different currencies and exchange rates. After the EU expansion, with only two currencies, and one exchange rate, there's less need to price discriminate between the countries when preferences in those countries are so similar.

With no price discrimination the representative firm must choose to invoice their single price in either their own currency or the euro; this choice is highlighted in Table 4. *When the representative firms choose not to price discriminate they are almost equally divided when choosing to invoice in their own currency or the euro.* If the representative firm finds it optimal to price discriminate then they are much more likely to invoice their different prices in the buyer's currency.

Table 4

Currency denomination shares with or without price discrimination

		Post-EU expansion	
		No Price Discrimination	**Price Discrimination**
Non-EU country	Non-EU country's currency	53.1%	79.6%
	Euro	46.9%	20.4%
EU-expansion country	Non-EU country's currency	53.1%	20.0%
	Euro	46.9%	80.0%
Original EU country	Non-EU country's currency	53.1%	41.4%
	Euro	46.9%	58.6%

To summarize, if there are similar preferences across countries then post-expansion the representative firms are much less likely to price discriminate between the three countries (as shown in Figure 1). With no price discrimination the representative firm is less likely to invoice in the price in the buyer's currency (as shown in Table 4). Thus, similar preferences across all countries can lead to the result given in Table 1: less euro denominated imports in the original EU post-expansion. This result is new to the

literature on the currency denomination of trade as the multiple market structure of firm sales has yet to be fully explored.

Conclusion

This paper includes a novel multiple market structure to determine the impact of EU expansion on the currency denomination of imports to the original European Union and the recently admitted EU expansion country. Because of the multiple market structure herein I find a unique result in the currency denomination literature. Specifically, when preferences are similar across countries firms are less likely to price discriminate across countries post-expansion than they were pre-expansion. With no price discrimination it is less likely that import prices in the consumer's country are denominated in their own currency. As such, it is possible that EU expansion could decrease the likelihood that imports in the original EU zone are denominated in the euro; thereby increasing macroeconomic instability in the original EU zone.

References

Bachetta, Phillippe and Eric van Wincoop. "A Theory of the Currency Denomination of Trade." *Journal of International Economics*. (2005) Vol. 67, p 295-319

Black, Stanley W. "Transaction Costs and Vehicle Currencies." *Journal of International Money and Finance.* (1991) Vol. 10, p 512-526

Gopinath, Gita, Oleg Itskhoki and Roberto Rigobon. "Currency Choice and Exchange Rate Pass-through." *NBER Working Paper Series*. (2007) http://www.nber.org/papers/w13432

Goldberg, Linda and Cedric Tille. "Vehicle Currency Use in International Trade." *Federal Reserve Bank of New York Staff Report 200, January 2005* (rev. March 2006) http://www.ny.frb.org/research/economists/goldberg/GoldbergTilleJune7.pdf

Goldberg, Linda and Cedric Tille. "Macroeconomic Interdependence and the International Role of the Dollar." *Exchange Rates — IMF Eighth Jacques Polak Annual Research Conference* (2007) http://www.imf.org/external/np/res/seminars/2007/arc/pdf/lg.pdf

Friberg, Richard. "In which currency should exporters set their prices?" *Journal of International Economics*. (1998) Vol. 45, p 59-76

Maddala, G. S. Limited-Dependent and Qualitative Variables in Econometrics. Cambridge, MA: Cambridge University Press, (1983).

Taylor, John B. "Low Inflation, Pass-through, and the Pricing Power of Firms." *European Economic Review.* (2000) Vol. 44, p 1389-1408

Appendix

The numerical simulation optimizes for each discrete choice of frequency of price adjustment (23 discrete choices for the 1-23 months the firm is allowed to maintain its sticky price), invoicing currency/price discrimination strategy (15 discrete choices as outlined by the scenarios in Table 1). The firm then chooses among those discrete options by selecting the highest profit over the course of the simulation (15 x 23 = 345 potential profit functions).

In order to create the demand functions for each representative firm the simulation randomly assigns a market size (M) and elasticity parameter (b). The market size for each of the three countries is uniformly distributed from 0 to 1. The elasticity parameter (b) for all three countries hovers around an average which is uniformly distributed from 4 to 10. The variance of the elasticity parameter (b) is uniformly distributed from 0 to 2. If

this variance is large then the randomly assigned elasticity parameter for each country is more likely to differ widely from those in other countries. The reference price in each country (*P*) follows a random walk but is constrained by a law of one price parameter which allows the law of one price to fail in a uniformly distributed window of 2% to 32% for each representative firm. The volatility of the reference prices is also randomly distributed.

The transaction cost of obtaining the euro (τ_{EU}) is uniformly distributed from 0% to .8% and the transaction cost to obtain foreign currency (τ_{noEU}) is uniformly distributed from 0 to 1%.

The firm's wage, (w_t) is given a random starting point uniformly distributed from 4 to 10. The wage is sticky and moves based upon a randomly determined rate of wage inflation. The increase in the sticky wage must be more than 5%; otherwise, the wage will not be adjusted. The annualized wage inflation rate is uniformly distributed from .5% to 8.5%.

The firm's menu cost (*F*) is uniformly distributed from 1% to 7% while the firm's risk aversion parameter (α) is uniformly distributed from .9 to 1.

The exchange rates follow a random walk with a randomly assigned variance taken from the distribution of nominal exchange rate variances. The exchange rates are limited by a no triangular arbitrage constraint. Forward rates are efficient; in this case, they are equal to the current period's exchange rate. In the post-expansion simulations, the only parameter to change is the exchange rate between the original EU country and the EU expansion country.