Currency Unions, Options, and Foreign Direct Investment

Hisham Foad*
Department of Economics
Emory University
Atlanta, GA

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Abstract

A multinational deciding on where to locate a foreign production facility may not be indifferent to the choice of location. Numerous variables such as production costs, market access, and local tax treatments will influence the decision as to where the plant is located. Another key variable in this decision is uncertainty. Following the work of Dixit, a firm has an option to make a risky investment, and if this investment is at least partially irreversible, the option has some positive value. As the uncertainty in the investment project increases, so too does the value of the option. When comparing two investment projects that are identical in all respects except their underlying profit volatility, the one with the greater degree of uncertainty will require a higher trigger level of profits to be exercised. This paper examines the impact of uncertainty in exchange rates on a multinational’s decision to locate within or outside a currency union. The option values and trigger levels of investment within and outside the union are derived as a function of exchange rate variances and correlations, transport costs, and market size. Simulations provide insights into the relative values of these variables that induce investment within or outside the currency union. The model is then calibrated to fit exchange rate data for the UK, Germany, and France. Under these estimates, a multinational would prefer to invest within the EMU even if the UK market were three times the size of the EMU combined markets. Such a striking result is supported by the empirical observation that the UK’s share of FDI inflows to the European Union has drastically declined since the introduction of the euro in 1999.

* Department of Economics, 1602 Fishburne Dr., Emory University, Atlanta GA, 30322. I would like to thank Bob Chirinko and Elena Pesavento and seminar participants at the 2004 SEA conference for their helpful comments. Please note that this is still a work in progress and any errors within are my own. Comments and questions may be directed to the author at hfoad@emory.edu or 404-727-1673.
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1. Introduction

In December 1997, a surprising announcement was made by Toyota Motor Corporation. The Japanese car manufacturer announced plans to build a new factory in Valenciennes, France rather than in the UK as had been anticipated. At the time, labor costs in France were approximately 10% higher than those in the UK, a differential further exacerbated with the French statutory working week expected to be reduced from 39 to 35 hours in 2000. Coupled with the fact that existing regulations made it more difficult to lay off workers in France than in Britain, why did Toyota choose to build its new factory in France? While it is true that the French government agreed to pay 10% of the initial investment, was this enough to offset the higher production costs? Was it the case (as some analysts have argued) that Toyota predicted recruitment problems in the UK due to low unemployment and skill shortages? Or was it that France is a member of the EMU while the UK is not? Toyota had released a statement earlier in the year saying that it would consider it “a matter of concern” if the UK stayed out of the EMU. Highlighting this, Toyota told all its UK suppliers in August of 2000 to settle all bills in euros stating a desire to “minimize currency risk exposure.” Was the decision to build a new production facility in France an example of Toyota acting on this concern?

Historically, the UK has been the largest recipient of inward FDI flows to the European Union. Looking at Figure 1, we see that the possible impact of the EMU on this trend. Between 1990 and 1998, the UK’s average share of total inflows to the European Union was approximately 20%. During this same period, the share of total EU inflows going to the Euro-Zone countries as a whole ranged from 60 – 75%. Around 1998, however, the UK began losing FDI to the EMU countries. In 1998, 29% of all FDI inflows to the EU went to UK, while the EMU’s aggregate share was just under 60%. By 2001, the UK’s share had fallen to 16%, while the EMU’s share had risen to 78%. By 2002, the UK share had fallen even further to 7%, while the EMU share rose to 89%. What had brought about this divergence? While it is true that overall flows to the EU have fallen in this period (reflecting a sluggish global economy), why has the fall in FDI
been so much more pronounced in the UK than in the EMU countries? Various explanations such as tight labor markets, differential tax incentives, and a greater degree of “hot” money invested in the UK due to looser regulations have been presented. Another potential explanation is that while much of Europe has adopted a single currency, Great Britain has maintained its own currency. This argument is supported by the fact that this pattern of declining FDI shares is also seen in Denmark and Sweden, both countries that have not adopted the euro as their currency.

Figure 1: Share of Total Inflows from World to EU-15

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1 There is also some evidence of declining FDI shares for non-EU countries such as Norway and Switzerland. This may be due to these countries not using the euro or greater trade barriers from not being in the EU.
Why should membership in a currency union have an effect on the flow of FDI into a country? To see why this might make a difference, consider a U.S. firm deciding on where to locate its European production facilities. The firm has already decided that because of transportation costs, home biases, trade barriers, and a host of other factors, it would rather serve the European market through a local production facility rather than exporting from a U.S. based production facility. If the fixed costs involved in setting up a new production facility are high enough, the firm will not produce in every European country. Rather, it will take advantage of the free trade and low transport costs between EU countries and only produce in one location. Given this, what is the optimal location for the firm? Some obvious factors in determining this choice include production costs, access to skilled labor, local infrastructure, and tax treatments. Holding these factors constant, is there any reason to believe that the firm would prefer to produce in an EMU member country over a non-EMU country? If the firm cares about exposure to exchange rate volatility, then there is. Suppose a firm produces in the UK and then sells its goods in the UK, France, and Germany. The firm’s profits are exposed to exchange rate volatility twice: from sales in France and sales in Germany. Contrast this situation to a firm producing in Germany. Profits are only exposed to one source of exchange rate volatility: sales in the UK. Sales in France are insulated from exchange rate risk since France and Germany use the same currency. Thus, if all traditional determinants of FDI are identical across locations, a firm may well have an incentive to locate within a currency zone. As has been shown by Dixit (1989) the firm need not be risk averse for this result to hold, as long as the firm has the option to make the direct investment in more than one period. The result will, however, depend on the assumption that sales within the EMU are not a negligible portion of total sales. If, for example, the firm had the majority of its sales in the UK, then it may prefer to produce in the UK because of positive transport costs. However, given that the EMU member countries taken together comprise a much larger market than the non-EMU countries and the fact that most FDI into the EU is export oriented, this assumption seems valid.

A theoretical basis for this argument can be found in irreversibility literature. When firms make irreversible (or only partially reversible) investments, the timing of these investments becomes important. Uncertainty about future market conditions gives
an option value to waiting. The higher the degree of uncertainty, the more profitable it is for a firm to hold off on its investments. This result is driven by the fact that once an investment is made, it cannot be completely recovered. Suppose a firm makes an investment in an overseas production facility. The amount spent on this investment will generally be greater than the amount that the firm can recoup through divestiture. A result of this is hysteresis in FDI. This is very similar to the effect of exchange rate shocks on trade patterns as exposited by Baldwin and Krugman (1989). A positive economic shock that would induce a reversible direct investment may not be enough to trigger an irreversible direct investment. A negative shock that would cause a firm to exit a foreign market may not be enough of a stimulus for exit when the full value of direct investment cannot be recovered.

Given this, uncertainty plays a role in foreign direct investment decisions. Holding all other factors constant, a firm is more likely to engage in direct investment when uncertainty is low. If a multinational wishes to serve all markets in a region, investment within a currency union will lead to less uncertainty than investment outside the union. All else being equal, a firm will choose to invest in the location that yields the lowest uncertainty, which will be within the currency union.

2. Literature Review

Before moving on to a theoretical model in which a multinational will prefer to locate its foreign production facility in a currency union, it will be useful to examine some of the theoretical and empirical work that has been done on direct investment and uncertainty. The literature has been split on two issues: whether firms are risk averse or risk neutral, and whether exchange rate uncertainty has a positive or negative effect on FDI. Itagaki (1981) uses a model with a risk-averse multinational and shows that exchange rate volatility (among other factors) will have an influence on how much production the firm locates abroad. Kim (1988) reinforces this claim, showing that changes in the equilibrium return-risk relationship of a direct investment can be primarily explained by exchange rate risk. Goldberg and Kolstad (1995) also use a model with a risk averse multinational, allowing for both exchange rate shocks and demand shocks, as
well as a correlation between these shocks. The optimal amount of productive capacity
located abroad is increasing with exchange rate volatility as well as the correlation
between exchange rate and demand shocks. Sung and Lapan (2000) show that increased
exchange rate variability may induce a multinational to increase the number of foreign
production facilities it operates, even if the multinational is risk-neutral. Cushman (1985)
examines the effect of a currency appreciation as well as exchange rate risk on direct
investment. Currency appreciations are found to reduce direct investment, while
increased exchange rate volatility tends to increase direct investment when looking at US
bilateral investment flows to developed countries.

In contrast, Campa (1993) examines the effect of exchange rate volatility on
direct investment to sixty-one US industries, and finds that increases in uncertainty were
associated with decreases in direct investment, with the largest decreases associated with
industries with high sunk costs. Bell and Campa (1997) examine this issue in the context
of the Chemical Processing industry. They find that input price and product demand
shocks have little to no effect on FDI, but that exchange rate shocks have a large effect,
especially in the European Union. The argument that exchange rate uncertainty reduces
FDI is supported by Amuedo-Dorantes and Pozo (2001) who find this negative
relationship while allowing for GARCH measure of exchange rate volatility. Following a
similar methodology, Apergis et al (2002) find that exchange rate volatility exerts a
negative impact on FDI inflows from the EU to Greece, indicating some negative profit
exposure of FDI investors.

3. Theoretical Model

3.1 Volatility and the Option Value of Investment

When considering a firm’s decision to invest, we need to consider not only the
expected costs and benefits of the investment, but also the timing of the investment. The
traditional Marshallian view states that a firm will invest when the expected present
discounted value of the investment just exceeds the cost of investment. Dixit (1989)
shows that this kind of “instant investment” can be dominated by a strategy of delaying
investment until the expected PDV of the investment is greater than the Marshallian trigger. Drawing an analogy from finance, Dixit views the firm’s ability to invest as an option. The strike price is the sunk cost of investing, and because there is uncertainty about the investment’s future returns, the option itself has some positive value. The value of this option is the information gained by waiting, less the foregone revenue from the investment. Increases in uncertainty or larger differences between the purchase and resale values of capital will increase the value of this option.

The theory developed in Dixit (1989) can provide valuable insights on the pattern of FDI within and outside a currency union. The direct investment decision of a multinational has an option value. Specifically, the decision to invest within a currency union has an associated option value, and the decision to invest outside the currency union has its own option value. By comparing the option values between these two investment decisions (and the associated returns that would induce investment) we are able to show that a single firm will be more likely to invest within a currency union than outside.

Suppose a multinational is considering a direct investment abroad\(^2\). The flow of net revenues per unit of time is given by \(X\), and the firm must pay a sunk cost of \(K\) to make the investment. In each period, \(X\) can either increase or decrease by a fixed percentage. As the length of each time period goes to zero, the distribution of \(X\) converges to a geometric Brownian motion with the following properties:

\[
\frac{dX}{X} = \mu dt + \sigma dz, \quad E(dz) = 0, \quad E(dz^2) = dt
\]

The inclusion of the term \(\mu\) allows for a time trend in the evolution of revenues (the probability of a single period increase in revenues need not equal the probability of a decrease in revenues.)

The goal of the firm is to maximize the expected present discounted value of future revenues. These future revenues are discounted at a rate of \(\rho > 0\), which is equal to the opportunity cost of riskless capital. Thus, given a current level of revenues \(X\), the expected PDV of future revenues from the investment is \(X/\rho\).

\(^2\) This derivation is adapted from Dixit (1989) and Cox et al (1979)
If the firm only had one period in which it could make the investment decision, then the firm would invest whenever $X/\rho > K^3$. There exists some level of current revenue ($M$) such that $M = \rho K$. This level is called the Marshallian trigger since it just induces investment when the firm only has one chance to invest. In reality, this view is myopic. The firm has a chance to make the investment in many (if not all) periods. In this regard, the firm possesses an option. It can always make the investment at cost $K$, but the expected PDV on the investment may change. Because of this, the option to delay the investment has a positive value. To see why, suppose that the current revenue level is at the Marshallian trigger, $M$. If the firm invests now, its net gain is equal to zero. What if the firm did not invest and waited until the next period? With some positive probability, the revenue level would be greater than $M$ and the firm would invest and profit. With some other positive probability, the revenue level would fall below $M$, and the firm would not invest, yielding zero net gain. Since both outcomes have some positive probability of occurring, the expected net gain from waiting is also positive. Thus, the strategy of investing at the Marshallian trigger revenue is dominated by the strategy of waiting. There is some value attached to waiting, meaning that the revenue level that triggers investment (call it $H$) will be greater than the Marshallian trigger.

Starting with this basic setup, Dixit (1989) derives the following expression for the value of the option to hold off on an investment at current profit level $X$:

$$V(X) = BX^\beta, \quad \beta = \frac{1}{2} \left( 1 + \sqrt{1 + \frac{8\rho}{\sigma^2}} \right)$$

Where $\sigma^2$ is the variance of investment revenue.

Whenever the current investment revenue is below the trigger level, the firm will hold off on the investment, and its value is given by the option value just derived. When the revenue exceeds the trigger, the firm will make the investment, and the value is given

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3 We assume irreversible investment – capital cannot be resold. As long as there is a wedge between the purchase and resale price of capital (because of depreciation, for example), then the results will still hold, although the investment trigger will be reduced.

4 The case where the sunk cost changes over time is not considered here. The results will still hold qualitatively if the sunk costs remain constant in expectation, however. It is assumed that the firm finances the investment at home with funds denominated in the home currency (thereby insulating the sunk cost from exchange rate volatility). An interesting extension would be to see how the results change when the investment is financed abroad.
by the expected PDV of investment revenues less the sunk cost. The investment value is characterized as:

$$V(X) = \begin{cases} 
BX^\beta & \text{if } X \leq H \\
X / (\rho - K) & \text{if } X \geq H 
\end{cases}$$  \hspace{1cm} (3)

At the option-adjusted trigger level (H), the firm is indifferent between investing and waiting. In other words:

$$BH^\beta = H / (\rho - K)$$  \hspace{1cm} (4)

The trigger level is endogenously determined by the firm. This level will not only satisfy equation (4), but will also equate the marginal return from waiting to the marginal return from investing now. This “smooth pasting” condition is

$$V'(X < H) |_{X=H} = V'(X \geq H) |_{X=H},$$

yielding:

$$\beta B H^{\beta - 1} = 1 / \rho$$  \hspace{1cm} (5)

We can use (4) and (5) to eliminate B and solve for the optimal trigger level $H^*$:

$$H^* = \frac{\beta}{\beta - 1} \frac{\rho K}{\rho}$$  \hspace{1cm} (6)

How does this optimal trigger level respond to changes in the variance of revenues? To see this, note that $\beta$ is a function of variance. Thus,

$$\frac{\partial H}{\partial \sigma^2} = \frac{\partial H}{\partial \beta} \cdot \frac{\partial \beta}{\partial \sigma^2}$$

From equations (2) and (6) we can find:

$$\frac{\partial H}{\partial \beta} = \frac{\partial H}{\partial \sigma^2} = \left(1 + \frac{8 \rho}{\sigma^4}\right)^{3/2} < 0,$$

and $\frac{\partial H}{\partial \sigma^2} > 0$.

**Proposition 1:** An increase in the underlying volatility of an investment project’s revenue stream will increase the optimal revenue level at which the firm makes the investment.

As the underlying volatility of the investment’s revenue stream increases, the higher the trigger level will be. If we consider two investments that are identical in every aspect except volatility of revenues, the more volatile investment will have to generate a larger
revenue stream to be undertaken. Said differently, the less volatile investment will be made before the volatile one.

3.2 *Currency Unions and Investment Trigger Levels*

Suppose there is a U.S. multinational that is considering building a production facility in Europe. The firm has decided that transport costs, home biases, trade barriers, or any of the other traditional FDI determinants are high enough that it would rather serve the European market through a European production facility than by producing in the US and exporting its goods. For ease of exposition, assume that there are only three countries in Europe: the UK (1), Germany (2), and France (3). Germany and France share a common currency, the euro, while the UK uses its own currency. The US firm only cares about profits denominated in dollars, so the returns on any investment made must be converted into dollars before being assessed by the firm. Transaction costs are low enough that the firm will only want to build one production facility in Europe, serving the entire region from this plant\(^5\). Is the firm more likely to invest inside or outside of the currency union? To answer this question, let us compare the option adjusted trigger revenues for investing within vs. outside the currency union. The firm can undertake two projects\(^6\):

A. Invest in the UK then sell in the UK, Germany, and France.
B. Invest in Germany then sell in the UK, Germany, and France.

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\(^5\) An interesting extension would be to endogenize this decision. Under what conditions would it be optimal to have a production facility in all three countries or one inside the currency union and one outside it as opposed to one facility serving the entire region? For the purpose of this paper, we assume that the sunk costs or economies of scale are high enough and trade costs are low enough between EU nations that multiple European production facilities are never preferred to one central production facility.

\(^6\) If we assume that production costs and local demand are identical in Germany and France, then we need only consider two projects: within or outside the currency union. As the focus of this paper is on the role of exchange rate volatility and not cost differences, this assumption seems plausible. Different cost structures, demands, access to credit, and tax treatments will be explored in a forthcoming empirical paper.
Assume that preferences across the three countries are given by the following CES utility function:

\[ U_k = \left( \sum_{i=1}^{N} q_{ik}^{\gamma} \right)^{\frac{1}{\gamma}}, k = 1, 2, 3 \quad 0 < \gamma < 1 \quad (7) \]

Consumers in country \( k \) choose the optimal quantities of \( q_{ik} \) to maximize utility subject to the following budget constraint:

\[ \sum_{i=1}^{N} p_{ik} q_{ik} = Y_k \quad (8) \]

Taking the ratio of two first order conditions, one with respect to \( q_j \) and one with respect to \( q_1 \) yields:

\[ q_{jk} = q_{ik} p_{ik}^e p_{jk}^{-e}, \quad e = \frac{1}{1-\gamma} \]

Substituting this expression into the budget constraint for country \( k \):

\[ q_{ik} p_{ik}^e \sum_{j=1}^{N} p_{jk}^{1-e} = Y_k \quad (9) \]

We can redefine the third term on the left hand side of (9) as a price index. Specifically, the exact price index for country \( k \) is given by:

\[ I_k = \left( \sum_{j=1}^{N} p_{jk}^{1-e} \right)^{\frac{1}{1-e}} \quad (10) \]

Using this, the demand function facing the producer of good 1 in country \( k \) is:

\[ q_{1k} = Y_k I_k p_{1k}^{1-e} p_{1k}^{-e} \quad (11) \]

In deciding on which investment project to proceed with, the multinational will first determine the optimal production structure based on expected market conditions. Given these production choices, both expected profit and expected profit volatility are used to determine the profit level at which the firm would proceed with the investment. The investment project with the lower trigger revenue will, all else being equal, be enacted before the project with the higher trigger.

To determine the optimal production structure under each project, the multinational chooses an output level in each market to maximize expected profits.
Markets are perfectly segmented, and the firm only uses one production facility. There are positive transport costs in the form of Samuelson iceberg costs. Specifically, for one unit of a good to arrive at its final destination, \( T > 1 \) units need to be shipped. We assume that all markets are equidistant, so that the cost of shipping from the UK to Germany is the same as shipping to France, and the same as shipping from Germany to France.

The multinational produces with an increasing returns technology such that the cost of producing \( X \) units is given by:

\[
C_k(X) = cX + F_k
\]  

(12)

It is assumed that the marginal cost of production is identical across the three markets, but the fixed cost may vary.

Production for all three markets takes place at a single production facility. If the multinational sells a total of \( q_1, q_2, \) and \( q_3 \) goods in markets 1, 2, and 3 respectively, then the total quantity of goods produced must be equal to the goods sold as well as those lost in transit. For example, if the MNC produces in market 1, then total production (\( X \)) must be:

\[
X = q_1 + Tq_2 + Tq_3
\]

The total cost of producing in market 1 and selling in all three markets is thus:

\[
C_1 = c(q_1 + Tq_2 + Tq_3) + F_1
\]

Thus, we can define the firm’s profit from project A (producing outside the EMU) and from project B (producing within the EMU) as:

\[
\Pi_A = e_1(p_1q_1 + -Tcq_2 - Tcq_3) + e_2(p_2q_2 + p_3q_3) - F_1
\]

(13)

\[
\Pi_B = e_1p_1q_1 + e_2(p_2q_2 + p_3q_3 - Tcq_1 - Tcq_3) - F_2
\]

(14)

The exchange rate between location \( i \) and the U.S. is given by \( e_i \), which is expressed in units of dollars per location \( i \)’s currency. The uncertainty in the net revenue of the direct investment is entirely due to movements in the exchange rate. It is assumed that demand and production costs can be perfectly predictable by the firm\(^7\). Movements in investment revenues each period will be caused by movements in the exchange rates. If the pound

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\(^7\) Clearly this is not a realistic assumption, but for the purpose of isolating the effect of exchange rate volatility on FDI, it does simplify things. One interesting extension examined by Goldberg and Kolstad (1993) was to look at the covariance between demand shocks and exchange rate shocks.
and the euro depreciate relative to the dollar, then the investment revenue will increase. Conversely, a depreciation of the dollar against the pound and the euro will cause revenues to fall. We choose units such that the expected value of each exchange rate is equal to 1. Given that the only uncertainty in the model is the value of the exchange rate, each projects expected profit is given by:

\[ E(\Pi_A) = p_1 q_1 + p_2 q_2 + p_3 q_3 - c(q_1 + Tq_2 + Tq_3) - F_1 \]

\[ E(\Pi_B) = p_1 q_1 + p_2 q_2 + p_3 q_3 - c(Tq_1 + q_2 + Tq_3) - F_2 \]

Or, expressed in terms of the demand function derived above:

\[ E(\Pi_A) = (Y_1 I_1^{-\epsilon})^{1/\epsilon} q_1^{-1/\epsilon} + (Y_2 I_2^{-\epsilon})^{1/\epsilon} q_2^{-1/\epsilon} + (Y_3 I_3^{-\epsilon})^{1/\epsilon} q_3^{-1/\epsilon} - c(q_1 + Tq_2 + Tq_3) - F_1 \]

\[ E(\Pi_B) = (Y_1 I_1^{-\epsilon})^{1/\epsilon} q_1^{-1/\epsilon} + (Y_2 I_2^{-\epsilon})^{1/\epsilon} q_2^{-1/\epsilon} + (Y_3 I_3^{-\epsilon})^{1/\epsilon} q_3^{-1/\epsilon} - c(Tq_1 + q_2 + Tq_3) - F_2 \]

The firm will choose the output it sends to each market to maximize expected profit for both investment projects. Under this setup, the firm will follow a strategy of markup pricing, yielding the following production schedule:

**Project A:**

\[ q_i = \left( T_i \frac{\epsilon}{\epsilon - 1} \right)^{-\epsilon} Y_i I_i^{-\epsilon}, \quad p_i = T_i \frac{\epsilon}{\epsilon - 1}, \quad T_i = \begin{cases} 1 & \text{if } i = 1 \\ T & \text{if } i = 2, 3 \end{cases} \]

**Project B:**

\[ q_i = \left( T_i \frac{\epsilon}{\epsilon - 1} \right)^{-\epsilon} Y_i I_i^{-\epsilon}, \quad p_i = T_i \frac{\epsilon}{\epsilon - 1}, \quad T_i = \begin{cases} 1 & \text{if } i = 2 \\ T & \text{if } i = 1, 3 \end{cases} \]

The optimal quantity sent to market \( i \) is decreasing in transport costs to market \( i \), increasing in the \( i \)'s market size \( (Y_i) \), and decreasing in market \( i \)'s price index \( (I_i) \). Once the firm determines the optimal production schedule for each project, it will then forecast each project’s variance using the quantities determined in (21) and (22). We can define the variance of profit as:

\[ Var(\Pi_A) = E[\Pi_A - E(\Pi_A)]^2 = E[e_1 - 1]^2 (p_1 q_1 - cq_1 - Tcq_2 - Tcq_3)^2 + E[e_2 - 1]^2 (p_2 q_2 + p_3 q_3)^2 \]

\[ + 2(e_1 - 1)(e_2 - 1)(p_1 q_1 - cq_1 - Tcq_2 - Tcq_3)(p_2 q_2 + p_3 q_3) \]

\[ Var(\Pi_B) = E[\Pi_B - E(\Pi_B)]^2 = E[e_1 - 1]^2 (p_1 q_1)^2 + E[e_2 - 1]^2 (p_2 q_2 + p_3 q_3 - Tcq_1 - cq_2 - Tcq_3)^2 \]

\[ + 2(e_1 - 1)(e_2 - 1)p_1 q_1 (p_2 q_2 + p_3 q_3 - Tcq_1 - cq_2 - Tcq_3) \]

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8 An indeterminate case is when one currency appreciates relative to the dollar while the other depreciates. The net effect will depend on the revenue levels and the production location, as well as the relative magnitudes of the exchange rate changes.

9 These conclusions can be verified by noting that since \( \gamma \) is between 0 and 1, \( \epsilon \) must be greater than 1.
Note that $E(e_i) = 1$, and let the variance of the exchange rate $(e_i)$ be $\sigma_i^2$ and the covariance between $e_i$ and $e_2$ be $\gamma_{12}$. The variances can be written as:

$$\text{Var}(\Pi_i) = \sigma_i^2(p_i q_1 - cq_2 - Tc q_3)^2 + \sigma_2^2(p_2 q_2 + p_3 q_3)^2 + 2\gamma_{12}(p_i q_1 - cq_2 - Tc q_3)(p_2 q_2 + p_3 q_3)$$

$$\text{Var}(\Pi_B) = \sigma_i^2(p_i q_1)^2 + \sigma_2^2(p_2 q_2 + p_3 q_3 - Tc q_1 - cq_2 - Tc q_3)^2 + 2\gamma_{12} p_i q_1 (p_2 q_2 + p_3 q_3 - Tc q_1 - cq_2 - Tc q_3)$$ (19)

Recall that the optimal trigger revenue as given by (6):

$$H^* = \frac{\beta}{\beta - 1} \rho K$$

where $\beta = \frac{1}{2} \left( 1 + \sqrt{1 + \frac{8\rho}{\sigma^2}} \right)$. 

Here, $\sigma^2$ is the variance of expected profits, as defined by (19) and (20). For each project, the firm will use their estimate of profit variance and use this value to determine the optimal trigger for each project.

$$H_{A}^* = \frac{\beta_A}{\beta_A - 1} \rho F_1$$

$$\beta_A = \frac{1}{2} \left( 1 + \sqrt{1 + \frac{8\rho}{\sigma^2}} \right)$$ (21)

$$H_{B}^* = \frac{\beta_B}{\beta_B - 1} \rho F_2$$

$$\beta_B = \frac{1}{2} \left( 1 + \sqrt{1 + \frac{8\rho}{\sigma^2}} \right)$$ (22)

From proposition 1, we know that the optimal trigger profit (or net revenue) is increasing in the underlying volatility of the investment project. Thus, if investment outside the EMU has a higher profit variance than investment within the EMU, investment outside the EMU will require a higher expected profitability to be enacted.

Under what conditions will investment outside the EMU have a lower profit variance than investment within the EMU? This will be true whenever $V_A > V_B$. First, assume that transport costs are equal to zero ($T = 1$) and note that we can re-write (19) and (20) as:

$$V_A = \sigma_i^2(R_1 - C_1)^2 + \sigma_2^2(R_2 + R_3)^2 + 2\gamma_{12}(R_1 - C_1)(R_2 + R_3)$$ (19’)

$$V_B = \sigma_i^2 R_1^2 + \sigma_2^2 (R_2 + R_3 - C_2)^2 + 2\gamma_{12} R_1 (R_2 + R_3 - C_2)$$ (20’)

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We define $R_i$ as the revenue gained from region $i$, and $C_i$ as the cost of producing in region $i$ (less fixed costs.) Since transport costs are equal to zero, the revenue from region $i$ will be the same under either project. With some manipulation, we can show that $V_A > V_B$ whenever the following is true:

\[
(R_2 + R_3) \left( \sigma_2^2 - \frac{C_1}{C_2} \gamma_{12} \right) > R_1 \left( \frac{C_1}{C_2} \sigma_1^2 - \gamma_{12} \right) + \frac{\sigma_2^2 C_2^2 - \sigma_1^2 C_1^2}{2C_2}
\]  

(23)

The left side of the inequality is the revenue taken from the EMU countries weighted by a function of exchange rate variance. The weight increases as the variance of the euro exchange rate increases or the covariance between the euro and the pound decreases. An intuitive explanation for this result is that when the firm produces in the EMU, they internalize some of the volatility of the euro. We assume that the firm sells in all three markets, so by producing outside the union, they will be exposed to fluctuations in the euro twice. Thus, an increase in the variance of the euro will, Ceteris Paribus, increase the variance of non-EMU production revenue. If the covariance between the euro and the pound is very high, the weights placed on both EMU revenue and non-EMU revenue are reduced. The advantage to internalizing exchange rate risk by locating within the EMU is reduced, as movements in one currency are closely matched by the other. At the limit, when $\sigma_1^2 = \sigma_2^2 = \gamma_{12}$, the location decision is based entirely on production costs – the firm will locate wherever it is cheapest to produce.\(^\text{10}\)

Suppose that production costs within and outside the EMU are identical, so that $C_1 = C_2$. With this assumption, (23) becomes:

\[
\frac{R_2 + R_3 - \frac{1}{2} C}{R_1 - \frac{1}{2} C} > \frac{\sigma_1^2}{\sigma_2^2} - \frac{\gamma_{12}}{\gamma_{12}}
\]

(24)

Note the left hand side of this inequality. As long as the revenue gained outside the currency union is not too much larger than the revenue from each country within the

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\(^{10}\) Allowing for transportation costs will change this result. If production costs between locations are similar, then positive transportation costs will induce firms to locate in the region with the largest demand. This result is presented as the “home market effect” in Krugman (1980).
union, the left hand side will be greater than 1. Under what condition(s) will the right hand side be less than 1? A simple manipulation shows that the right hand side is less than 1 if and only if the euro variance exceeds the pound variance \((\sigma_e^2 > \sigma_p^2)\).

**Proposition 2:** If there are no transport costs and revenue from within the EMU is at least as large as revenue from outside the EMU, then a sufficient condition for which a direct investment in the EMU will have a smaller revenue variance than a direct investment outside the EMU is that the variance of the euro exceeds the variance of the pound.

This is a sufficient, but not necessary condition. It is possible to have non-EMU production variance be greater than EMU production variance even if the pound variance is greater than the euro variance. This could occur if EMU revenue were significantly larger than UK revenue, for example. How innocuous is the assumption that currency union revenue is as least as large as that from outside the union? Considering the fact that there are more countries, people, and income within the union (representing greater aggregate demand) than in those EU countries not using the euro, this is a very plausible assumption.

### 3.3 The Importance of Transport Costs

Proposition 2 was derived under the assumption of zero transport costs. If we allow for transport costs, then this proposition may no longer hold. Recall the optimal output and pricing structure in (17) and (18.) It is clear that when we allow transport costs, the regional revenues will differ across the choice of production location. Specifically, region \(j\)’s revenue will be \(R_j\) when production takes place in \(j\). When production takes place in region \(k \neq j\), then region \(j\)’s production revenue is \(R_j T^{1-\varepsilon}\). Since both \(T\) and \(\varepsilon\) are greater than 1, \(T^{1-\varepsilon}\) will be less than 1. Thus, including transport costs reduces revenue coming from export markets. As transport costs increase, the contribution of export markets to total revenue is reduced. To see this, consider what happens when we let transport costs go to infinity: (as \(T \to \infty, T^{1-\varepsilon} \to 0\).) We can write each project’s revenue variance as:
\[ V_A = \sigma_1^2 (R_1 - C_1)^2 + \sigma_2^2 (R_2 T^{1-\varepsilon} + R_3 T^{1-\varepsilon})^2 + 2 \gamma_{12} (R_1 - C_1)(R_2 T^{1-\varepsilon} + R_3 T^{1-\varepsilon}) \]
\[ V_B = \sigma_1^2 (R_1 T^{1-\varepsilon})^2 + \sigma_2^2 (R_2 + R_3 T^{1-\varepsilon} - C_2)^2 + 2 \gamma_{12} (R_1 T^{1-\varepsilon})(R_2 + R_3 T^{1-\varepsilon} - C_2) \]

Allowing transport costs to go to infinity:

\[ \lim_{T \to \infty} V_A = \sigma_1^2 (R_1 - C_1)^2 \]  \hspace{1cm} (25)
\[ \lim_{T \to \infty} V_B = \sigma_2^2 (R_2 - C_2)^2 \]  \hspace{1cm} (26)

In this case, the variance of a UK investment would exceed the variance of an EMU investment when pound volatility exceeded euro volatility, all else being equal. Note that this is directly in contrast to Proposition 2. The existence of transport costs reduces the ability to internalize currency risk by locating in the EMU, since it becomes more costly to operate in markets beyond the production location. Thus, we would expect that any positive effects of EMU membership on FDI flows would be decreasing in transport costs.

4. Simulations

Under what conditions will the expected profit level that would trigger an investment project outside a monetary union be greater than the trigger profit for an investment within the union? Simulations can provide some insights into this question. In constructing these simulations, we will be comparing the optimal trigger of a direct investment outside the monetary union to that from within the union. Production costs are assumed to be identical across locations, and we assume that the multinational serves all markets from its foreign production facility. In the absence of uncertainty, the multinational will then choose to locate in the largest market, so as to minimize transport costs. When uncertainty does exist, however, the market with the lower trigger will receive the investment.
Figure 2 plots the profit level that would trigger UK FDI over the trigger for EMU FDI as well as the ratio of expected profits from each type of investment. When the ratio of trigger profits is above the ratio of expected profits, investment will take place in the EMU, and vice versa. When these two ratios intersect, the multinational is indifferent between production locations. To see how the optimal trigger responds to changes in relative market size (as measured by income), we fix the exchange rate variances at their empirical values. To make comparisons between the pound and euro (and avoid any potential bias from the pound being worth more, in terms of dollars, than the euro), an exchange rate index for each series was constructed, using January 1st, 1999 as the base. Then, the pound-dollar and euro-dollar exchange rate index variance was calculated over the period 1/1999 – 1/2004. The empirical index volatilities were $\sigma_1^2 = 40.41$ (pound index), $\sigma_2^2 = 145.07$ (euro index), and the correlation coefficient was $\rho_{12} = 0.941$\(^{11}\). The variance of the euro to dollar exchange rate is more than three times that of the pound to dollar rate, while the correlation between these two series is very high. Given proposition 2, we would expect a direct investment in the UK to have a larger profit variance (and thus a higher trigger) than a direct investment in the EMU for similar inter-regional revenues. As we can see in figure 2, this is indeed the case. When the UK and the EMU have identical market sizes, the revenue required to trigger an investment project in the UK is nearly 75% larger than that required to trigger EMU investment ($H_A/H_B = 1.75$). Given these variances, how large a market would the UK need to have to gain FDI over the EMU? We can find this by locating the intersection of relative trigger profit and relative expected profit. These ratios are equal when the UK has a market size three times that of the EMU. Thus, the UK would need to have a market more than three times larger than the EMU to gain FDI over the EMU, given these empirical variances. The effect of the larger euro exchange rate volatility is so dominant that a multinational would choose to locate in the EMU, even when its largest market is outside the union.

How sensitive is this result to a change in transport costs? As transport costs increase, the importance of the export markets is lessened, as the producer will be shipping less and less to these markets. In the limit as transport costs become infinite, the

\(^{11}\) The same results hold if we do not construct exchange rate indexes - the variances are much smaller, but the variance of the euro is still greater than that of the pound.
multinational does not export at all, and is only concerned about volatility in the production market. Figure 3 plots the ratio of optimal trigger profits at the empirical volatilities for three different transport costs: zero, 20% and 40%. The pattern we see emerging is that as transport costs increase, changes in market size have a smaller effect on the optimal trigger. This follows from the fact that as transport costs increase, the FDI project becomes less and less export oriented, and volatility in the home market is what matters.

Given the observed volatility in the euro and the pound, this model claims that the UK would have to have a market size three times that of the EMU to gain direct investments. What if these exchange rate volatilities changed? If transport costs are not prohibitive and there is not too large a difference in market sizes, then the multinational will choose to locate in the region with the largest exchange rate volatility, so as to insulate against that volatility. Figure 4 charts relative trigger profit against relative expected profit for four different exchange rate volatilities. When the pound is twice as volatile as the euro, the multinational will choose to invest in the UK over the EMU when the UK reaches about 55% of the EMU’s market size. When the pound is 1.5 times as volatile, market size in the UK must be at least 68% as large as in the EMU. When the volatilities are equal, then the larger market will get the investment. When the euro is twice as volatile as the pound, investment in the UK will only take place when the UK represents a market 1.97 times as large as the EMU.

The simulations in Figure 4 assumed that the correlation between the pound and the euro was both positive and strong, set at 0.8. While this assumption makes logical sense and fits with the empirical data, the correlation between these exchange rates could be any number between –1 and 1. Figure 5 looks at how this relationship changes for three different values of the exchange rate correlation. The exchange rate volatilities are set equal and transport costs are set at 20%. Under these assumptions, the optimal trigger profits will be equal to one another when the UK and EMU markets are identical. The exchange rate correlation will affect how the relative trigger behaves away from this point. Suppose that production costs were identical across locations and there are no transport costs. If exchange rates are perfectly negatively correlated, then whichever region has the larger market will have a lower trigger. The intuition behind this is that
since any appreciation in one currency is perfectly matched by a depreciation in the other, the best way to insulate against exchange rate volatility is to located in the largest market. If the exchange rates were perfectly correlated then there would be no incentive to locate in one market over the other (again assuming identical production costs.) In this case, regardless of market size, the optimal triggers are always identical. As the correlation increases from –1 to 1, the effect of market size on the optimal trigger decreases. Although tempered somewhat by positive transport costs, this pattern is depicted in Figure 5. Market size has a large effect on the optimal trigger profit when the correlation is -0.8, and a much smaller effect when the correlation is 0.8.

5. Conclusion

This paper began with the observation that the pattern of FDI into the European Union has changed since the inception of the EMU. Countries such as Great Britain, Sweden, and Denmark had seen their share of total FDI into the EU decline, while countries such as France, Germany, and Italy had seen their FDI shares increase. Is there any reason to believe that the establishment of a monetary union played a role in this shift? When looking at direct investments as options to invest in a particular location, there may very well be. The option to hold off on an investment until new information is learned has some positive value, and when factoring this in, the expected return on an investment that will cause the firm to make that investment will be greater than the Marshallian trigger. The investment return that will induce investment not only depends on the cost of making the investment, but on the value of waiting. Starting with some simple assumptions such as risk neutrality and a firm that wishes to serve all European markets from one central foreign production facility, we derived two important results. First, the expected return that triggers investment is increasing in the underlying variance of those returns. Thus, when comparing two investments with the same expected return, the investment with the lower volatility will be undertaken first. Second, when comparing two potential investment projects with identical production costs, one in a currency union and one outside it, a sufficient condition for the investment to be made in
the currency union is that the variance of the currency union’s exchange rate with the multinational’s home currency is greater than the variance of the non-union locations exchange rate. This result will hold as long as the potential revenue from the currency union is at least as large as the potential revenue from outside the union and that transport costs are not prohibitive.

Given these results and the fact that the euro has shown a much larger degree of volatility than the pound since the inception of the EMU, we can see that firms are much more likely to invest in the EMU than outside it. In fact, when using the empirical values of exchange rate volatility, this result will hold even if the potential revenue from the UK is three times that from the EMU. This result was derived under the assumption of 20% transport costs. While this is a reasonable estimate, an increase in transport costs would tend to decrease the incentive to invest in the EMU. The principal attraction of the EMU to a multinational is that it offers multiple export markets sharing a common currency. As transport costs increase, the relevance of these export markets decrease.

The model was then tested for different values of volatility between the pound and the euro. As the pound increases in volatility relative to the euro, the UK market size required to divert investment from the EMU falls. However, much of this depends on the correlation between the euro and the pound. If the two currencies are not highly correlated (or even negatively correlated), then differences in volatility will have a large effect. If the correlation is strong and positive, however, differences in volatility will have a smaller effect.

While this paper has helped to shed light on the trend for FDI to move within a monetary union, it clearly overlooks several key issues. First, the simulations assumed identical production costs across locations. As production costs are a key determinant of FDI, allowing these costs to vary may change the results. While it may seem plausible to think of similar production costs between the UK, France, and Germany, this may not be such an innocuous assumption when expanding the sample to include other EU countries such as the Eastern-Bloc countries set that recently joined.

Another key issue is to endogenize the firm’s choice of how many production locations it would like to operate. It was assumed here that the firm preferred foreign production to exporting from its home location, but that sunk costs were high enough and
transport costs low enough to eliminate the possibility of the firm operating a production facility in every market. It would be interesting to capture this element within the model, as this could shed some light on the tradeoff between insulting exchange rate volatility and increased irreversible investments.

Finally, this is an issue that is ripe for empirical testing. Is it really the case that the UK has been losing FDI to the EMU countries, or is this change an insignificant random movement? Are exchange rates at least partly to blame for this phenomenon? If so, is it possible to quantify the FDI that the non-EMU countries have lost by not joining? What other factors have played a role in this changing pattern and how are they related to the change in exchange rate regimes. This kind of analysis would be very useful in testing some of the theoretical predictions made in this paper, and may also provide some important quantitative results for the decision to join a currency union.
References


Figure 2: Trigger Revenue and Relative Market Size
($\sigma_1 = 40.41, \sigma_2 = 145.07, \rho = 0.941, T = 1.2, \gamma = 0.5$)
Figure 3: Varying Transport Costs
\( (\sigma_1 = 40.41, \sigma_2 = 145.07, \rho = 0.941) \)
Figure 4: Trigger Revenue and Relative Exchange Rate Volatility
($\rho = 0.8, T = 1.2$)
Figure 5: Relative Trigger and Exchange Rate Correlation
($\sigma_1 = \sigma_2, T = 1.2$)