Two monies, two markets? Variability and the option to segment

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Abstract

This paper examines the decision to create barriers to arbitrage for a firm selling on two national markets. Sunk costs of market segmentation- imply that the option to segment markets is more valuable the greater the variability of purchasing power between markets. One result is that a monetary union may lead to market integration when a fixed exchange rate did not. Extensions examine hysterisis, transport costs and general equilibrium modeling.

Keywords: Exchange rate pass-trough, law of one price, EMU, price discrimination, real options.

JEL: F13, F15, F41, L40.

1 Introduction

Why does arbitrage exert so weak equalizing pressure on prices across national borders? Large deviations from the law of one price (LOP) for traded goods are pervasive and many firms are able to react to exchange rate variability by "Pricing-to-market", stabilizing prices in the consumer's currency (see Engel and Rogers, 1996, 1999 and Goldberg and Knetter, 1997). Understanding the barriers that segment markets is central to a large number of issues on international economics - for predicting the price effects of institutional changes, for explaining the high correlation between real and nominal exchange rates (see Engel, 1999) and for the study of trade under imperfect competition (market

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segmentation is a key assumption in for instance Brander and Krugman, 1983 and much subsequent work).

One path to try understanding why the border matters so much for prices is to theoretically model and empirically study various frictions that segment markets - different cultures, languages, difficulties in enforcing contracts and informational asymmetries are but some pickings from a very long list of potential frictions.

This paper explores another path. We examine the decision to create frictions. To a considerable degree the mechanisms which segment markets are influenced by firms' own decisions and the mechanisms are likely to be costly to establish and maintain. By its control of distribution, marketing and product design a firm may increase the price differential needed to make arbitrage attractive. Various forms of vertical constraints, having different brand names in different locations and bundling with non-traded goods are examples of practices that facilitate (third degree) price discrimination.[1] These are all mechanisms that are likely to be associated with some costs for the firm.[2] In a one period problem the firm will choose to segment markets if the gain in profit from segmenting outweighs the cost. Furthermore, there is a strong flavor of irreversibility associated with many of the mechanisms and it is often realistic to think of the costs for these hinders to arbitrage as sunk. For example assume that a firm has built a separate brand name in a country - the resources devoted to this are typically not recoupable should it decide to integrate and use the same brand name as in other countries. By segmenting today the firm then buys an option to segment tomorrow at a lower cost - an option that increases the value of segmenting today.

One motivation for this paper is to explore if different currencies can contribute to our understanding of frictions that segment markets. Two types of mechanisms have been discussed previously: Firstly, even if LOP held on average, sticky prices and volatile exchange rates would create the higher variability of relative prices across borders documented by Engel and Rogers (1996, 1999). Secondly, it is claimed by many that if prices are expressed in the same currency, increased price transparency forces LOP to hold to a much greater extent. Indeed, an explicit purpose of the Economic and Monetary Union (EMU) in Europe is to increase market integration. In this paper we present another mechanism by which a monetary union would imply greater market integration. The mechanism would not be increased price transparency, but the very low probability of future exchange rate variability. The estimated half-lives of deviations from purchasing power parity are typically on the magnitude of several years (see for instance Rogoff, 1996) and many of the fluctuations in purchasing

[1] Gould (1977) analyzes price discrimination as a motivation for vertical control. In an international context Horn and Shy (1996) analyze bundling of traded goods with non-traded goods and resulting deviations from LOP. Somewhat related is also Malueg and Schwartz (1994) who analyze welfare effects of market segmentation and arbitrage.

[2] In addition to the direct effects on costs from the above measures (for instance by foregoing economies of scale in marketing) there is often a risk of intervention by competitive authorities (see for instance Scherer and Ross, 1990, for a discussion on the legal position on price discrimination).

power are associated with nominal exchange rate fluctuations. The key insight is that if there are less fluctuations in purchasing power between two similar markets, the benefits of market segmentation will be lower.[3]

The reasoning can be applied to many situations where a firm contemplates third degree price discrimination with (potential for) fluctuations in the sensitivity of demand between groups of consumers. The mechanisms in the current paper for instance imply that there is an option value associated with market segmentation as long as sales taxes can differ between locations. Given the very high volatility of real and nominal exchange rates in comparison with other demand shifters it is nevertheless the perhaps most natural setting for the analysis.

Close in spirit to the analysis are Baldwin (1988), Baldwin and Krugman (1989) and Dixit (1989) who view the decision to be present on a foreign market as a sunk cost but ignore the Home market.[4] Related is also Broll and Eckwert (1999) who show that for a price taking firm active on two segmented markets increasing exchange rate volatility increases the value of the option to export.

The next section presents the model. We proceed with an illustration using simple functional forms before tackling the issue of whether to segment markets or not. The final Section extends the analysis and discusses hysterisis, transport costs and general equilibrium implications.

2 The model

Examine the maximization problem facing a firm which produces a good which it sells on two markets which we call Home and Foreign. Let there be two periods $i = 1, 2$. Each period has the following sequence of events: first the exchange rate, e, for period i is observed, the firm then decides whether to separate or integrate markets in period i, sets price(s) for period i, and period i profits are realized. Let e denote the units of the firm's home currency needed to buy one unit of the Foreign currency. The exchange rate in period 2, e_2, is assumed to be a random variable with a continuous probability density function $f(e_2)$.

If markets are segmented, operating profits are given by Π and if markets are integrated operating profits are given by π. We assume that if markets are segmented, demand in each location is independent of price in the other location

[3] Goldberg and Verboven (1998) show wide price differences (up to 30 percent) between five European car markets between 1980 and 1993. In keeping with the claim in this paper they note that (p.2) car manufacturers actively seek to keep European markets geographically segmented by for instance maintaining the selectivity of the distribution system. Exchange rate fluctuations have been important in driving the price differentials. In 1990 United Kingdom and Italy were the most expensive (pre-tax hedonic prices) countries and by 1996 they were the cheapest - "the major exchange rate realignments seem to have played an important role in this reversal" (p. 5). The exchange rate thus appears to play an important role in a story of price discrimination on European car markets, and therefore for the incentives to segment markets.

[4] They focus on hysterisis in prices and the exchange rate. Since large exchange rate changes induce entry and exit of firms, prices and quantities will not return to pre-shock values just because the exchange rate returns to its original value.

whereas under integrated markets price is set so that LOP holds. Demand in each location depends on the price of the firm's product in that location (p and p^* respectively) and on the general price level in each country, given by P and P^*. Assume that P/P^* varies less than perfectly with e, such that there is a positive correlation between real and nominal exchange rates. Costs of production are given by $C(q, q^*)$ where q and q^* are quantities sold in Home and Foreign, respectively. The per period profit maximization problems are given by (time index suppressed):

$$\begin{aligned} \Pi &\equiv \max_{p,p^*} pq(p,P) + ep^*q^*(p^*,P^*) - C(q,q^*) \qquad (1) \\ \pi &\equiv \max_{p,p*} pq(p,P) + ep^*q^*(p^*,P^*) - C(q,q^*) \text{ s.t. } p = ep^* \end{aligned}$$

Only very weak assumptions are needed on the profit function to establish results (we assume that operating profits are higher under price discrimination than without and that the loss of not being able to price discriminate is increasing in the difference in purchasing power between groups).[5]

Assumptions A: i) In each period there is a unique exchange rate which minimizes $\Pi - \pi$, denoted $e_{\min}$. ii) $\infty > \frac{d(\Pi-\pi)}{d|e-e_{\min}|} > 0$.

For simplicity let the discount rate equal 1. The firm faces a decision of whether to segment the two national markets. Assume that segmenting markets is associated with a cost M if markets were segmented in the last period and a cost N otherwise, with $N > M$.

We will consider the decision problem faced by a firm at the beginning of period 1 which enters that period with segmented markets. The firm will segment in period 1 if the gain from segmenting is higher than the gain from integrating. First we turn to a simple example to establish some intuition.

3 An illustration

Assume there are constant marginal costs of production (c) and that the firm faces demand that is linear in price in each country $(1-p)$ and $(a-p^*)$ respectively, where a denotes the intercept of the Foreign demand curve. Assume that $e_1 = E[e_2] = 1$. The linear case is attractive not only because it yields transparent expressions, but also because the predictions from this simple model matches observed pass-through behavior well.[6] We first examine the per period

[5] The assumptions are implied by the LeChatelier principle - in the words of Dixit (1990, p. 113) - "the fewer variables are held fixed, the more convex should the maximum value function be". Profits where the relative price is free to vary should thus be more convex than profits where the relative price $\frac{p}{ep^*} = 1$. Thus, assumption A will hold under some regularity conditions, we have not pursued the exact nature of those regularity conditions (see Milgrom and Roberts, 1996 or Roberts, 1999, for a discussion of such conditions). Importantly we make no assumptions as to competitive structure (except that the difference in profits should be differentiable, and thereby continuous).

[6] Pass-through of an exchange rate change onto import prices equals one half in this model, an estimate that is close to the median estimate of pass-through on shipments to the US (Goldberg and Knetter, 1997).

profit maximization before proceeding to the market segmentation decision.

3.1 Segmented markets

In each period the maximization problem with respect to prices under segmented markets is given by

$$\max_{p,p^*} (p-c)(1-p) + (ep^* - c)(a - p^*)$$

Solving for the optimal prices yields

$$p = \frac{1+c}{2} \quad (2)$$

$$p^* = \frac{a + c/e}{2} \quad (3)$$

When $a = e = 1$ the optimal price will be the same on both markets, otherwise they differ. The profits from sales at the optimal prices are given by

$$\Pi = \frac{(1-c)^2}{4} + \frac{e(a-c/e)^2}{4}$$

Figure 1 illustrates the effect on price and profits of a depreciation of the Home currency (a move in e to e'). Since marginal costs are constant and markets are segmented the optimal price on the Home market is unaffected by the depreciation. On the Foreign market the depreciation is equivalent to a decrease in the marginal costs for the firm and this induces a decrease in the foreign currency price of the good. Foreign currency earnings increase by the area marked with diagonal lines and decrease by the area marked with vertical lines - implying an increase in profits.

Figure 1 about here

3.2 Integrated markets

When markets are integrated the maximization problem is given by (using $\overline{p}$ to denote the price)

$$\max_{\overline{p}} (\overline{p}-c)(1-\overline{p}) + (\overline{p}-c)(a-\overline{p}/e)$$

yielding the optimal price

$$\overline{p} = \frac{(1+a)}{2}\frac{e}{1+e} + \frac{c}{2}$$

and profits

$$\pi = \left(\frac{(1+a)e}{2(1+e)} - \frac{c}{2}\right)\left(\frac{1+a}{2} - \frac{c(1+e)}{e}\right)$$

The effect of not being able to segment markets is that the optimal price for the integrated markets will not be optimal for any one of the markets individually. A depreciation of the home currency still yields an increase in profits, but the positive effect is tempered by that the optimal price will be "too high" on the home market and "too low" on the foreign market compared to what would have been the case under separated markets.

3.3 Market segmentation

To examine the choice of whether to segment markets begin by finding the threshold values of e_2 at which a firm that segmented in period 1 will continue to segment in period 2. The firm will continue to segment if $\Pi(e_2) - \pi(e_2) \geq M$ or specifically if

$$\Pi(e_2) - \pi(e_2) = \frac{1}{4(1+e_2)} \left(1 + e_2 a(e_2 a - 2)\right) \geq M \tag{4}$$

Rewrite (4) as a quadratic equation in e_2 and solve for the two roots at which (4) holds with equality to establish the two thresholds

$$\begin{aligned} \underline{e}_m &= 1/a + 2M - 2\sqrt{a^2/4 - 1/4 + M(2+M)} \\ \overline{e}_m &= 1/a + 2M + 2\sqrt{a^2/4 - 1/4 + M(2+M)} \end{aligned}$$

where clearly $\overline{e}_m > \underline{e}_m$. In the same manner we calculate the critical values of the exchange rate at which a firm which did not segment in period 1 will choose to segment in period 2, the two levels of e_2 where $\Pi(e_2) - \pi(e_2) = N$. Figure 2 illustrates the case where $a = 1.2$, $M = 0.02$ and $N = 0.03$ and $c = 0.1$.

Figure 2 about here

When $e_2 = 1$ the markets are in this case similar enough that the firm chooses not to segment them. The Home market is smaller than the Foreign and the optimal price on the Home market is lower than the optimal price on the Foreign market when $e = 1$. An appreciation of the Home exchange rate increases the purchasing power of Home market relative to the Foreign, and for a sufficiently appreciated exchange rate there is no difference in profits between the integrated and segmented markets cases. As e appreciates even more prices again diverge, the optimal price on the home market is now greater than price on the foreign market. We see that $\Pi - \pi$ is convex in e, the farther from the minimum difference that e is, the greater is the difference in operating profits between segmented and integrated markets. This ensures that there are only two values where the difference in profits equals M and only two where it equals N.

For period 2 levels of the exchange rate between $\underline{e}_m$ and $\overline{e}_m$ the firm will integrate markets since the difference in operating profits between integrated and segmented markets is too small to motivate segmentation. For $\overline{e}_m < e_2 < \overline{e}_n$ a firm that segmented in period 1 will continue to do so and gain higher profits than a firm that integrated in period 1 (which will continue to integrate since $N > M$). If the exchange rate is more depreciated than $\overline{e}_n$ a firm will segment no matter what it did in period 1, but the cost of doing so will depend on its history. So the decision in period 1, of whether to integrate markets or not, will hinge on the probabilities of where the period 2 exchange rate will be in relation to the thresholds. If the exchange rate probability function has sufficient mass in the tails it will pay to segment markets in period 1. We examine this idea formally in the next section in the general setting.

4 The decision to segment markets

4.1 Period 2

As in the Illustration the first step in the analysis is to find the threshold values in period 2 at which the firm will discontinue segmenting markets and the thresholds at which it will commence market segmentation. In period 2 a firm that segmented markets in period 1 will choose to continue segmenting if

$$\Pi(e_2) - M \geq \pi(e_2) \tag{5}$$

Assumption A assures that (5) yields two thresholds, $\overline{e}_m$ and $\underline{e}_m$ with $\overline{e}_m > \underline{e}_m$. To make the analysis interesting we want the exchange rate at which $\Pi - \pi$ reaches its minimum to be sufficiently close to the expected exchange rate:

Assumption B: $\underline{e}_m < E(e_2) < \overline{e}_m$.

Similarly

$$\Pi(e_2) - N \geq \pi(e_2)$$

yields two thresholds at which a firm that integrated in period 1 will choose to segment in period 2, $\overline{e}_n$ and $\underline{e}_n$ where $\overline{e}_n > \underline{e}_n$. The ranking of the thresholds is such that $\underline{e}_n < \underline{e}_m < E(e_2) < \overline{e}_m < \overline{e}_n$.

4.2 Period 1

In period 1 the firm will keep segmenting markets if the benefit from segmenting exceeds the benefit of integrating, that is if

$$\begin{aligned} & \Pi(e_1) - M + \int_{\underline{e}_m}^{\overline{e}_m} \pi(e_2) f(e_2) de_2 + \int_0^{\underline{e}_m} [\Pi(e_2) - M] f(e_2) de_2 + \int_{\overline{e}_m}^{\infty} [\Pi(e_2) - M] f(e_2) de_2 \\ \geq \ & \pi(e_1) + \int_{\underline{e}_n}^{\overline{e}_n} \pi(e_2) f(e_2) de_2 + \int_0^{\underline{e}_n} [\Pi(e_2) - N] f(e_2) de_2 + \int_{\overline{e}_n}^{\infty} [\Pi(e_2) - N] f(e_2) de_2 \end{aligned} \tag{6}$$

The first line of (6) is the value of segmenting markets in period 1. Period 1 profits are then given by operating profits when markets are segmented ($\Pi(e_1)$) minus the cost of segmenting markets, M. If the period 2 exchange rate, e_2 lies between $\underline{e}_m$ and $\overline{e}_m$ the firm will integrate in period 2 and gain profits $\pi(e_2)$.

This is the third term. If e_2 is lower than $\underline{e}_m$ the firm will continue segmenting markets gaining operating profits $\Pi(e_2)$ and paying the cost of continuing to segment, M. This is the fourth term, the fifth is the equivalent for when $e_2 > \overline{e}_m$. The second line in Equation (6) is the value of integrating markets in period 1. Rewriting (6) establishes

Proposition 1 *Under assumptions A and B the firm will segment markets in period 1 if and only if* $-M+(\Pi(e_1) - \pi(e_1))+(N-M)\left(\int_0^{\underline{e}_n} f(e_2)de_2 + \int_{\overline{e}_n}^{\infty} f(e_2)de_2\right)$
$+\int_{\underline{e}_n}^{\underline{e}_m} [(\Pi(e_2) - \pi(e_2)) - M] f(e_2)de_2 + \int_{\overline{e}_m}^{\overline{e}_n} [(\Pi(e_2) - \pi(e_2))) - M] f(e_2)de_2 \geq 0.$

It will be profitable for the firm to continue segmenting markets if the cost of doing so (M in the first period) is lower than the gain. The gain consists of the difference in operating profits in period 1 ($\Pi(e_1) - \pi(e_1)$) plus the expected value of entering the next period with segmented markets. There are two parts to this expected value, if $e_2 < \underline{e}_n$ or $e_2 > \overline{e}_n$ the firm will segment in period 2 no matter what it did in period 1. The larger the difference between N and M the more important will this term be. For exchange rates that are between thresholds, $\underline{e}_n < e_2 < \underline{e}_m$ (and conversely for a depreciated exchange rate) the firm will operate with segmented markets only if it segmented in period 1. All terms except the first are non-negative and will be positive if some of the probability mass of the exchange rate distribution falls outside the thresholds. This leads us to the following corollary:

Corollary 2 *If e_2 is certain with $\underline{e}_m < e_2 < \overline{e}_m$, the firm will segment in period 1 if and only if $-M + \Pi(e_1) - \pi(e_1) > 0$. Letting e_2 be random with Pr $[e < \underline{e}_m] > 0$ and/or Pr $[e > \overline{e}_m] > 0$ increases the value of segmenting in period 1.*

Variability strengthens the incentive for segmenting. For a firm such as this there is a fundamental difference between a fixed exchange rate and a monetary union. A fixed exchange rate entails the possibility of future exchange rate changes - making the option to segment at a lower cost valuable.

Most starkly the intuition is brought out if we assume that $\Pi(e_1)-\pi(e_1) = 0$. For sufficiently high probability of future exchange rate changes the firm will pay the cost of segmenting even though it gains nothing in current operating profits from doing so. Much of the "real options" literature has focused on the equivalent of a call option: in our model this would be the type of setup if $M = 0$ and we only examine exchange rate changes in one direction.[7] The financial option equivalent to our real option is what is popularly called a "strangle": a combination of an out-of-the-money call option and an out-of-the-money put option. In analogy with the real option in this paper, the long strangle will

[7] See for instance Dixit and Pindyck (1994), Lander and Pinches (1998).

be valuable when the price of the underlying asset moves sufficiently in either direction.

For the purpose of the analysis take as reference a firm for which the condition in Proposition 1 holds with equality. Denote the difference in profits in period 1 for which Equation (6) holds with equality by $\Delta_{crit} = \Pi(e_1) - \pi(e_1)$ for a given distribution of e_2. It turns out to be convenient to center a discussion around how Δ_{crit} is affected by changes in the underlying parameters.

Corollary 3 *The more weight in the tails of the probability density function for the exchange rate, the lower is* Δ_{crit}

Proof. See appendix A ■

Increasing risk increases the value of segmenting in the first period. The quite general nature of the Corollary deserves to be emphasized. All that is required for results to hold is that operating profits are higher under price discrimination than without, that the more demand of the groups differ, the greater is the difference in operating profits and that profits in period 2 are a deterministic function of the exchange rate. The firm does not know the realization of the exchange rate in period 2, it knows however for every possible realization what profits it would achieve - if this were not the case the thresholds would also be stochastic.

In the context of price equalization in Europe it should be noted that a common currency comes at the same time as other moves to create a common market are taken. Harder enforcement of competitive rules and elimination of border controls can be seen as making the maintenance cost of segmenting larger - something that also promotes market integration.[8]

Corollary 4 Δ_{crit} *is increasing in* M.

Proof. see Appendix B. ■

There is a trivial effect since increasing M increases the cost of segmenting in period 1. In addition the value of entering period 2 with segmented markets is lower when the cost of maintaining segmentation is high. There are two sources of this latter effect: firstly the lower the difference between N and M the less will it be worth to segment at a lower cost (the third term in Proposition 1). Secondly, $\underline{e}_m$ will decrease and $\overline{e}_m$ will increase which together with higher M make the last two terms lower.

However, it should be noted that measures which increase the maintenance cost of segmenting are likely to increase the cost of starting to segment as well. The more it costs to start segmenting in the future, the more will it be worth to continue segmenting in period 1.

Corollary 5 Δ_{crit} *is decreasing in* N.

[8] Volkswagen for instance were fined more than 100 million Ecu in 1997 for (threats of) revoking licences of Italian dealers that sold to Austrian or German customers.

Proof. Given in Appendix C. ■

A competitive authority that for some reason wanted to increase market integration would therefore strive for raising the maintenance cost of segmenting and decreasing the cost of starting to segment - in the limiting case where $N = M$ the option value of segmenting disappears (since segmenting in this period does not affect the cost of segmenting in future periods). To allow price discrimination when the real exchange rate is at exceptional levels could thus be a means of stimulating market integration in more normal times. The at first somewhat counterintuitive corollary that a competitive authority which strives after market integration should decrease the costs of starting to segment markets, is put somewhat in perspective by the following:

Corollary 6 *When both N and M change by the same amount, Δ_{crit} is increasing, as long as there is sufficiently low probability mass on $e_2 \in [\underline{e}_{n'}, \underline{e}_n], [\overline{e}_n, \overline{e}_{n'}]$.*

Proof. Given in Appendix D. ■

Unless there is very much probability mass between the "old" and "new" thresholds for starting segmentation, measures that make segmentation harder will indeed lead a firm to integrate markets that would otherwise have segmented. In other words, raising the both the maintenance and start-up costs of segmenting promotes market integration.

5 Extensions

5.1 Hysterisis

The analysis so far has used only two periods, extending the analysis to more periods does not change the thrust of results. Previous analysis of sunk costs in conjunction with exchange rates has focused on hysterisis - dependent variables that do not return to pre-shock values after a large shock. The flavor of that type of analysis can be seen by a simple example which follows Baldwin and Krugman (1989) closely: Assume that the exchange rate for period t is given by $e_t = 1 + \varepsilon_t$ with $\varepsilon_t \sim N(0, \sigma^2)$.[9] Since the exchange rate is constant plus noise, expected present value of the firm will be constant and only dependent on whether the firm segmented in the previous period or not. Denote V_I the value of having integrated markets and V_S the value of having segmented markets and let the discount rate be given by δ. The same notation as previously is used (but

[9] The mean reversion of the (real) exchange rate is important for realism (the standard assumption in the options literature that the underlying variable follows a Brownian motion without mean reversion would imply that the relative purchasing power could grow without bounds). However if we were to model the exchange rate as a mean reverting Brownian motion this would in all likelyhood force the use of specific functional forms and resorting to calibration (see Dixit and Pindyck, 1994). We have instead opted for as simple a framework as possible.

note that the threshold levels of the exchange rate will be different). Then we have

$$\begin{aligned} V_I &= \int_0^{\underline{e}_n} \left[\Pi(e) - N + \delta V_S\right] f(e)de + \int_{\underline{e}_n}^{\infty} \left[\Pi(e) - N + \delta V_S\right] f(e)de + \\ & \int_{\underline{e}_n}^{\overline{e}_n} \left[\pi(e_2) + \delta V_I\right] f(e)de \end{aligned}$$

$$\begin{aligned} V_S &= \int_0^{\underline{e}_m} \left[\Pi(e) - M + \delta V_S\right] f(e)de + \int_{\underline{e}_m}^{\infty} \left[\Pi(e) - M + \delta V_S\right] f(e)de \\ & \int_{\underline{e}_m}^{\overline{e}_m} \left[\pi(e_2) + \delta V_I\right] f(e)de \end{aligned}$$

The thresholds where the firm decides to commence segmenting are given by (focusing on the case where $e > e_{\min}$, the argument is analogous for $e < e_{\min}$)

$$\Pi(\overline{e}_n) - \pi(\overline{e}_n) - N + \delta V_S = \delta V_I \tag{7}$$

and the thresholds for continuing to segment by

$$\Pi(\overline{e}_m) - \pi(\overline{e}_m) - M + \delta V_S = \delta V_I \tag{8}$$

Here the difference in operating profits minus the cost of segmenting, plus the discounted value of entering the next period with segmented markets equals the value of entering the next period with integrated markets. Combining (7) and (8) establishes that

$$\Pi(\overline{e}_n) - \pi(\overline{e}_n) - (\Pi(\overline{e}_m) - \pi(\overline{e}_m)) = N - M > 0$$

which implies that $\overline{e}_n > \overline{e}_m$ since the difference in operating profits is increasing in the deviation of e from $e_{\min}$. The level of the exchange rate which leads a firm to start segmenting markets is more depreciated than the level sufficient for it to continue segmenting. The implication is that the model exhibits hysterisis: whether the firm segments or not will depend on history. Say a firm starts with integrated markets and $e_t \in [\overline{e}_m, \overline{e}_n)$. Then in $t+1$ it is subjected to a large exchange rate shock which leads it to segment, if the exchange rate returns so that $e_{t+2} = e_t$ it will segment in period $t+2$ even though it previously integrated at the same exchange rate.

5.2 Arbitrage

The previous analysis rested on the assumption that the further the exchange rate deviated from $e_{\min}$, the greater was the gain of segmenting markets. This is a simplification - the more prices diverge, the more consumers will eventually buy in the cheaper location. For instance the strong dollar of the mid 1980s and the resulting price differentials on European cars sparked substantial parallel imports. A further simplification was to assume that under integrated markets price must be set so that LOP holds. Typically there will be transport costs such that cross-price effects are zero for some values of the exchange rate close enough to $e_{\min}$.

In this section we briefly explore the implications of these possibilities. Assume that there is some exogenous transport cost of t for consumers and that the firm may increase this transport cost by an amount F by investing M. Profit maximization problems are then given by

$$\begin{aligned} \Pi &\equiv \max_{p,p^*} pq(p,P) + ep^*q^*(p^*,P^*) - C(q,q^*) \text{ s.t. } |p - ep^*| \leq t + F \quad (9) \\ \pi &\equiv \max_{p,p*} pq(p,P) + ep^*q^*(p^*,P^*) - C(q,q^*) \text{ s.t. } |p - ep^*| \leq t \end{aligned}$$

For values of e sufficiently close to $e_{\min}$ transport costs will prevent arbitrage. If consumers in each country face the same transport cost then all will buy in the cheaper country once the deviation from LOP is larger than t. Thus for the firm that has not taken the segmentation cost of M the constraint will become binding when $|p - ep^*| = t$. By paying a cost of segmentation M, the firm will shift the points at which profit maximization is subject to a binding constraint outwards thus gaining a higher operating profit as illustrated in Figure 3.

Figure 3 about here

For sufficiently high (low) levels of the exchange rate both constraints are binding and the difference between operating profits may be declining as e increases or decreases.[10] There will now be four thresholds that are of interest, denote these $\underline{e}_{m1}$, $\underline{e}_{m2}$, $\overline{e}_{m3}$ and $\overline{e}_{m4}$ (having set $N = \infty$). Following the same logic as previously we establish that the firm will segment in period 1 if and only if

$$\begin{aligned} & -M + (\Pi(e_1) - \pi(e_1)) + \int_{\underline{e}_{m1}}^{\underline{e}_{m2}} [\Pi(e_2) - \pi(e_2) - M] f(e_2) de_2 \\ & + \int_{\overline{e}_{m3}}^{\overline{e}_{m4}} [\Pi(e_2) - \pi(e_2) - M] f(e_2) de_2 \\ \geq & \ 0. \end{aligned}$$

[10] An extreme example would be where the currency of the foreign country depreciates so much (in real terms) that foreign demand goes to zero, even if price were set at marginal cost. Then the difference in profits between the "integrated" and the "segmented" case would be 0.

The sign of this expression will hinge on where the probability mass lies for the exchange rate. Sufficient weight far out in the tails will lead the firm to integrate if it is indeed the case that the difference in profits between the integrated and segmented cases diminishes as the exchange rate moves sufficiently far. If the firm believes that there is a high probability of moderate exchange rate variability but a low probability of extreme variability then the firm will continue to segment.

As before higher costs of segmenting, M, makes segmenting less attractive. There is a direct effect through higher costs of segmenting today, and a further impact trough making it less valuable to enter the next period with segmented markets. Higher exogenous transport costs make it more likely that $\Pi(e_1) - \pi(e_1)$ equals 0, thereby decreasing the value of investing in further segmentation (and conversely, lower transport costs increase the value of segmenting). Thus allowing for transport costs and arbitrage opportunities does not change the fundamental results that variability creates an option value of market segmentation and that the value of this option is decreasing in the cost of maintaining segmentation.[11]

Little attention has previously been paid to price discrimination when segmentation is imperfect. Anderson and Ginsburgh (1999) appear to be the first to theoretically examine price setting with imperfect leakage in an international setting. They examine the case where consumers differ in their transport costs and thus combine third and second degree price discrimination. For some cases in their setup higher transport costs for consumers may actually decrease profits. Consider the case where there is only second degree price discrimination - small levels of transport costs can then be an efficient instrument for segmenting customers, an instrument which the firm would lose if transport costs rose to much. They examine the case when there is both second and third degree price discrimination only under a certain parameterization, finding that higher transport costs yields higher profits.[12]

5.3 General equilibrium

A firm's price adjustment will be dependent on if it has chosen to segment markets or not. Price adjustment in turn affects the correlation between the nominal and the real exchange rates - and thereby the incentives for segmentation facing other firms.

At a first glance the "new open economy macroeconomics" (see e.g. Obstfeld and Rogoff, 1995, 1999, Betts and Devereux, 1996 or Devereux and Engel, 1998) appears to offer an off the shelf framework in which to examine the current issues - there is monopolistic competition and two countries that are equal in

[11] Results would look much the same if we instead of modeling transport costs as fixed used an "iceberg" (a share of the good melts in transport) specification - then maximization would be subject to $1/t \leq p/ep^* \leq t$.

[12] Surprisingly, their analysis has very few precursors in general, one exception is Lowell and Wertz (1981).

equilibrium (which made the conclusions in Proposition 1 particularly stark).[13] Especially Obstfeld and Rogoff (1999) are close to the setup in the present paper since they allow (labor) costs to be rigid but let prices be set after uncertainty is resolved.

However, this literature employs constant elastic demand which is the same on both national markets and assumes constant marginal costs. Optimal prices under segmented markets on the two markets are then given by (with ρ denoting the constant demand elasticity and c marginal cost)

$$p = ep^* = \left(\frac{\rho}{\rho - 1}\right) c \ \forall e$$

The pass-through elasticity of an exchange rate change is perfect ($\frac{dp^*}{de}\frac{e}{p^*} = -1$) - optimal prices on the two markets will always be equal since demand elasticities are equal and market integration poses no restriction on profits.

By assuming differences in costs or different demand elasticities for the respective countries we would create incentives for segmenting, but such extensions are beyond the scope of the present paper. Bergin and Feenstra (1999) extend a model of the Obstfeld-Rogoff type to a demand function yielding less than full pass-through. This could prove a valuable starting point for analysis of endogenous segmentation in a general equilibrium setting. However they rely on linearizations to handle the model which also is problematic for our purposes since the greater curvature of profits in the exchange rate under segmented markets is driving the incentives for segmenting.

6 Conclusions

So, why does arbitrage exert so weak equalizing pressure on prices across national borders? The answer explored in this paper is that it is because firms choose to segment markets. Higher costs of maintaining segmentation promoted integration but higher costs of starting to segment in the future and higher future exchange rate variability tended to deter integration in the present period. One implication of the model is that a monetary union should promote market integration. However, it should be stressed that the present paper has not tried to make a welfare analysis of monetary union.[14] Rather we wanted to explore if there could be a basis for beliefs that monetary union could imply goods market integration and to understand a potential mechanism.

A number of extensions present themselves - it should in many cases be straightforward to extend the analysis to explicitly examine oligopolistic competition and issues of market segmentation as strategic commitment. General equilibrium analysis should be very fruitful but has some pitfalls as noted.

[13] Betts and Devereux (1996) amongst others indeed examine how the model behaves under the assumption that a share of firms segment markets and set prices in the importers' currency.

[14] For a discussion and analysis of welfare effects of international price discrimination see Malueg and Schwartz (1994).

The theories also lend themselves well to empirical examination. Further studies of deviations from LOP and PPP under various institutional arrangements should be valuable.[15] The difference in the model between having fixed exchange rates and a monetary union squares well with the empirical evidence presented by Rose (1999) - using a gravity model he finds a large positive effect of a monetary union on trade, but only small effects of lowering exchange rate volatility. Tentatively one could also see some connection between hysterisis in a model of the present type and the amazingly long time that the world economy remained more segmented after World War 1 than before. Most notably it will be exciting to observe how price differentials develop within the EMU. The mechanisms explored in this paper should show up not only in price differentials but also in issues as if products differ between markets - is the same product name employed? Does packaging have text in several languages? Where is a warranty honored? What is the extent of vertical integration?

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Appendix A

Define a distribution $g(e)$ such that $\int_0^s g(e_2)de_2 > \int_0^s f(e_2)de_2 \forall s < \underline{e}_m$ and $\int_t^\infty g(e_2)de_2 > \int_t^\infty f(e_2)de_2 \forall t > \overline{e}_m$. Thus $\Delta_{crit}(f(e)) - \Delta_{crit}(g(e)) = (N - M)\left(\int_0^{\underline{e}_n}(g(e_2) - f(e_2))de_2 + \int_{\overline{e}_n}^\infty g(e_2) - f(e_2))de_2\right)$

$+\int_{\underline{e}_n}^{\underline{e}_m} [(\Pi(e_2) - \pi(e_2)) - M] (g(e_2) - f(e_2)) de_2 + \int_{\overline{e}_m}^{\overline{e}_n} [(\Pi(e_2) - \pi(e_2))) - M] g(e_2) - f(e_2)) de_2.$

All terms on the right hand side are positive $\Rightarrow \Delta_{crit}(f(e)) > \Delta_{crit}(g(e))$

Appendix B

Define $M' = M + \Delta M$ with $\Delta M > 0 \Rightarrow \underline{e}_{m'} < \underline{e}_m$ and $\overline{e}_{m'} > \overline{e}_m$. Some calculation establishes that $\Delta_{crit}(M') - \Delta_{crit}(M) = \Delta M \left(1 + \int_0^{\underline{e}_n} f(e_2)de_2 + \int_{\overline{e}_n}^{\infty} f(e_2)de_2\right)$

$+ \int_{\underline{e}_{m'}}^{\underline{e}_m} (\Pi - \pi - M) f(e_2) de_2 + \int_{\overline{e}_m}^{\overline{e}_{m'}} (\Pi - \pi - M) f(e_2) de_2$

$+\Delta M \int_{\underline{e}_n}^{\underline{e}_{m'}} f(e_2)de_2 + \Delta M \int_{\overline{e}_{m'}}^{\overline{e}_n} f(e_2)de_2$. All terms on the right hand side are positive$\Rightarrow \Delta_{crit}(M') > \Delta_{crit}(M)$.

Appendix C

Define $N' = N + \Delta N$ with $\Delta N > 0 \Rightarrow \underline{e}_{n'} < \underline{e}_n$ and $\overline{e}_{n'} > \overline{e}_n$.

$\Delta_{crit}(N) - \Delta_{crit}(N') = \Delta N \left(\int_0^{\underline{e}_{n'}} f(e_2)de_2 + \int_{\overline{e}_{n'}}^{\infty} f(e_2)de_2\right)$

$+ \int_{\underline{e}_{m'}}^{\underline{e}_m} (\Pi - \pi - N) f(e_2) de_2 + \int_{\overline{e}_m}^{\overline{e}_{m'}} (\Pi - \pi - N) f(e_2) de_2$

All terms on the right hand side are positive$\Rightarrow \Delta_{crit}(N) > \Delta_{crit}(N')$.

Appendix D

$\Delta_{crit}(M', N') - \Delta_{crit}(M, N) = \Delta M \left(1 + \int_{\underline{e}_{n'}}^{\underline{e}_{m'}} f(e_2)de_2 + \int_{\overline{e}_{m'}}^{\overline{e}_{n'}} f(e_2)de_2\right)$

$+ \int_{\underline{e}_{m'}}^{\underline{e}_m} (\Pi - \pi - M) f(e_2) de_2 + \int_{\overline{e}_m}^{\overline{e}_{m'}} (\Pi - \pi - M) f(e_2) de_2$

$- \int_{\underline{e}_{n'}}^{\underline{e}_n} (\Pi - \pi - M) f(e_2) de_2 - \int_{\overline{e}_n}^{\overline{e}_{n'}} (\Pi - \pi - M) f(e_2) de_2$. The first three terms are positive, the last two negative, which establishes the corollary.