Essays on Exchange Rates and Prices

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Essays on Exchange Rates and Prices

Fredrik Wilander

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Dissertation for the Degree of Doctor of Economics
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To Marianne and Thomas

Contents

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Stockholm, January 2006
Fredrik Wilander

Summary of Thesis

Introduction

Research in the field of International Finance has hardly ever been more exciting than it is today. The past decade has witnessed large swings in the dollar, the Southeast Asian currency crises, the launch of the European Monetary Union and the successful introduction of the euro as a means of payment and eventually as an international currency. These events have highlighted the role of exchange rate fluctuations for both consumers and firms in an open economy. This is particularly so for Sweden, a small, relatively open economy outside the European Monetary Union, an area which holds many of it's major trading partners.

The fact that prices of both domestically sold and imported goods are not completely flexible raises several important questions. How will the pricing and quantity decisions of exporting firms change when prices are not flexible? How will the link between exchange rates and prices of imported goods on the one hand, and prices of goods sold in different countries on the other hand, be affected by nominal rigidities? Do consumers take advantage of cross-country price differences brought about by flexible exchange rates and sticky prices? These are issues that this thesis will try to shed light on. Below we summarize in more detail the included papers.

Summary of Papers

This thesis consists of five papers. The common theme of the first three papers is that prices of goods are not completely flexible, something that will affect how both consumers and firms respond to exchange rate changes. The last two papers, one empirical and one theoretical, study the effect of exchange rate variability and uncertainty on export pricing and profits, and also the relationship between exchange rate uncertainty and the market value of exporting firms.

Paper 1: *An Empirical Analysis of the Currency Denomination in International Trade*

This paper investigates the choice of currency in international trade transactions by Swedish exporting firms. In a world of nominal rigidities, the currency in which prices are set will affect both expected profits of exporting companies, as well as how consumers and firms in general are affected by exchange rate changes. While the theoretical literature on optimal choice of price-setting and invoicing currency for exporting firms is extensive (see for example Baron (1976), Donnenfeld and Zilcha (1991), Friberg (1998), Bacchetta and van Wincoop (2005) and Engel (2005)), remarkably little empirical research on the subject has been carried out. Grassman (1973) noted in a seminal paper that in trade between industrialized countries the currency of the producer was generally used. Producer Currency Pricing (PCP) then became known as Grassman's Law. Donnenfeld and Haug (2002, 2003) study the impact of exchange-rate volatility on the denomination of U.S. and Canadian imports respectively, and find a positive correlation between exchange rate volatility and the use of the importer's currency, sometimes denoted Local Currency Pricing (LCP). Goldberg and Tille (2005) derive and test a model of industry specific factors that could explain invoicing patterns. They confirm earlier studies that point to the dollar being the currency of choice in transactions with the U.S. as well as in other transactions in exchange traded and/or reference priced goods. They argue that the latter finding is largely attributable to industry herding behavior in currency choice and not to macroeconomic factors.

We use a unique and extensive microdata set on individual payment transactions between foreign importers and Swedish exporting firms in order to analyze the choice of invoicing currency in international trade. It is the first paper to examine currency invoicing at such a disaggregated level. The main findings are that high exchange rate volatility vis-à-vis the Swedish krona reduces the likelihood of using the importer's currency while high GDP and GDP per capita in the importing country increases the likelihood. A large market share of a third country increases the likelihood of using the third country's currency. A further finding is a decreased use of Swedish krona in exports and a rise in the use of the euro as a vehicle currency

Paper 2: *State Dependent Pricing, Invoicing Currency and Exchange Rate Pass-Through* (with Martin Flodén)

In this paper, written jointly with Martin Flodén, we analyze exchange rate pass-through (the relation between import prices and exchange rates) in a dynamic model with menu costs. When prices cannot be continuously updated, the currency in which export prices are denominated will affect the degree to which changes in the exchange rate are transmitted to prices of imported goods. Trivially, if for example all exporters to a foreign market set prices in the importer's currency (Local Currency Pricing or LCP) and prices cannot be updated, exchange rate pass-through to import prices would be zero. If all prices instead are set in the exporter's currency (Producer Currency Pricing or PCP), then exchange rate changes would be fully transmitted into import prices as long as they are not updated. However, if prices were completely flexible, pass-through would be independent of pricing convention (LCP or PCP), and only depend on functional forms of cost and demand, as well as the form of competition.

In the present paper, we provide a link between the fixed and flexible price analyses by specifying a dynamic framework with exogenous choice of exporting currency, but with endogenous pricing decisions. More specifically, we consider the pricing strategies of firms that produce in a home country, sell on a foreign market, and can change the price in response to exchange rate fluctuations, while being subject to menu costs. The degree of pass-through is then endogenous and depends on (i) the invoicing convention (LCP or PCP), (ii) the size of menu costs in relation to the costs of using suboptimal prices (since this determines how often firms update prices), and (iii) the frictionless degree of pass-through (since this determines how much prices are changed when firms choose to update prices).

Our main finding is that when LCP is favored to PCP, the exporter changes prices less frequently under LCP than under PCP. The intuition is that in this setting, the optimal currency choice is the one that on average minimizes the difference between fixed and flexible price profits, and thereby the frequency of price updates. When LCP is preferred, this results in limited pass-through and a low correlation between exchange rate movements and import prices. While eventually exchange rate pass-through may be determined by factors other than nominal rigidities, our model explains why extensive local currency pricing implies lower volatility of imported goods prices also in the medium run.

We further analyze the impact of large versus small innovations in the exchange rate. Since larger fluctuations in the exchange rate raise the opportunity cost of holding prices fixed, firms update prices more frequently. Under LCP we therefore find that pass-through is larger for large exchange rate innovations while for PCP, the degree of pass-through is smaller for large fluctuations.

Paper 3: *Demand and Distance: Evidence of Cross Border Shopping* (with Marcus Asplund and Richard Friberg)

While many studies have documented deviations from the Law of One Price in international settings (for example Engel and Rogers (1996), Goldberg and Knetter (1997), Haskel and Wolf (2001), Anderson and Van Wincoop (2004), Goldberg and Verboven (2005)), evidence is scarce on the extent to which consumers take advantage of price differentials and engage in cross border shopping.

We use data from 287 Swedish municipalities to estimate how responsive alcohol sales are to foreign prices, and relate the sensitivity to the location's distance to the border. Typical results suggest that the elasticity with respect to the foreign price is around 0.4 in the border region; moving 200 (400) kilometers inland reduces it to 0.2 (0.1). For example, a 10 percent reduction in the Danish price of spirits causes a fall in per capita sales of roughly 4 percent at the border (Malmö). This large cross price elasticity is almost half the own price elasticity. The effect diminishes gradually as one moves further from the border, but fall in sales is estimated to drop below 1 percent only at 460 kilometer from the border. Not until we reach 1000 kilometers can we reject that the effect is zero.

With the deeper integration of the European Union (EU) and its expansion, the effects of cross border trade has become an important policy issue as in many cases the price differences are due to taxes set by individual member states. This is true also for country price differences for alcohol, so our evidence has implications for the debate on tax competition/harmonization. Taking the recent Danish spirits tax cut in October 2003 and making a back of the envelope calculation of the effects on Swedish tax revenues suggest a direct loss of about 214 million kronor (some 24 million euro per year or 2.7 euro per capita). While the tax revenue implications in general will depend on many factors, these numbers nevertheless suggest that the literature on tax competition between governments (Kanbur and Keen, 1993, Wang, 1999 and Nielsen, 2001), has empirical relevance.

Paper 4: *When is a Lower Exchange Rate Pass-Through Associated with Greater Exchange Rate Exposure?* (with Martin Flodén and Witness Simbanegavi)

In this paper, written jointly with Martin Flodén and Witness Simbanegavi, we study the relationship between exchange rate pass-through and exchange rate exposure (the relation between profits and exchange rates) under flexible prices. The pass-through of exchange rate changes into import prices, as well as the effect of exchange rate fluctuations on the value of the firm are two closely related topics, yet only one previous paper, (Bodnar et al 2002), studies their relationship in a theoretical model. In that study the authors set up a duopoly model with an exporting firm and an import competing foreign firm. They show that exchange rate pass-through and exposure should be negatively correlated across industries. The intuition for this result is that when the substitutability between the domestically produced good and the imported good increases in an industry (which in effect increases the price elasticity of demand for the firms) both firms have greater incentives to stabilize prices, and hence exchange rate pass-through falls. Profits on the other hand become more sensitive to exchange rate changes, so exposure increases. Hence if industries differed mainly in the substitutability between domestically produced and imported goods, one should see a negative relationship between exchange rate pass-through and exposure across industries.

In the paper we add variation on the supply side across industries and study how this will affect the relationship between pass-through and exposure. We introduce a convex cost function and study the effects of changing the elasticity of costs with respect to output. We do this both in a simple model of monopolistic competition as well as in the oligopoly models used by Bodnar et al (2002). We find that increasing the convexity of costs reduces both exchange rate pass-through and exposure, both in the case of monopolistic competition as well as under the duopoly price and quantity models. The conclusion is thus that if industries differ mainly on the supply side, this would imply a positive correlation between pass-through and exposure. We find that when we allow for non-constant marginal costs, the model also seems to fit the data better, both in respect to the estimated elasticities, and their correlation across industries.

Paper 5: *Common Currencies and Equity Prices: Evidence from a Political Event*

Recent empirical research has found that sharing a common currency leads to large and positive effects on the level of bilateral trade between two countries. Monetary unions seems to act like "trade boosters", increasing trade between member countries, without diverting trade between member and non-member countries, something that has been documented by Rose (2000), Persson (2001), Frankel and Rose (2002) and Micco et al. (2003), to name a few.

We will use a political event, the Swedish referendum on whether or not to join the European Monetary Union (EMU), as a natural experiment to examine the relationship between common currencies and the market value of exporting firms. If Sweden would have voted to join the EMU, exchange rate uncertainty as well as transaction costs would have been greatly reduced for many exporting companies. Prior to the election, these potential gains (adjusted for the probability of a favorable outcome) should have been included in equity prices. The day after the election the probability of a favorable outcome was zero and one would expect a decline in equity prices of exporting firms. We find evidence of statistically significant negative abnormal returns on the trading day after the election for two out of fifteen examined industry indices, but no effect on the stock-market as a whole or in a sample of individual exporting companies. The small effects found in this study are in line with earlier research that find a weak relationship between exchange rates and equity prices, and indicate that the large increases in bilateral trade due to countries sharing a common currency may not benefit individual exporting firms to the same extent.

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Papers

PAPER 1

An Empirical Analysis of the Currency Denomination in International Trade

Fredrik Wilander

ABSTRACT. This paper examines the choice of currency in international transactions by Swedish exporting firms. Using a unique and extensive data set from the Swedish Central Bank's Settlement Reports, we model the firms' choice of export currency as a multinomial logit model. The main findings are that high exchange rate volatility reduces the likelihood of using the importers currency while high GDP and GDP per capita in the importing country increases the likelihood. A large market share of a third country increases the likelihood of using the third country's currency. A further finding is a decreased use of Swedish krona in exports and a rise in the use of the euro as a vehicle currency

1. Introduction

This paper investigates the choice of currency in international transactions by Swedish exporting firms. In a world of nominal rigidities, the currency in which prices are set partly determines the degree of exchange-rate pass-through. It therefore partly determines how consumers and firms are affected by exchange rate changes in the short run. For instance, if prices are fixed, and all exporting firms selling to a foreign market set prices in the importing country's currency, then the pass through would be zero. Since a change in the exchange rate would have little effect on the relative price of imported goods, the response of the real exchange rate would be large. The implications of this are examined in the new open economy macro literature. Engel (2002), shows that local currency pricing (setting price in the importers currency) may have large effects on exchange-rate policy.

[0] This paper has benefited from comments by Philippe Bacchetta, Charles Engel, Richard Friberg, Jonas Vlachos as well as two anonymous referees, seminar participants at the Stockholm School of Economics Lunch Workshop and at the seminar series at the Swedish Research Institute of Industrial Economics and the research department at the Swedish Central Bank. I gratefully acknowledge help from Anders Lindström and Magnus Svensson at the Swedish Central Bank in obtaining the data material and Solveig Westin at Statistics Sweden for help with data inquiries. I also thank Bankforskningsinstitutet for financial support.

Several stylized facts regarding the choice of currencies for invoicing have been observed. For trade in manufactured goods between industrialized countries, the exporter's currency has been the usual choice. This empirical regularity was first noted by Grassman (1973) in his study of invoicing patterns of Swedish firms, and hence this practice is often referred to as Grassman's Law. However, invoicing practices also differ between countries. Imports to the U.S. are typically invoiced in dollars, while Japanese exports are primarily invoiced in dollars rather than yen (Black, 1990). Furthermore McKinnon (1979) reports that exchange-traded and/or primary commodities, for instance oil, are usually priced in U.S. dollars. Finally, Tavlas (1991) reports that inflationary currencies are less likely to be used in foreign trade. However, beyond these observations, little empirical research on the specific mechanisms that give rise to certain currencies being used in international transactions has been conducted. Donnenfeld and Haug (2002, 2003) study the impact of exchange-rate volatility on the denomination of U.S. and Canadian imports respectively, and find a positive correlation between exchange rate volatility and local currency pricing. Goldberg and Tille (2005) derive and test a model of industry specific factors that could explain invoicing patterns. They confirm that the dollar is indeed the currency of choice in transactions with the U.S. as well as in other transactions in exchange traded and/or reference priced goods. They argue that the latter finding is largely attributable to industry herding behavior in currency choice and not to macroeconomic factors.

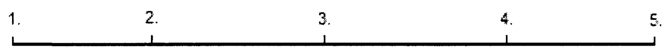
This paper contributes to the empirical literature on currency invoicing in several ways. It uses a unique and extensive micro data set on individual payment transactions between foreign importers and Swedish exporting firms. It is the first paper to examine currency invoicing at such a disaggregated level. It also extends the multinomial logit analysis by Donnenfeld and Haug to separate the effect of different vehicle currencies. Finally the dataset covers the period from 1999-2002 which marks the start of the single European currency, the euro. Given that Sweden did not join the European Monetary Union, our data provides us with answers regarding the role of the euro in trade outside the monetary union.

The paper is organized as follows. Section 2 briefly reviews some of the theoretical literature on currency invoicing, section 3 discusses the data, section 4 presents the empirical model and estimation results, section 5 discusses robustness and econometric issues and section 6 concludes.

2. Theoretical Foundations

To see what different roles a currency can play one can characterize a typical international transaction in the following way:

Figure 1: Time line of a typical international transaction.



1. Price is set in currency chosen by exporter.
2. Exchange rate is realized.
3. Foreign importers place their orders.
4. Exchange Rate is realized.
5. Payment is made.

The first step in the time line corresponds to the unit of account function of a currency. As producers determine in what currency prices should be set they do not know the future behavior of the exchange rate. After the exchange rate has been realized, foreign importers place their orders. The time in between the third and the fifth step corresponds to the store of value function of a currency. The final step in the international transaction is the payment made by the importer to the producer. This corresponds to the medium of exchange function of a currency. The problem for the exporter is to determine in what currency to price the company's products. The exporter can set a price denominated in its home currency, so called producer currency pricing (PCP). Another possibility is to set prices in the currency of the importer, commonly referred to as local currency pricing or LCP. A third possibility is to set price in a currency that is neither the domestic currency of the producer or the importer (sometimes denoted a vehicle currency).

We will now turn to a brief survey the theoretical literature on the currency denomination of exports. The survey will focus on the unit of account function of a currency, as it is the price setting behavior of firms that is emphasized in open economy macroeconomic literature. It will focus on the effects of exchange rate volatility, market size of the importing country as well as the role of currency unions. We will also briefly discuss the role of these variables in the theoretical literature on the medium of exchange function of a currency. Finally we will also consider some alternative explanations for the choice of currency denomination in international trade.

2.1. Exchange Rate Volatility. If prices cannot be updated continuously and without cost in response to exchange rate fluctuations, variability in the exchange-rate will have different effects on expected profits depending on which currency is chosen, as analyzed by Baron (1976), Donnenfeld and Zilcha (1991), Friberg (1998), Bacchetta and van Wincoop (2003) and Engel (2005). These papers show how the currency choice depends on the shape of the firm's profit function with respect to the exchange rate. Since the profit function is linear in the exchange rate under local currency pricing, if the profit function under PCP is globally convex (concave) in the exchange rate, then the exporter's (importer's) currency should be used.

At a first glance this clean result seems to give easily testable implications on the link between exchange rate volatility and the choice of currency. However, there are several caveats. First, the optimal invoicing choice does not depend on exchange rate volatility, although the gains from making the correct choice are greater the more volatile is the exchange rate. Second, whether the profit function under PCP is concave or convex depends on the functional forms of cost and demand[1].

In a recent paper, Engel (2005) solves for the optimal choice of export currency with preset prices. In the general model, the condition that pins down optimality of PCP is a complicated expression depending on the covariance of the exchange rate with several variables. However, assuming constant elasticity of demand, linear costs and that all costs are denominated in the exporter's currency, then it is possible to derive a condition for which optimality of PCP is directly linked to the variance of the exchange rate. PCP will be the preferred choice if the variance of the log exchange rate is high compared to the covariance between the local wage rate and the log exchange rate[2]. So for the set of firms for which costs and demand is as described above, greater exchange rate volatility lead to increased producer currency pricing. In general however, the effect is ambiguous[3].

2.2. The Role of Market Size. In the unit of account literature, Bacchetta and van Wincoop (2005) extends the classical partial equilibrium analysis of a single firm exporting to one foreign market, allowing the exporting country to have a large market share. The foreign market demand facing a firm is then, given the number of exporting

[1] For example, a linear demand function and linear or convex costs imply that the profit function under PCP is concave, while a constant elasticity demand function and linear costs result in the opposite. It is also possible, as pointed out by Bacchetta and van Wincoop (2005) that the profit function has both concave and convex parts.

[2] More specifically, PCP will be preferred if $\mathrm{Var}(\log S) > \frac{1}{2}\mathrm{Cov}(w,S)$ where S is the exchange rate and w is the local wage rate.

[3] Hartmann (1998) analyzes a different mechanism, related to the medium of exchange role of currencies. In a simple model of bid-ask spread he shows that the spread between a domestic dealers selling and buying rate is increasing in exchange rate volatility. Since the spread is assumed to be set symmetrically around the true equilibrium exchange rate, for a domestic exporter this would clearly favor PCP if volatility is high, since foreign currency payments can only be converted to domestic currency at a more unfavorable rate.

firms and the number of domestic firms in the importing country, a function of the price that the firm charges relative to the price index in the foreign market. The larger is the share of firms from the exporting country that sets price in the exporters' currency, the more will the foreign price index depend on the exchange rate. The result is then that the larger is the market share of the exporting country, the more likely is a marginal exporting firm to set price in its own currency[4]. The intuition is that the relative price of its goods will be less sensitive to exchange rate changes, thereby reducing demand uncertainty associated with PCP. An indirect way to test this would be to argue that this effect is more likely to be present when the importing country is relatively small, and even more likely in developing countries with little or no domestic production. A different way to test this strategic complementarity effect is to realize that the intuition carries over to the case of vehicle currency pricing. If a third country has a large market share, and firms from that country use PCP, then setting price in the third country's currency is more beneficial. This is also the result in Johnson and Pick (1997). In their model vehicle currency pricing is only beneficial if there is a competing exporter also using that currency.

2.3. The Effect of Currency Unions. Another interesting and testable theoretical result from Bacchetta and van Wincoop (2005) is the fact that when a number of countries form a monetary union, the new currency will be used more extensively in international transactions than the sum of the currencies it replaces. This applies both to imports and exports. The intuition for the case of exports to union member countries is that prior to the formation of a currency union, it is the exporter's market share in each of the countries forming the union that determines if the exporter's or importer's currency should be used. For example, a Swedish firm may set prices in krona when exporting to a smaller country such as Portugal, while setting price in the local currency when exporting to a larger country with a bigger domestic market, such as France. In the model, the concept of a country only means that the currencies differ. Hence, after the creation of a currency union, it is likely that the firm's market share in the enlarged single market is not sizeable enough for krona (PCP) to be the desired choice, and the firm may denominate all it's exports to the union in the union's currency, regardless of the individual size of countries. We would hence expect that

[4] Size of the importing country is an important factor also in the medium of exchange literature. Krugman (1984) argues that currencies of larger countries will be used, as firms from small countries are relatively more experienced in dealing with exchange rates. This line of reasoning was formalized in Matsuyama et. al (1993). They use a two country model of random matching in which two national currencies compete and find that an equilibrium in which one country's currency is accepted as medium of exchange by agents from the other country is only possible when the relative size of the other country is not to large.

local currency pricing to countries in a currency union, such as EMU-member states, is more prevalent other things equal.

2.4. Other explanations for the choice of invoicing currency. We have so far considered variation in invoicing patterns across destinations. One issue which we have not touched upon that may have implications for the currency denomination in trade is related to the store of value function of a currency. As noted in the introduction, Tavlas (1991) found that in countries with high inflation, the local currency is less likely to be used. One potential explanation for this is related to the store of value function of a currency. An exporter should be unwilling to set price and accept future payments in an inflationary currency, as it is such a poor store of value.

There are also important goods and industry specific factors to consider. One factor is the relative bargaining power of exporters and importers[5]. Another factor is product differentiation. Since exporters of differentiated goods usually have some degree of market power, they have the possibility of fixing the export price in their own currency. Firms selling homogenous goods are price takers which limits the scope for pricing to market[6] (McKinnon, 1979). Goldberg and Tille (2005) argue that this effect leads to herding behavior in industries selling homogenous products. The herding effect can be stronger than the impact of macroeconomic variables if the elasticity of substitution between products in an industry is sufficiently high. The implication is that invoicing patterns should differ substantially across industries.

One additional issue worth mentioning is the practice of matching cash inflows with outflows, so called operational hedging. A firm incurring large variable costs in a foreign currency, most likely due to imported intermediate goods, could be more tempted to invoice in that currency instead of its own. Thus one would expect to find a negative relationship between the degree of PCP and the degree of imported intermediate goods in an industry.

3. Data

The data set used in this paper is from the settlement reports from the Swedish Central Bank. All payments to Swedish firms through Swedish banks above a threshold

[5] One paper that analyzes this mechanism is Viaene and de Vries (1992). They develop a model of bargaining between importers and exporters in which the higher bargaining power of exporting companies leads to the dominance in invoicing in the exporter's currency.

[6] Engel (2005) discusses a related mechanism. Fixing local wages, prices of competing products and assuming that all costs are denominated in the exporter's currency and increasing in quantity, then PCP is more likely the lower is the demand elasticity. Hence, for a firm selling a homogenous good PCP would indeed be an inferior choice.

level are reported[7]. The data used here contain these observations from 1999 through 2002, for nine industries classified by SNI-code[8]. It shows the date of the transaction, from which country the payment came, the amount in Swedish krona, and in what currency payment was made. As noted above, the role of a currency in an international transaction takes the form first as a unit of account, but also as a store of value and medium of exchange. The data set here captures the medium of exchange role, in what currency the actual payment from the importer to the producer was made. However, with few known exceptions, the same currency is used in all parts of an international transaction.

The data set contains the following industries: apparel, chemicals, food, furniture, motor vehicles, optical and medical instruments, paper and pulp, telecommunications equipment and wood products[9].

All in all there are 147 countries represented although we will drop some due to unavailability of data. The econometric specification will include 69 countries. The countries for which data is missing represent however only a small fraction of the overall number of observations. Table A1 in Appendix A shows Swedish exports to major trading partners in 2002. There are roughly 188000 individual observations. Table 1 outlines the choice of export currency by Swedish firms.

[7] The threshold level was increased in 2000 from 75000 krona (about \$10000) to 100000 krona (\$13000) and once again in 2002 to 150000 krona (\$20000).

[8] SNI is the Swedish Industrial Classification System. On the two-digit level it is roughly equivalent to for instance NAIC, the North American Industrial Classification System.

[9] A handful of very large corporations are reported separately and are not included.

Table 1: Invoicing practices of Swedish firms during period 1999-2002.

Fraction of transactions to EMU member countries	1999	2000	2001	2002
PCP	40.65	39.27	37.72	34.40
LCP	49.85	49,71	51.54	54.45
VCP (dollar)	6.97	8.83	9.12	10.26
VCP (euro)	n/a	n/a	n/a	n/a
VCP (other)	2.54	2.18	1.62	0.89
Fraction of transactions to the U.S.	1999	2000	2001	2002
PCP	31.12	30.83	26.22	22.99
LCP	65.31	64.31	69.93	72.25
VCP (dollar)	n/a	n/a	n/a	n/a
VCP (euro)	2.25	3.75	2.22	3.51
VCP (other)	1.33	1.10	1.64	1.25
Fraction of transactions to rest of world (excluding U.S. & EMU countries)	1999	2000	2001	2002
PCP	42.39	39.51	36.06	33.72
LCP	17.31	17.03	16.73	17.03
VCP (dollar)	23.25	23.34	23.36	21.85
VCP (euro)	11.46	16.79	21.57	25.88
VCP (other)	5.59	3.34	2.28	1.51

It is interesting to note the diminishing use of Swedish krona[10]. This is true for exports to all different geographical regions, and although not revealed in Table 1, holds in each of the nine industries[11]. A second interesting finding is the increased use of the euro as a vehicle currency in trade with countries outside the European Monetary Union. Vehicle currency pricing in euro has more than doubled between 1999-2002. Table 1 also shows that the use of dollar in invoicing has not fallen. One conclusion is thus that for Sweden, the increased use of the euro has come at the expense of the krona, and not the dollar.

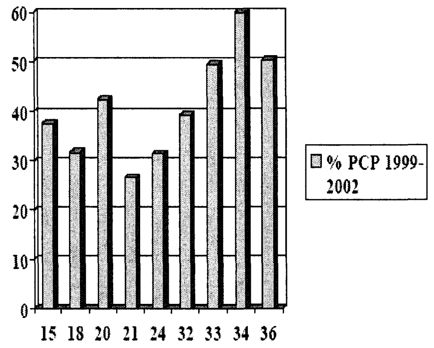
It is also interesting to note that the fraction of exports invoiced in krona differs substantially between industries. Figure 2 shows the fraction of exports invoiced in

[10] Compared to Grassman's findings in 1973 the fraction of PCP is now substantially lower, and continues to fall. The total amount of PCP is actually even lower than suggested by Table 1, as transactions in Swedish krona are on average smaller than transactions using the importer's currency. This was also the finding in Grassman (1973).

[11] This pattern is not due to increases in the threshold, as the same pattern over time is found also for observations where the value of the payment exceeds the highest threshold ($20000).

krona during the period 1999-2002.

Figure 2: Percentage of Exports Invoiced in Swedish Krona, per Industry



Note: Industries; 15: Food; 18: Apparel; 20: Wood Products;
21: Paper and Pulp; 24 Chemicals: 32 Telecom;
33: Optical/Precision and Medical Instruments; 34: Motor Vehicles; 36: Furniture

Motor vehicles, for example, had no less than 60% of its exports invoiced in krona, while the corresponding fraction for Pulp was only 26.5%. Judging from only nine industries it is difficult to draw any conclusions, but for these industries it seems as greater product differentiation can be associated with more PCP[12].

The issue of cash flow matching mentioned in section 2.4 is examined in Figure A1 in Appendix A. Using data from Statistics Sweden we regress the fraction of invoicing in Swedish krona on the degree of imported intermediate goods used in production on an industry basis. However, there seem to be no relationship in our data[13].

4. Estimation and Results

To test the predictions from the theoretical part, a multinomial logit model will be used. The discrete dependent choice variable captures the currency choice made by individual exporting firms. If the dependent variable is coded to take on the value 1, then for that observation the price is set in krona, 2 refers to price set in the importer's currency, 3 refers to dollar being used as vehicle currency and 4 refers to refers to any

[12] One classification of product differentiation is that of Rauch (1999). Rauch divides products into three categories: goods traded on an exchange (homogenous), reference priced, and differentiated. Using this classification on U.S. SITC codes, pulp falls under either homogenous or reference priced, while motor vehicles are differentiated goods.

[13] A least squares regression of the fraction of PCP on the value of imported intermediate goods used in production yields a weakly positive coefficient with a p-value exceeding .6.

other currency used as a vehicle currency. So for example, a payment in euro from Norway would be coded as 4, while a payment in euro from Germany would be coded as 2. Coding in this way exhausts the list of potential choices. Since data here is individual specific rather than choice specific, the model will take the following form

$$\Pr(Y_{it} = j) = \frac{e^{\beta_j \mathbf{x}_{it}}}{\sum_{k=1}^{4} e^{\beta_k \mathbf{x}_{it}}}, \; j = 1, 2, 3, 4. \tag{4.1}$$

The model is normalized by setting $\beta_1 = 0$, so PCP is chosen to be the base category, or comparison group. The vector X includes the independent variables and can be divided into two components

$$\boldsymbol{\beta}_j \mathbf{X}_{it} = \boldsymbol{\alpha\gamma} + \boldsymbol{\delta}\mathbf{x}_{it} \tag{4.2}$$

The subvector x includes variables that will be used to test the predictions from the theoretical literature. In order to test the effect of exchange rate volatility on currency denomination, the yearly variance of the exchange rate between Sweden and the country from which the payment came will be included. It is calculated as the variance of the difference of log weekly exchange rates[14]. In order to asses the importance of size of the import market we will include PPP-adjusted GDP (in billions of dollars) and GDP per capita (in thousands of dollars) from the World Development Indicators database. Moreover, the U.S./Swedish market share is included as an explanatory variable. It is calculated as the ratio of U.S. exports to Swedish exports to a given country for each industry and year, using data from U.S. International Trade Commission on U.S. Industry Exports by NAIC code. What we are interested in is if this variable affect the likelihood of Swedish companies invoicing in dollars. Given the inclusion of this variable, exports to the U.S. will not be included in the multinomial specification. Included in x are also macroeconomic variables in the importing country such as inflation, financial market efficiency (total value traded in stockmarket as a share of GDP) as well as the black market premium[15]. Inflation data is taken from International Financial Statistics while the variable proxying for financial market efficiency is from Demirguc-Kunt and Levine (2001).

The subvector γ includes distance (in thousands of kilometers) between Sweden and the importing country, a dummy variable indicating if the country is a member of the European Union and fixed effects. The fixed effects include year dummies and industry

[14] What we want to capture is the variance of unexpected innovations in the exchange rate. Since the log of exchange rate follows a random walk, this is a suitable measure.

[15] This variable is calculated as the spread between the official exchange rate and the rate in the black market. Data is from Wacziarg and Welsh (2003).

dummies. The year dummies are included since there is a trend in the data and the industry dummies because of the difference in invoicing patterns in different industries. This means that we are analyzing cross-country variation in invoicing patterns. Section 5 will discuss the sensitivity of the results to exclusion of fixed effects.

What is of primary interest is the marginal effects of the importing country's characteristics on the choice probabilities. Unlike a linear model, here the marginal effects of the independent variables on the dependent variables is not given by the β-vector. Differentiating (4.2) w.r.t. to X yield $P_j[\boldsymbol{\beta}_j - \sum_{k=1}^{5} P_k \boldsymbol{\beta}_k]$. So, the marginal effect of any specific characteristic on a choice probability need not have the same sign as the estimated coefficient. Both the estimated coefficients and marginal effects will be reported. In a second specification we will model the choice of local currency pricing against all other invoicing choices. Thus we will set $j = 2$ and obtain a regular logit model. In this specification we will include exports to the U.S. and instead remove the market share variable. We will also include a second dummy, taking the value of one if the country is a EMU-member. A positive and significant coefficient would provide evidence in favor of the theoretical predictions by Bacchetta and van Wincoop on the extensive use of local currency pricing to countries forming a monetary union.

Since the data includes many observations from each country, so that the explanatory variables are the same over many observations, the standard errors need to be adjusted. We form clusters, or groups, on the country level, and let the error term be correlated within a cluster. We still assume that observations are independent between groups.

The estimation results from the multinomial estimation are presented in Table 2.

Table 2: Multinomial Logit Model

Number of obs.	188597		
Pseudo R2	0.1277		
	LCP	VCP (dollar)	VCP (other)
Variables	Marginal Effects Coefficients	Marginal Effects Coefficients	Marginal Effects Coefficients
Blackmarket Premium	−.0006 −.0025 (.0035)	.0001 .0004 (.0002)*	.0001 .0004 (.0004)
Distance	.0049 .03869 (.0375)	.0079 .0945 (.0354)***	−.0020 .0027 (.0232)
European Union	.2411 .9266 (.3237)***	−.0986 −.6193 (.2299)***	−.0677 −.5379 (.4120)
Exchange Rate Volatility	−23.6584 −92.1784 (40.5726)**	6.4522 30.6721 (15.1143)**	5.8343 39.9320 (37.5865)
Financial Efficiency	−.0401 .1839 (.4185)	.0585 .8084 (.5976)	.1123 1.5623 (.4597)***
GDP[1]	.0004 .0023 (.0007)***	.0002 .0028 (.0010)***	−5.84e−05 .0005 (.0020)
GDP per Capita	.0179 .0696 (.0221)***	−.0071 −.0430 (.0160)***	−.0024 −.0073 (.0150)
Inflation[1]	−.0796 −.3325 (.2807)	−.0002 −.0111 (.0066)*	.0032 .0250 (.0047)***
US/Swedish Market share[2]	.0040 −6.48e−04 (8.90e−04)	.0018 .0041 (.0018)**	−.0109 −.1348 (.0999)
constant	n/a −2.8674 (.6931)	n/a −1.310 (.5949)	n/a −1.926 (.2859)

Notes: Clustered standard errors in parenthesis.

***, **, * denotes significance at the 1%, 5%, and 10% level respectively.

1 implies that Marginal Effects, Coefficients and Standard Errors Multiplied by 10

2 implies that Marginal Effects, Coefficients and Standard Errors Multiplied by 1000

The first thing to note is that increased exchange rate volatility leads to reduced probability of pricing in the importer's currency. As noted in section 2, the effect of exchange rate volatility on invoicing currency is ambiguous so it is not clear what result should be expected[16]. Donnenfeld and Haug (2002, 2003) find that the fraction of local currency pricing for Canadian and U.S. imports is positively related to their measure

[16] Note however that the result is consistent with the special case of exporters facing constant elasticity of demand and linear costs in Engel (2005).

of exchange rate volatility. One must however bear in mind that the U.S. constitutes a special case in terms of currency invoicing in that such a large fraction of exports and imports are denominated in dollars. The dominance of dollar invoicing to Canada is also extensive[17]. The finding in this paper indicates that a positive relationship between exchange rate volatility and local currency pricing will not hold for all countries.

A further finding related to exchange rate volatility is that high volatility of the krona against the currency of the importer may lead to substitution towards a vehicle currency, most notably the dollar.

Secondly, higher GDP and GDP per capita in the importing country increases the likelihood of the importer's currency being used, as predicted by both the medium of exchange and unit of account literature. Another interesting finding is the effect of a large U.S. to Swedish market share on the likelihood of Swedish exporters pricing in dollars. The effect is positive and statistically significant. This result, as argued above, provides indirect evidence for the strategic complementarity effect discussed by Bacchetta and van Wincoop (2005). Financial market efficiency seems not to affect the likelihood of choosing LCP over PCP, but may positively affect the likelihood of choosing a vehicle currency other than the dollar (perhaps surprisingly).

Finally we also perform a Wald test of the hypothesis that $\sum_j \beta_j = 0$ for $j = 3, 4$ where we test both the coefficients of the black market premium and inflation. We can reject the null hypothesis that the sum of the coefficients on black market premium for outcome 3 and 4 is zero at the 10% level while the corresponding test for the coefficients on inflation can be rejected at the 5%-level. This indicates that when exporting to countries with a high black market premium and high inflation, a vehicle currency may be used.

Table 3 displays the results from regular logit, probit and linear probability models where the choice set is restricted to local currency pricing versus all other choices. The dependent variable thus takes the value of one if the transaction was denominated in the importers currency and zero otherwise. In this specification the variables of interest are primarily GDP and GDP per capita, exchange rate volatility and the EMU dummy variable.

[17] In our sample, no less than 41% of the payment transactions from Canada were denominated in U.S dollars which, as can be seen from Table 1, is a much higher fraction than for exports to other countries.

Table 3: Binomial Models. Choice set restricted to LCP versus all other currencies.

	Logit	Probit	Linear Model
Number of obs.	196801	196801	196801
Pseudo R2	.1619	.1640	.3208

Variables	Marginal Effects Coefficients	Marginal Effects Coefficients	LS-Coefficients Standard Errors
Blackmarket Premium	−.0004 −.0019 (.0019)	−.0003 −.0007 (.0006)	.0001 .0001
Distance	.0002 .0011 (.0463)	.0011 .0029 (.0254)	−.0040 .0081
EMU	.1541 .6674 (.1118)***	.1523 .4041 (.0654)***	.1409 .0396***
European Union	.1349 .5989 (.3041)*	.1325 .3579 (.1786)*	.0408 .0488
Exchange Rate Volatility	−10.1873 −44.2272 (30.4476)	−10.8284 −28.7522 (18.2729)	−7.311 4.037*
Financial Efficiency	−.0474 −.2057 (.4775)	−.0489 −.1298 (.2878)	−.1223 .1129
GDP[1]	.001 .004 (.0010)***	.001 .002 (.0004)***	.001 .0002***
GDP per Capita	.0234 .1017 (.0241)***	.0222 .0588 (.0125)***	.0154 .0028***
Inflation	−.0021 −.0093 (.0207)	−.0019 −.0052 (.0097)	.0010 .0013
constant	n/a −3.2284 (.7703)	n/a −1.8846 (.4042)	.0154 .0853

Notes: Clustered standard errors. In parenthesis for logit and probit models.
***, **, * denotes significance at the 1%, 5%, and 10% level respectively.

1 implies that Marginal Effects, Coefficients and Standard Errors Multiplied by 10

Here the marginal effects from the logit and probit estimations should be compared to the coefficients from the linear regression, since these are obviously also the marginal effects. In all three specifications the marginal effects of GDP and GDP per capita are positive, as predicted. The marginal effects of an increase in the variance of the exchange rate are negative, but only statistically significant in the linear regression. The reason for this is most likely the included EMU-dummy[18]. The effect of a change in zero to one for the EMU dummy is positive and statistically significant. Since we control for other factors influencing the choice of invoicing currency, this indicates that local currency pricing is more prevalent to countries that belong to a monetary union. Note that this effect is robust to the inclusion of a dummy variable indicating that a country is a member of the European Union. The coefficients on the remaining variables differ somewhat depending on specification, but none of those coefficients are significantly different from zero in any specification.

To summarize, we find that exchange rate volatility leads to reduced local currency pricing in all specifications. We also find that, higher GDP and GDP per capita leads to increased local currency pricing while a high black market premium and inflation instead lead to invoicing in a vehicle currency. Moreover we find that if a third country has a large market share, vehicle currency pricing in that country's currency becomes more attractive. Finally, in the regular logit model we test if local currency pricing is more prevalent to countries in a monetary union and we find that this is indeed the case.

5. Robustness

This section discusses the sensitivity of the reported results to changes in specification, as well as some econometric problems associated with the use of the multinomial logit model.

As mentioned in section 4, in order to study the variation in currency denomination across destinations it is important that the econometric specification includes both industry fixed effects and year fixed effects. It is nonetheless of interest to examine the sensitivity of the reported results to pooling the data. Since there is a trend in the dependent variable over time, as well as large disparities in invoicing patterns across industries, the explanatory power of the model should decrease when we remove the fixed effects that capture this variation. This is also the case, especially when removing industry fixed effects. For the multinomial specification, the signs of coefficients and marginal effects on all variables that were significant in the baseline specification are

[18] The estimated variance of the euro is among the lowest for all four years, while at the same time local currency pricing is prevalent to countries within the EMU. Hence, the EMU-dummy is likely to capture some of the effects of exchange rate volatility on local currency pricing.

however unchanged, although there are some changes in associated p-values. Removing year fixed effects imply that the p-value for the coefficient on exchange rate volatility corresponding to local currency pricing increases from .023 to .138. Also the positive effect of black market premium and inflation on the use of a vehicle currency is not significant. Otherwise the results are unchanged. Dropping the industry dummies have no effect on the sign of coefficients and marginal effects, but the coefficient on GDP for local currency pricing is no longer statistically significant, and neither is the effect of a large U.S. market share on the likelihood of invoicing in dollars, although the p-value is still .157. That the latter result holds conditional on inclusion of industry fixed effects seems reasonable given the large differences in invoicing patterns across industries. A final difference is that the negative coefficient on inflation for local currency pricing is now statistically significant. Otherwise the results are unchanged compared to the baseline specification. For the binary choice models all results reported in section 4 were robust to the exclusion of fixed effects, as well as to the exclusion of U.S. exports.

It can also be of interest to examine if results are sensitive to the way certain variables are calculated. We therefore replace the estimate of exchange rate volatility with a measure of the variance of monthly instead of weekly spot rates, more specifically the coefficient of variation of monthly spot rates. This makes no difference, the marginal effect of volatility on local currency pricing is still negative, while the effect on vehicle currency pricing is positive. Another variable with many possible definitions is financial market efficiency. In the baseline specification it is calculated as the total value traded on the stock market in the importing country, divided by the GDP of the importing country. We replace it with a measure of the overall size of financial markets (deposit money bank assets and stock market capitalization as a share of GDP) as well as private credit to GDP. In the first case results are unchanged relative to the baseline specification, while for private credit to GDP the results are somewhat changed as the likelihood of local currency pricing increases significantly when private credit to GDP increases. However, private credit to GDP may not be a good measure of the efficiency of financial markets and in general we cannot say that there are any effects of this variable on the likelihood of local currency pricing.

One final issue concerns the assumption of independently distributed error term in the multinomial model, often referred to as the assumption of independence of irrelevant alternatives (IIA). This means that the odds ratios, or relative probabilities, are assumed to be independent of other alternatives. This assumption is possible to test using tests developed by Hausman and McFadden (1984) and Small and Hsiao (1985). We use both tests and find that the test by Hausman and McFadden fail to reject the null hypothesis of independence, while the Small and Hsiao test do reject the null.

Greene (2000) argues that when the assumption of independence fails, an alternative to the multinomial model is needed. He suggests a multivariate probit estimation instead. Appendix B discusses the multivariate probit model as well as estimation results. In general the results are very similar to the multinomial model and hence we conclude that the estimates from the multinomial model are valid.

6. Concluding Remarks

This paper has examined the currency denomination in international trade by modeling the firm's choice of export currency as a multinomial logit model. The main findings are that high exchange rate volatility reduces the likelihood of local currency pricing while high GDP and GDP per capita increases it. A large market share of a competing third country (here the U.S.) increases the likelihood of using that country's currency. In some specifications there is also a statistically significant negative relationship between inflation in the importing country and reduced likelihood of local currency pricing on the one hand, and increased vehicle currency pricing on the other hand. A further finding is that the use of Swedish krona is falling across all industries while there at the same time has been an increase in vehicle currency pricing in euro. The use of the euro in transactions involving non EMU members has roughly doubled between 1999-2002.

The negative effect of exchange rate volatility on local currency pricing found in this study contrasts previous empirical work by Donnenfeld and Haug (2002, 2003) who found that exchange rate volatility increases the likelihood of local currency pricing. This difference should perhaps not be surprising. The dataset employed in this study covers 69 countries, both developing and industrialized. The samples in Donnenfeld and Haug are restricted to include only 16 highly industrialized countries and also focus on imports to Canada and the U.S. for which there is a strong dominance of dollar invoicing. The results in this paper indicate that one should be careful to extrapolate the positive correlation between local currency pricing and exchange rate volatility found in earlier studies.

The result found in this study that higher GDP in the importing country increases the likelihood of local currency pricing is however consistent with the finding in Donnenfeld and Haug (2003) that higher GDP in the exporting country increases the likelihood of producer currency pricing. This is also the prediction by both the medium of exchange literature and unit of account literature.

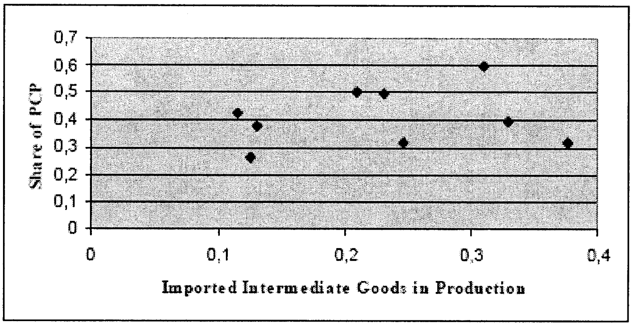
Finally, both the increased likelihood of local currency pricing when exporting to countries in a currency union, and the increased likelihood of invoicing in a vehicle currency when other competitors with a large market share do so as well, are consistent with the theoretical predictions by Bacchetta and van Wincoop (2005).

7. Appendix A

Table A1: Major Swedish Export Destinations

Position 2002	Country	% Share (of total exports)
1	U.S.A	11.5
2	Germany	10.1
3	Norway	8.8
4	Great Britain	8.2
5	Denmark	6.2
6	Finland	5.8
7	Netherlands	5.3
8	France	5.1
9	Belgium	4.7
10	Italy	3.5
Source:	Swedish Trade Council	

Figure A1: Relation between Imported Inputs and Share of PCP



Source: Statistics Sweden

8. Appendix B

When the assumption of independence of irrelevant alternatives fails, Greene (2000) argues that an alternative to the multinomial logit model needs to be specified. He suggests a multivariate probit model. Using a simulated maximum likelihood approach[19] we estimate three equations simultaneously, and allow for correlated error terms between equations. Formally the multivariate model takes the following form

$$\begin{aligned} y_1 &= \beta_1 X + \epsilon_1 \text{ with } y_1 = 1 \text{ for LCP, 0 otherwise} \\ y_2 &= \beta_2 X + \epsilon_2 \text{ with } y_1 = 1 \text{ for VCP in dollars, 0 otherwise} \\ y_3 &= \beta_3 X + \epsilon_3 \text{ with } y_1 = 1 \text{ for VCP other, 0 otherwise} \end{aligned}$$

Moreover, ϵ is multivariate normal with zero expected value and variance one, and with correlation across equations equal to ρ. X is the vector of explanatory variables that are the same for each equation (although this is not necessary) and is similar to the multinomial specification. Year and industry fixed effects are included. Note that the specification of choices is not identical to the multinomial logit model were the base category is producer currency pricing, here the base category in each equation refers to all outcomes except the one for which $y = 1$. Hence a direct comparison with the m-logit model is not appropriate, but for certain variables we nonetheless expect a similar result. We still expect exchange rate volatility to negatively affect the likelihood of local currency pricing, and GDP and GDP per capita to have a positive effect. We still expect that the likelihood of using the dollar as a vehicle currency is increasing in U.S. to Swedish market share. For the variables inflation and black market premium it is difficult to compare given the specification of the dependent variable. Table B1 below reports the estimated coefficients from the multivariate probit model. The marginal effects for this model is not possible to estimate, but given that each equation is an ordinary probit the marginal effect will always have the same sign as the estimated coefficient. However, we cannot make any quantitative interpretations.

The main results remain unchanged also in the multivariate probit case. Specifically, exchange rate volatility reduces the likelihood of choosing LCP, while GDP and GDP per capita increase it. The effect of inflation is negative and but only weakly significant with a p-value of .10 for a double sided test. The probability of invoicing in dollars is increasing in the U.S. to Swedish market share and it is also more likely if the bilateral

[19] The Stata program for estimation of multivariate probit models using simulated maximum likelihood is written by Lorenzo Cappelari and Stephen P. Jenkins, Institute for Social and Economic Research, University of Essex.

exchange rate between Sweden and the importing country is volatile (this effect is also only weakly significant with p-value of .10). Vehicle currency pricing in any currency but the dollar is the preferred choice if inflation in the importing country is high and the financial markets are well developed.

Table B1: Multivariate Probit estimation with simulated maximum likelihood.

Number of obs.	188597		
	Equation 1	Equation 2	Equation 3
Variables	Coefficients Standard Errors	Coefficients Standard Errors	Coefficients Standard Errors
Blackmarket Premium	-.0008 .0011	.0001 .0001	.0001 .0003
European Union	.6845 .1985***	-.4245 .1526***	-.3544 .1952**
Exchange Rate Volatility	-37.7854 13.79636***	10.5423 5.3357**	29.7256 25.3965
Distance	.0030 .0230	.0592 .0256**	-.0194 .0138
Financial Efficiency	-.1842 .3135	.1996 .3152	.7855 .2726***
GDP[1]	.0011 .0005**	.0008 .0005*	-.0006 .0010
GDP per Capita	.0486 .0109***	-.0331 .0092***	-.0034 .0078
Inflation	-.0158 .0095*	-.0106 .0039***	.0174 .0028***
U.S/Swedish market share[2]	.0012 .0043	.0149 .0086*	-.1840 .1460
constant	-1.5525 .3272	-1.0379 .2905	-1.2836 .2000

Note: Standard errors clustered on country.

***, **, * denotes significance at the 1%, 5%, and 10% level respectively.

1 implies that Marginal Effects, Coefficients and Standard Errors Multiplied by 10

2 implies that Marginal Effects, Coefficients and Standard Errors Multiplied by 10000

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PAPER 2

State Dependent Pricing, Invoicing Currency, and Exchange Rate Pass-Through

Martin Flodén and Fredrik Wilander

ABSTRACT. We analyze exchange rate pass-through and volatility of import prices in a dynamic framework where firms are subject to menu costs and decide on price adjustments in response to exchange rate innovations. The exchange rate pass-through and import price volatility then depend on the invoicing currency in combination with functional forms of cost and demand functions. In particular, there is lower pass-through, less frequent price adjustments, and lower price volatility when prices are set in the importer's currency than when prices are set in the exporter's currency.

1. Introduction

In a recent speech to the Congress the Federal Reserve chairman, Alan Greenspan, noted that the fall of the dollar during the latter part of 2003 has had little effect on prices of imported goods and services, as "foreign exporters have been willing to absorb some of the price decline measured in their own currencies and the consequent squeeze on profit margins it entails". Abundant empirical research indeed demonstrates that exchange rate pass-through to import prices is less than unity.[1] In particular this seems to be the case for the U.S. where import prices are to a large extent insulated from movements in the dollar versus the currencies of many of its major trading partners. In spite of extensive theoretical research, the determinants of exchange rate pass-through remain unclear.

Spurred by the dollar appreciation in the late 1970's and early 1980's, a large body of theoretical work analyzed exchange rate pass-through and pricing to market, i.e.

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[1] See for instance Goldberg and Knetter (1997) and Goldberg and Verboven (2001). Engel and Rogers (1996) and Parsley and Wei (2001) examine pass-through to consumer prices.

failure of import prices to fully respond to changes in exchange rates.[2] These models are characterized by imperfect competition in a flexible price setting. The degree of pass-through is then determined by functional forms of cost and demand functions as well as the form of competition.

Another strand of the literature introduces nominal price stickiness and considers the short run response of import prices to exchange rate fluctuations. When firms do not instantaneously adjust prices in response to fluctuating exchange rates the choice of currency in which to price exports becomes important. The exporting firm can set prices either in its domestic currency (Producer Currency Pricing or PCP) or in the currency of the importer (Local Currency Pricing or LCP), and these models imply that there is either zero (LCP) or complete (PCP) pass-through.[3]

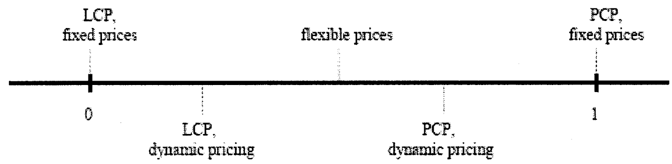
In the present paper, we provide a link between these short run and long run analyses by specifying a dynamic framework with endogenous pricing decisions. More specifically, we consider the pricing strategies of firms that produce in a home country, sell on a foreign market, and can change the price in response to exchange rate fluctuations, while being subject to menu costs. The degree of pass-through is then endogenous and depends on (i) the invoicing convention (LCP or PCP), (ii) the size of menu costs in relation to the costs of using suboptimal prices (since this determines how often firms update prices), and (iii) the frictionless degree of pass-through (since this determines how much prices are changed when firms choose to update prices). Typically, our dynamic setting generates a degree of pass-through between that implied by fixed-price and flexible-price models, as is illustrated in Figure 1.[4]

[2] Early contributions include Krugman (1987) and Dornbusch (1987).

[3] The sticky-price literature either analyzes the optimal choice of export currency in a partial equilibrium framework such as Baron (1976), Donnenfeldt and Zilcha (1991), Friberg (1998) and Bacchetta and van Wincoop (2002), or takes the choice of currency as exogenous and explores the consequenses of this choice in general equilibrium macro models such as Obstfeld and Rogoff (2000) and Chari, Kehoe and McGrattan (2002).

[4] In the presence of inflation or other factors that imply asymmetric pricing rules, it is however possible that pass-through under LCP exceeds the flexible-price pass-through. We demonstrate this below.

Figure 1: Degree of Pass-Through Implied by Different Pricing Assumptions



Our main finding is that when LCP is favored to PCP, the exporter changes prices less frequently under LCP than under PCP. This results in limited pass-through and a low correlation between exchange rate movements and import prices. While eventually exchange rate pass-through may be determined by factors other than nominal rigidities, our model explains why extensive local currency pricing implies lower volatility of imported goods prices also in the medium run.

We further analyze the impact of large versus small innovations in the exchange rate. Since larger fluctuations in the exchange rate raise the opportunity cost of holding prices fixed, firms update prices more frequently. Under LCP we therefore find that pass-through is larger for large exchange rate innovations while for PCP, the degree of pass-through is smaller for large fluctuations. Our model also generates asymmetric responses to appreciations and depreciations, especially in the presence of inflation. Since periods of high inflation imply that firms would adjust prices upward even in the absence of fluctuating exchange rates, under LCP they are more likely to keep prices fixed in the case of a depreciation. Under PCP, given a depreciation, firms are unwilling to allow prices to fall by the full amount and quickly adjust prices upwards. In both cases, a depreciation of the exporters' currency leads to lower pass-through than an appreciation.

Our findings have potential to shed light on a number of issues in open economy macroeconomics. For instance, Obstfeld and Rogoff (2000) argue that the literature assuming LCP and pricing-to-market is hard to reconcile with empirical evidence, and one of their arguments is that although pass-through is estimated to be less than unity, it is higher than zero. According to our analysis, any degree of pass-through in the interval between zero and unity is consistent both with LCP and PCP. This is also the case in Devereux et al. (2004). Although pass-through is implicitly restricted to be either zero or unity for any particular firm in their model, the average pass-through is in the unit interval since firms endogenously choose the invoicing currency.

Moreover, the low correlation between exchange rates and import prices under LCP estimated in our model can explain the recent failure of U.S. import prices to change significantly in response to the falling value of the dollar also over longer time horizons.[5] Finally, several empirical studies have examined asymmetric responses to depreciations and appreciations without finding a clear result. We point out that the average pass-through must be identical for depreciations and appreciations in a stationary world, but we demonstrate that the frequency and magnitude of price responses can differ. Such asymmetric responses may result in non-linear relations between pass-through and the sign and magnitude of exchange rate fluctuations. It is therefore important that the econometric model is carefully specified, and we demonstrate that typical regressions can result in biased estimates of the pass-through. In the presence of inflation, prices are not stationary and pass-through may differ for depreciations and appreciations. We demonstrate that pass-through then is higher after appreciations than after depreciation.

In a recent paper, Ran (2004) analyzes pass-through in a framework similar to ours but with quadratic adjustment costs for prices and a constant exchange rate. Assuming linear demand and constant marginal cost, he finds that the degree of pass-through to surprise exchange rate shocks depends on the current price relative to the steady state price, and on the pricing convention. The quadratic adjustment costs induce firms to change prices continuously and always by a small amount, which is not consistent with real-world pricing behavior (Blinder, 1994). Moreover, since the exchange rate process is not explicitly modelled, the scope for an analysis similar to ours is limited.

We now turn to describe the model. Then, in Section 3 we summarize the analysis from the static pass-through literature and discuss how it relates to our dynamic setting. In Section 4 we use artificial data generated by the model to examine how pass-through is affected by the choice of invoicing currency. Finally, Section 5 concludes.

2. The Model

We consider the pricing strategies of an exporting firm that produces in its home country and only sells in a foreign country. Define p and p^E as the export price in the foreign currency and in the exporter's currency, respectively. Let s denote the nominal exchange rate (home currency units per foreign currency unit) so that $p^E = sp$. The firm's invoicing currency is exogenous. Under LCP, the firm sets the price in the foreign currency, while it sets the price in domestic currency under PCP. Furthermore, let $\bar{p}$

[5] LCP is particularly common in the United States. According to Bekx (1998), 80 percent of U.S. imports are priced in dollars, while the fraction of imports priced in local currency is around 40 percent in other large developed countries. For a survey of the currency denomination in international trade, see Hartmann (1998).

and $\bar{p}^E$ denote the average price levels in the foreign and home countries, let π and π^E denote the (constant) inflation rates, and define the normalized prices $\hat{p}^E = p^E/\bar{p}^E$ and $\hat{p} = p/\bar{p}$. The real cost of producing quantity x is $C(x)$, and foreign demand is given by $D(\hat{p})$. The real profit function is then

$$\Pi(q,\hat{p}) = q\hat{p}D(\hat{p}) - C(D(\hat{p}))$$

where $q = s\bar{p}/\bar{p}^E$ is the real exchange rate.

We assume that the real exchange rate follows some stationary Markov process. In the beginning of each period, the firm observes the exchange rate and decides whether to keep the price from the previous period or to pay a menu cost ξ to change its price. The firm's problem is then to solve

$$V(q,\hat{p}) = \max\left\{V^k(q,\hat{p}), V^c(q)\right\}. \tag{2.1}$$

where $V(q,\hat{p})$ is the firm's value in the beginning of a period if the real exchange rate is q and if the firm's relative price is $\hat{p}$ unless a new price is chosen, V^k is the value of keeping the price from the previous period, and V^c is the value if a new price is set. Let β denote the discount factor, and define an inflation and exchange rate adjustment factor as[6]

$$\zeta' = \begin{cases} \frac{1}{1+\pi} & \text{under LCP} \\ \frac{q}{q'(1+\pi^E)} & \text{under PCP} \end{cases}.$$

The value of keeping the price is then

$$V^k(q,\hat{p}) = \Pi(q,\hat{p}) + \beta \mathrm{E}V(q',\zeta'\hat{p})$$

while the value of choosing a new optimal price is

$$V^c(q) = \max_{\hat{p}} \Pi(q,\hat{p}) - \xi + \beta \mathrm{E}V(q',\zeta'\hat{p}).$$

The solution to this problem is characterized by the value functions together with three policy functions, $P(q)$, $\underline{P}(q)$, and $\overline{P}(q)$. The firm will change the price if $\hat{p}$ deviates sufficiently from the optimal price. $\underline{P}(q)$ and $\overline{P}(q)$ denote the lower and upper bound of the firm's region of inaction so that the firm chooses to keep the price as long as $\hat{p} \in \left[\underline{P}(q), \overline{P}(q)\right]$. If the price is outside of this region, the firm will choose a new price according to the optimal pricing rule $P(q) = \arg\max_{\hat{p}} \Pi(q,\hat{p}) - \xi + \beta EV(q',\zeta'\hat{p})$. The solution algorithm is described in the appendix.

[6] The normalized foreign-currency price $\hat{p}$ may change even in the absence of active pricing decisions. These changes are captured by ζ.

2.1. Functional Forms and Parameter Values. One time period is one quarter and we set $\beta = 0.98$. We assume that the cost and demand functions are $C(y) = y^{\alpha}$ and $D(p) = \theta p^{-\mu}$. As a baseline calibration of the demand function we set $\theta = 20$ and the price-elasticity to $\mu = 4$. In the cost function, we consider three specifications for the convexity, $\alpha = 1.10$, $\alpha = 1.25$, and $\alpha = 1.50$.[7] The firm's cost of adjusting the price is assumed to be the same under LCP and PPP, although one could argue that these costs are different in nature. We choose the adjustment cost ξ so that 25 percent of firms change prices every quarter under LCP when $\alpha = 1.25$. This frequency of price updates is in line with Bils and Klenow (2004), who report that half of goods display a price that lasts for 5.5 months or less. The resulting menu cost is $\xi = 0.031$ which implies that average adjustment costs are 0.24 percent of average revenue.[8] In the baseline specification, we ignore inflation and set $\pi^E = \pi = 0$, and $\bar{p}^E = \bar{p} = 1$.

The log real exchange rate is assumed to follow an AR(1) process,

$$\log(q_{t+1}) = \rho \log(q_t) + \varepsilon_{t+1},$$

where $\varepsilon \sim N(0, \sigma^2)$. Based on estimates in Chari et al. (2002), we set the persistence to $\rho = 0.83$ and the standard deviation to $\sigma = 0.075$.

3. Static Frameworks

Before analyzing the full dynamic model, we relate our model to the existing literature that examines pass-through in static settings. We ignore inflation in this section and therefore use the notation $s = q$ and $p = \hat{p}$.

3.1. Flexible Prices. If prices are fully flexible ($\xi = 0$) our model reduces to a static maximization problem as portrayed in Feenstra (1989) and Friberg (1998). The firm chooses the price p to solve

$$\max_{p} \; spD(p) - C(D(p))$$

Under certainty and letting $s^* \equiv \frac{1}{s}$ the solution to this problem can be characterized as the familiar mark-up relation

$$p = s^* C_D \left(1 - \frac{1}{\mu}\right)^{-1}$$

[7] If the capital stock is fixed and production is $y = h^{1/\alpha}$, then $1/\alpha$ is the labor share in production and $\alpha = 1.5$ is in line with typical values. If the capital stock can be varied, lower values of α are realistic.

[8] Dutta et al. (1999) found that adjustment costs constitute 0.5 percent of revenue.

where μ is the price elasticity of demand. By totally differentiating the above expression and rearranging, we obtain the degree of exchange rate pass-through (the price change in percent due to a one percentage change in the exchange rate) as

$$\varepsilon_{p(s)} = \frac{dp}{ds^*}\frac{s^*}{p} = \left[\varepsilon_{MC(D)} + \varepsilon_{MR(p)}\right]^{-1} \tag{3.1}$$

where $\varepsilon_{MC(D)}$ is the elasticity of marginal cost with respect to output and $\varepsilon_{MR(p)}$ is the elasticity of marginal revenue with respect to the price. With the functional forms specified in Section (2.1), expression (3.1) implies that $\varepsilon_{p(s)} = [\mu(\alpha - 1) + 1]^{-1}$. This shows that there is less than full pass-through as long as the marginal cost is increasing. We also see that there is less pass-through if the cost function is more convex or if demand is more convex.[9]

3.2. Choice of Export Currency with Fixed Prices. In the setting above, the choice of invoicing currency is irrelevant since prices can be optimally adjusted. But if prices must be fixed in advance of the realization of s, this is obviously not the case. If firms use PCP, as s changes, so does the import price which causes shifts in demand, and hence profits. If firms use LCP, changes in the exchange rate do not lead to demand shifts but to changes in cash flows from sales. Using the same notation as above, the profit functions corresponding to LCP and PCP are

$$\Pi^{LCP} = spD(p) - C(D(p)) \tag{3.2}$$

and

$$\Pi^{PCP} = p^E D(\frac{p^E}{s}) - C(D(\frac{p^E}{s})). \tag{3.3}$$

Note that the profit function under LCP is linear in the exchange rate. So pricing in the importer's currency yields the highest expected profits if the profit function corresponding to PCP is concave in the exchange rate, i.e. if the second derivative of Π^{PCP} with respect to s is negative.[10]

Bacchetta and van Wincoop (2003) and Engel (2005) show that if the cost and demand functions are as specified in Section (2.1), then LCP will be preferred to PCP if $\mu(\alpha - 1) > 1$, and PCP will be preferred otherwise. Bacchetta and van Wincoop

[9] According to Friberg (1998), a sufficient condition for pass-through to be less than 100 percent is that demand is not too convex when marginal costs are constant. As our example demonstrates, with the specific functional forms considered here, increased convexity of demand reduces pass-through if costs are convex. It is the interaction term between convexity of demand and costs, $\mu(\alpha - 1)$, that determines pass-through.

[10] Our argument is a little simplified since firms typically do not fix the price at the certainty-equivalent level. See Friberg (1998) for a proof.

provide the intuition for this result. PCP implies that prices and hence demand fluctuates. If demand is convex, these fluctuations raise average demand. If marginal cost was constant this would raise profits and would favor PCP over LCP. However, fluctuating demand implies frequent contractions and expansions of output, which raises average costs if the cost schedule is convex. This mechanism favors LCP over PCP, and will dominate as long as costs increase sufficiently quickly when firms expand output.

3.3. Pre-Set but Adjustable Prices. Friberg (1998) and Engel (2005) show that the mechanisms generating low pass-through under flexible prices also raise the attractiveness of local currency pricing relative to producer currency pricing when prices are fixed. The intuition is that both limited exchange rate pass-through and LCP allow exporters to limit demand fluctuations by stabilizing local-currency prices. Demand fluctuations raise profits if demand is sufficiently convex relative to the convexity of costs, but reduce profits if costs are relatively convex and producers commit to meet demand. This establishes a link between the flexible-price and fixed-price literatures; when we see little pass-through in the flexible-price literature, we see zero pass-through in the fixed-price literature.

Not surprisingly, the convexity of demand and cost functions have similar effects on pass-through also in our setting with pre-set but adjustable prices. Let $\Pi^*(s) = \max_p \Pi(s,p)$ denote the current-period profits at the exchange rate s when prices are flexible, and let $L(s,p) = \Pi^*(s) - \Pi(s,p)$ denote the loss of charging the price p rather than the profit-maximizing price. Firms will adjust the price after seeing s if $L(s,p)$ is large relative to the adjustment cost. Bacchetta and van Wincoop (2003) show that[11]

$$\mathrm{E}_{t-1}\left[\Pi^{LCP}\left(s_t, p_{t-1}^*\right) - \Pi^{PCP}\left(s_t, p_{t-1}^*\right)\right] \left\{ \begin{array}{ll} < 0 & \text{if } \mu(\alpha-1) < 1 \\ > 0 & \text{if } \mu(\alpha-1) > 1 \end{array} \right.$$

where $p_{t-1}^* = \arg\max_p \Pi(s_{t-1}, p)$. Since the flexible-price profit Π^* is independent of the invoicing currency, we get

$$\begin{aligned} & \mathrm{E}_{t-1}\left[L^{LCP}\left(s_t, p_{t-1}^*\right) - L^{PCP}\left(s_t, p_{t-1}^*\right)\right] \\ = \; & \mathrm{E}_{t-1}\left[\Pi^{PCP}\left(s_t, p_{t-1}^*\right) - \Pi^{LCP}\left(s_t, p_{t-1}^*\right)\right]. \end{aligned}$$

We then see that

$$\mathrm{E}_{t-1}\left[L^{LCP}\left(s_t, p_{t-1}^*\right) - L^{PCP}\left(s_t, p_{t-1}^*\right)\right] \left\{ \begin{array}{ll} > 0 & \text{if } \mu(\alpha-1) < 1 \\ < 0 & \text{if } \mu(\alpha-1) > 1 \end{array} \right. ,$$

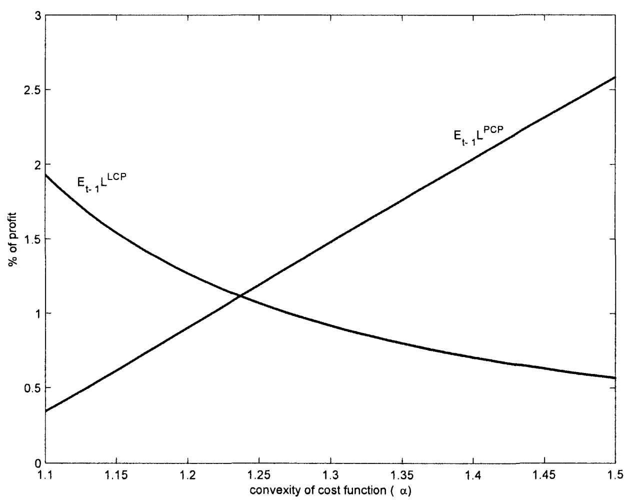
i.e. that the expected loss of not updating the price is lower under LCP than under PCP if the cost function and/or the demand function is sufficiently convex. In deciding upon the frequency with which to update prices, a firm trades off the marginal benefit

[11] This result holds locally for small variances of the exchange rate.

of more frequent price adjustments to the marginal cost of changing prices more often. Since the adjustment cost is the same under LCP and PCP, firms adjust prices more frequently under LCP than under PCP if $\mu(\alpha - 1) < 1$, and they adjust prices less frequently under LCP if $\mu(\alpha - 1) > 1$.

Figure 2 plots the expected loss under LCP and PCP, using the parameterization from section 2.1 and assuming that $\log s_{t-1} = 0$. The figure shows how the incentives to update prices depend on the convexity of the cost function. Under LCP, the loss of holding prices constant falls from 2 percent of profits when $\alpha = 1.10$ to just above 0.5 percent when $\alpha = 1.50$. Under PCP, the loss of holding price constant increases with α. The figure also confirms the theoretical result that the loss under LCP and PCP are approximately equal when $\alpha = 1.25$

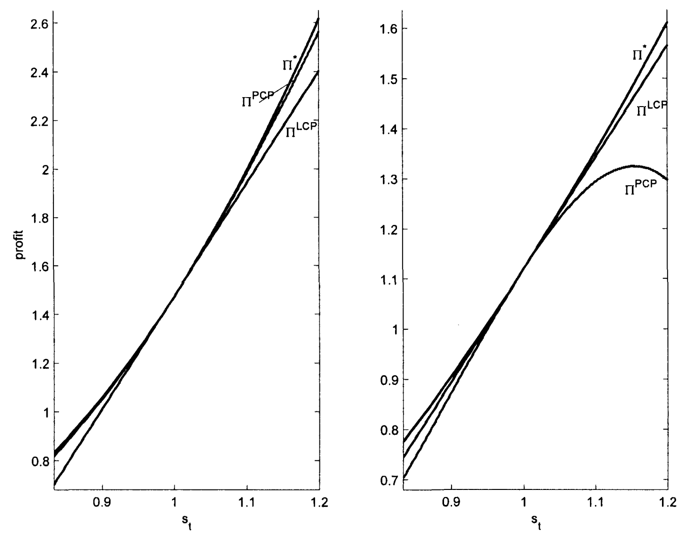
Figure 2: Expected Loss and the Convexity of Costs



Note: The figure shows the expected loss (relative to profits at $s_t = 1$) of not adjusting the price when the price is pre-set at $p = P^*(1)$.

To illustrate the intuition behind these results, Figure 3 plots $\Pi\left(s_t, p^*_{t-1}\right)$ for different realizations of s_t. Note that profits with fixed prices under PCP do not deviate much from profits under flexible prices when α is low, but the foregone profit under LCP is substantial if the exchange rate fluctuates. When the cost function is very convex, i.e. when α is high, the opposite results hold.

Figure 3: Loss as a Function of Realized Exchange Rate



Note: The figure shows profits as a function of the exchange rate when the price is flexible (Π^*), and when the price is pre-set at the price that maximizes profits at $s_t = 1$ (Π^{LCP} and Π^{PCP}).

If the cost function is convex as in the right panel in Figure 3, firms will prefer to follow an LCP strategy and they will change prices infrequently. This behavior then implies low pass-through and increased price stickiness. On the aggregate, it leads to increased volatility of the real exchange rate. This is potentially interesting, as Engel (1999) and Chari et al. (2002) find that the volatility of real exchange rates is mostly due to deviations of the law of one price for tradable goods. Although the results are similar to the static models with fixed prices where the pass-through by construction is zero or unity, the mechanism that yields these results is quite different. Here we look beyond this first period and examine the incentives for firms to adjust prices, and we let the length of price stickiness be endogenous.

4. Simulation Results

We use the model to generate artificial data on prices and the exchange rate. To do this, we simulate the history of a firm during 1000 time periods and repeat this simulation 200 times. We discard the first 200 time periods from each simulated series so that assumptions about the initial conditions are irrelevant. The 160,000 remaining observations on prices and the exchange rate are used in our analysis. The artificial data on p and s are used to estimate the degree of pass-through, which is defined as the percentage change in import prices in response to a percentage change in the exchange rate.[12] In the appendix we argue that pass-through should be estimated with a linear projection of the form

$$y_{t+1} = \hat{\gamma}_0 + \hat{\gamma}_1 x_{t+1} + \varepsilon_{t+1}. \tag{4.1}$$

where x is the change in the real exchange rate,

$$x_{t+1} = \log \frac{s_{t+1}(1+\pi)}{s_t(1+\pi^E)},$$

and y is the change in the real price level,

$$y_{t+1} = \log \frac{p_{t+1}}{p_t(1+\pi)},$$

under the restriction that $\hat{\gamma}_0 = 0$.

4.1. The Baseline Model. Bacchetta and van Wincoop (2003) demonstrate that PCP will be preferred to LCP in a static model if $\mu(\alpha - 1) < 1$, and LCP will be preferred if $\mu(\alpha - 1) > 1$. To examine interesting variations in the model behavior we set the price elasticity of demand to $\mu = 4$ and consider different convexities of the cost function. We focus in particular on $\alpha \in \{1.10, 1.25, 1.50\}$. We assume that inflation is zero in both countries in all three specifications.

Table 1 shows some summary statistics of these simulated economies. The first thing to note is that our dynamic model is consistent with the cutoff point in Bacchetta and van Wincoop. When $\mu(\alpha - 1) = 1$, firms are indifferent between PCP and LCP and average profits are the same. More interesting is the low frequency of price adjustments under LCP when it is favored over PCP ($\alpha = 1.5$). Figure 4 shows a subsample of the simulated price and exchange rate series and illustrates the remarkable difference in price stickiness that stems from the choice between LCP and PCP. The filled circles indicate that the firm has updated its price under PCP and the filled squares indicate that the firm has updated the price under LCP. As expected, and consistent with the results in Table 1, we see that prices are updated less frequently under LCP. Prices therefore respond slowly to changes in the exchange rate and the pass-through is low.

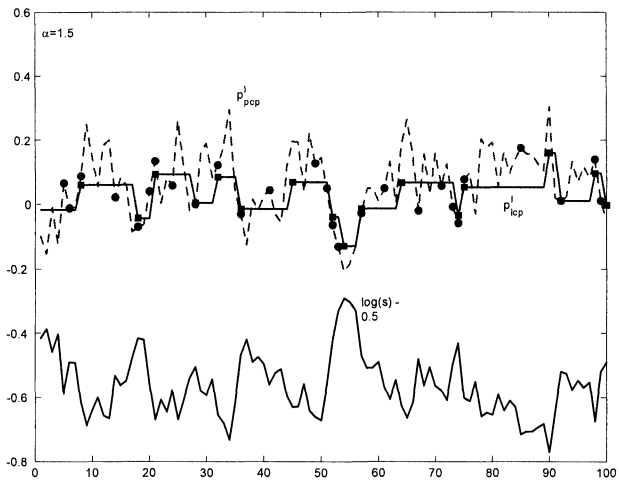
[12] The model generates data on $\hat{p}$ and q. This data is then transformed into p and s.

Table 1: Benchmark Model Specification

Convexity of costs	low $\alpha = 1.10$			medium $\alpha = 1.25$			high $\alpha = 1.50$		
	Flex	LCP	PCP	Flex	LCP	PCP	Flex	LCP	PCP
Mean profits	1.615	1.598	1.608	1.282	1.269	1.269	1.161	1.152	1.145
Mean price	1.000	1.003	1.006	1.000	0.999	1.005	1.000	1.000	1.004
Pass-through	0.714	0.575	0.893	0.500	0.319	0.673	0.333	0.156	0.474
Updates	1.000	0.376	0.124	1.000	0.248	0.247	1.000	0.159	0.354

Note: 'Mean price' is $p/\hat{p}^{\text{flex}}$, 'updates' is the fraction of periods when the firm updates its price.

Figure 4: Price Adjustments under LCP and PCP



Note: The figure shows a subsample of the simulation when the LCP and PCP economies are hit by identical exchange rate shocks.
The filled squares and circles indicate that the price has been adjusted under LCP and PCP, respectively.

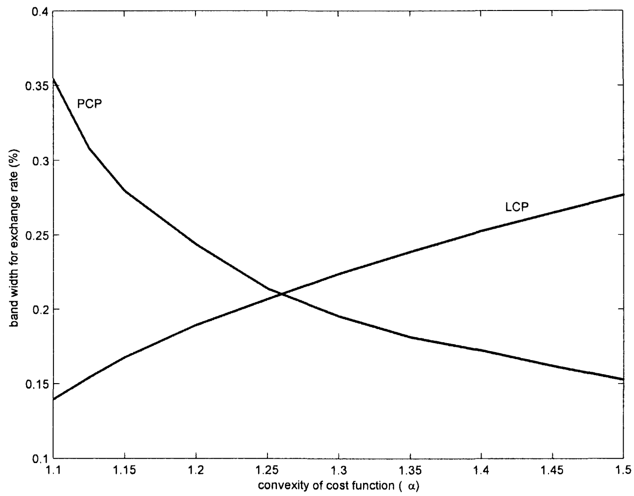
The long periods of price stickiness and low volatility of the import price, given that firms set prices in the importer's currency, comes from three different sources. The first is trivial, the price importers face is insulated from the small movements in the exchange rate as long as no price adjustments take place. Second, and less trivial, firms change prices infrequently, which leads to long periods without major changes in the import price. The "constructed" zero pass-through under LCP during the period for which prices are contractually fixed, can thus be extended to longer time periods, given that the exchange rate innovation is not too large. Finally, the import price oscillates closer around the average price under LCP. Therefore, LCP implies lower pass-through and less correlation between exchange rates and imported goods prices even when firms can change prices.

Table 1 also shows that the degree of pass-through is low regardless of which invoicing currency that is used if LCP is preferred over PCP, i.e. when α is high. The intuition behind this result is straightforward. The fact that LCP is preferred over PCP demonstrates that it is more important to stabilize the import price than the export price. To stabilize the import price, firms must update prices frequently under PCP, and these price updates insulate import prices from exchange rate fluctuations.

Figure 5 illustrates the mechanisms behind these results. Recall that firms' pricing decisions are described by the policy functions $P(s)$, $\underline{P}(s)$, and $\overline{P}(s)$ such that the preset price p is updated to $P(s)$ if $p < \underline{P}(s)$ or $p > \overline{P}(s)$. A straightforward comparison of these policy functions under LCP and PCP is not meaningful since the dynamics of p depends on the invoicing currency. But we can transform these functions into functions of an exogenous process. Assume that the price is fixed at $\hat{p}$ and assume that $\hat{p}$ maximizes the instantaneous profit if the exchange rate is $\hat{s}$, i.e. $\hat{p} = P^*(\hat{s})$. Then transform the rules $\underline{P}(s)$, and $\overline{P}(s)$ to rules for the deviation of the exchange rate from $\hat{s}$, $\underline{S}(\hat{s})$, and $\overline{S}(\hat{s})$ such that the price is updated if $s/\hat{s} < \underline{S}(\hat{s})$ or $s/\hat{s} > \overline{S}(\hat{s})$. Figure 5 plots $\overline{S}(1) - \underline{S}(1)$, i.e. the width of the inaction bands evaluated at the average exchange rate.

For low values of α the inaction bands are wide under PCP – the exchange rate is allowed to appreciate or depreciate by more than 15 percent before the price is adjusted when $\alpha = 1.10$. But as the convexity of the cost function increases, the loss of not adjusting the price under PCP increases and the inaction bands narrow. Under LCP, the costs of not adjusting the price are highest when the convexity of the cost function is low relative to the convexity of the demand function. The inaction bands are therefore small, and updates frequent, when α is low. Note also that Figures 2 and 5 show that the invoicing currency that minimizes the average loss generates the widest inaction band, i.e. that price updates are more frequent if an inferior invoicing currency is used.

Figure 5: Size of Inaction Bands



Note: The figure shows the size of inaction bands for the exchange rate implied by $\underline{P}(\cdot)$ and $\overline{P}(\cdot)$ at $s_t = 1$.

Table 1 also shows that average prices are slightly higher under PCP than under LCP, by about 0.5% on average. This has already been noted in the static price literature (Baron, 1976), where the optimal price-quantity combination under PCP is influenced by the exporter's risk aversion.[13] By setting a price higher than the certainty equivalent price, a risk averse exporter can reduce demand fluctuations (and hence fluctuations in profits). In our framework, even risk neutral exporters set a slightly higher price under PCP since a large depreciation of the exchange rate would lead to substantially increased demand which is costly to meet if costs are convex.

[13] In that literature, the failure of what is frequently called the separation theorem to hold under PCP, relies on the fact that the exporter is not able to perfectly hedge the demand risk by buying forward contracts in her own currency. To limit demand fluctuations a risk averse exporter sets a slightly higher price. If a perfect hedge was possible, the optimal price would not be influenced by the risk aversion and the separation theorem would hold.

4.2. The Magnitude of Exchange Rate Fluctuations. Does increased exchange rate volatility lead to a higher or lower pass-through? As pointed out in a recent paper by Pollard and Coughlin (2003), this should depend on if goods are priced in the exporter's or the importer's currency. Regardless of invoicing currency, larger swings in the exchange rate imply greater incentives to adjust prices.[14] Pass-through is unity under PCP if firms do not update prices, and pass-through falls as the updating frequency increases. Larger exchange rate fluctuations therefore reduce pass-through. The mechanism is the opposite under LCP. The import price is fixed as long as firms do not update prices, but pass-through increases with the updating frequency. Pass-through is then higher for large shocks. Pollard and Coughlin examined 19 U.S. industries and found that larger exchange rate innovations on average implied larger pass-through coefficients, but with some variation between industries. Given that U.S. imports are usually denominated in dollars, their findings are consistent with the theory discussed above.

Our model nicely generates the results anticipated by Pollard and Coughlin. Figure 6 plots the average simulated exchange rate pass-through elasticity as a function of shock size under PCP and LCP. The estimated elasticity is decreasing in shock size under PCP, while the opposite pattern holds for LCP. The mechanism generating these patterns is the one described above. The willingness to pay the fixed cost of updating prices is higher when shocks are large since the pre-set price then deviates substantially from the optimal instantaneous price. Table 2 confirms that the fraction of firms that update prices is higher for large shocks than for small shocks, regardless of the direction of the shock or invoicing currency. Moreover, the difference in updating frequency between local currency pricing and producer currency pricing is greater when shocks are large. Since firms find it optimal to choose the invoicing strategy that minimizes adjustments (since these are costly) this indicates that the gains from an optimal choice are larger the more volatile the exchange rate is.[15]

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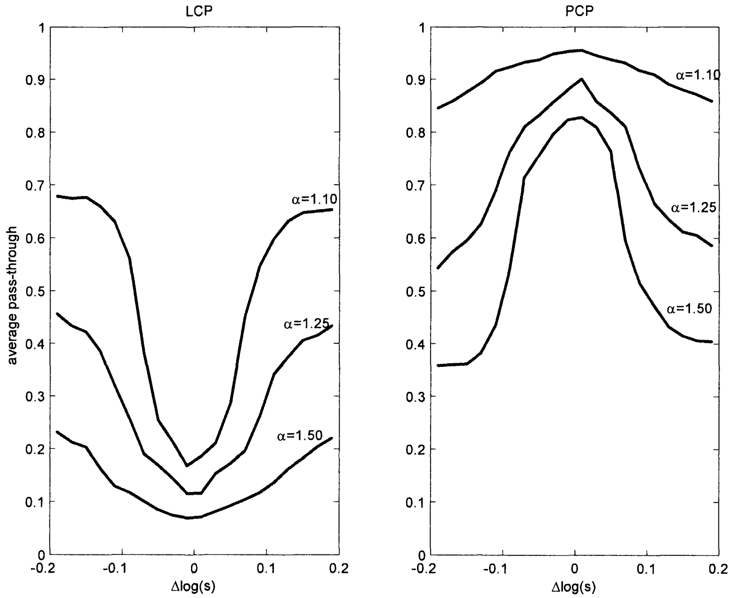
[14] Devereux and Siu (2004) and Burstein (2005) similarly note that large monetary policy shocks can have small output effects since many firms choose to adjust prices in response to these large shocks.

[15] Note however that the optimal choice in our model does not depend on the volatility of the exchange rate.

Figure 6: Pass-Through and Shock Size



Note: The figure plots the average pass-through, $-\Delta \log (p) / \Delta \log (s)$, for different exchange rate shocks.

Table 2: Asymmetric Responses to Appreciations and Depreciations

Convexity of costs	low $\alpha = 1.10$			medium $\alpha = 1.25$			high $\alpha = 1.50$		
	Flex	LCP	PCP	Flex	LCP	PCP	Flex	LCP	PCP
$\Delta s < 0\%$									
pass-through	0.714	0.581	0.892	0.500	0.321	0.670	0.333	0.157	0.468
updates	1.000	0.356	0.118	1.000	0.255	0.236	1.000	0.161	0.331
$\lvert\Delta p\rvert$	0.045	0.087	0.048	0.031	0.066	0.073	0.021	0.051	0.085
$\lvert\Delta s\rvert$	0.063	0.105	0.113	0.063	0.110	0.111	0.063	0.113	0.107
$\Delta s > 0\%$									
pass-through	0.714	0.568	0.894	0.500	0.317	0.675	0.333	0.154	0.480
updates	1.000	0.395	0.129	1.000	0.242	0.259	1.000	0.157	0.378
$\lvert\Delta p\rvert$	0.045	0.078	0.044	0.031	0.069	0.066	0.021	0.052	0.075
$\lvert\Delta s\rvert$	0.063	0.100	0.109	0.063	0.108	0.108	0.063	0.110	0.102
$\Delta s < -10\%$									
pass-through	0.714	0.678	0.873	0.500	0.386	0.605	0.333	0.187	0.373
updates	1.000	0.910	0.320	1.000	0.719	0.660	1.000	0.443	0.873
$\lvert\Delta p\rvert$	0.098	0.102	0.051	0.069	0.072	0.080	0.046	0.055	0.098
$\lvert\Delta s\rvert$	0.138	0.140	0.152	0.138	0.144	0.145	0.138	0.151	0.141
$\Delta s > 10\%$									
pass-through	0.714	0.636	0.878	0.500	0.377	0.617	0.333	0.181	0.413
updates	1.000	0.888	0.340	1.000	0.661	0.698	1.000	0.423	0.877
$\lvert\Delta p\rvert$	0.098	0.097	0.047	0.069	0.076	0.074	0.046	0.056	0.091
$\lvert\Delta s\rvert$	0.137	0.140	0.148	0.137	0.144	0.142	0.137	0.149	0.140

Note: 'Updates' is the fraction of periods when the firm updates its price, and $|\Delta p|$ and $|\Delta s|$ are the absolute values of the average price change (in exporter's currency if PCP) and exchange rate change for firms that update their price.

4.3. Asymmetric Pass-Through under Appreciations and Depreciations. Both theoretical and empirical studies have analyzed asymmetric responses to exchange rate fluctuations. The theoretical literature has identified two main predictions.[16] The first theory, pointed out by Knetter (1994), notes that firms operating under capacity constraints, which limit potential sales, do not benefit from low prices. Hence, a depreciation of the exporter's currency might result in a lower pass-through than an appreciation, for which the capacity constraint is not binding. On the other hand, Froot and Klemperer (1989), Marston (1990), and Krugman (1987) argue that firms competing strategically for market shares may have the opposite result on pass-through. Low prices are then the means by which firms compete, so an appreciation of the

[16] The price response to exchange rate fluctuations is similar to the price response to variations in marginal costs. Empirical studies, in particular Borenstein et al. (1997) and Pelzman (2000), have found that price responses to cost shocks are asymmetric. Theoretically, Devereux and Siu (2004) and Ellingsen et al. (2004) show that the incentive to raise prices in response to increases in marginal costs typically is greater than the incentive to reduce prices in response to falls in marginal costs.

exporter's currency will result in firms adjusting by reducing the markup, while during a depreciation they will maintain the markup and allow prices to fall. While the empirical literature on asymmetries is extensive, it has found mixed support for these competing theories of asymmetric responses.[17]

Note, however, that price reductions must on average be as large as price increases in a stationary setting without inflation. Both appreciations and depreciations will therefore result in similar average pass-through. The estimated pass-through conditional on appreciations and depreciations reported in Table 2 are consequently similar.[18] But the way in which firms respond to appreciations and depreciations may still be asymmetric. If, for example, the loss of having a too low price relative to the loss of having a too high price is large, we would expect firms to frequently raise prices by a small amount and to infrequently reduce prices by a large amount.

Table 2 shows that our framework generates such asymmetries. Under PCP, firms adjust prices more frequently in response to depreciations than to appreciations, but the price changes (conditional on changing) are larger under appreciations. This is consistent with the asymmetries displayed in Figure 3. In particular, under PCP a depreciation typically implies that the pre-set price is inefficiently low and consequently that demand will be high if the price is not adjusted. If the cost function is relatively convex, the loss of not adjusting the price is larger after depreciations ($\Delta s > 0$) than after appreciations.

4.4. Inflation and Asymmetric Pass-Through. According to the Ss-pricing literature, prices should respond asymmetrically to cost and demand shocks when firms expect future inflation to be positive.[19] More specifically, firms should be more reluctant to reduce prices than to raise prices, because they would have raised prices in the absence of shocks. The results in Table 3 are based on a model specification where we set the quarterly inflation rate to two percent in both countries. The asymmetries induced by inflation are substantial, and the asymmetries reported in Table 2 for the baseline model are swept away by this more powerful mechanism.

From Table 3 we see that the price response to exchange rate fluctuations is asymmetric in the presence of inflation – there is higher pass-through in response to appreciations than in response to depreciations. Since firms know that they will need to raise

[17] Perhaps the binding quantity constraint explanation has been given the most support, although this is far from evident. For a nice survey of the empirical literature, see Pollard and Coughlin (2003).

[18] The small asymmeties are a result of asymmetric respones discussed below, which generate nonlinearities that are not captured by the regressions.

[19] Adjustment costs need not only be actual menu costs, but can also include e.g. customer relations costs. Arguably, these costs may be low if firms passively update prices with inflation. In the extreme case when firms costlessly can index prices to inflation, the analysis reduces to that without inflation.

prices in the future, the incentive to reduce prices in response to depreciations is low under LCP, and pass-through is consequently low. On the contrary, firms are quick to raise prices in response to appreciations since the underlying inflation also pushes prices up.

Contrary to the typical pattern displayed in Figure 1, Table 3 shows that pass-through in response to appreciations can be higher under LCP than under flexible prices. The intuition is clear; when there are adjustment costs, firms raise prices more than what is motivated by today's exchange rate shock due to the upward trend in prices. But there is no such need to compensate for future inflation when prices can be adjusted costlessly.

Table 3: Price Responses under Inflation, $\pi = \pi^E = 2\%$

Convexity of costs	low $\alpha = 1.10$			medium 1.25			high 1.50		
	Flex	LCP	PCP	Flex	LCP	PCP	Flex	LCP	PCP
Mean profits	1.615	1.598	1.603	1.282	1.267	1.268	1.161	1.148	1.144
Mean price	1.000	1.003	1.001	1.000	1.000	1.004	1.000	1.001	1.009
Full sample									
pass-through	0.714	0.622	0.761	0.500	0.382	0.652	0.333	0.269	0.472
updates	1.000	0.405	0.282	1.000	0.323	0.306	1.000	0.289	0.387
$\Delta s < -10\%$									
pass-through	0.714	0.738	0.863	0.500	0.503	0.745	0.333	0.381	0.480
updates	1.000	0.984	0.002	1.000	0.946	0.193	1.000	0.882	0.640
$\Delta s > 10\%$									
pass-through	0.714	0.627	0.690	0.500	0.302	0.537	0.333	0.172	0.370
updates	1.000	0.768	0.789	1.000	0.291	0.892	1.000	0.072	0.958

Under PCP, a depreciation of the exporter's currency implies that the import price falls, and an appreciation implies that the import price rises if the firm does not react. Since inflation drives the profit-maximizing import price up over time, the loss of not adjusting the export price is more costly after depreciations than after appreciations. We therefore see more adjustments after depreciations than after appreciations. These frequent price updates after depreciations reduce pass-through under PCP.

Note that inflation leads to larger pass-through in response to appreciations than depreciations both under LCP and under PCP. The presence of inflation thus generates the same asymmetric pass-through for both invoicing currencies, although the underlying mechanisms are almost the opposite.

5. Concluding Remarks

This paper has used a dynamic framework to analyze exchange rate pass-through and import price volatility. By simulating the response of an individual firm to an explicitly modelled stochastic exchange rate, we have examined how the choice of invoicing currency affects consumer prices over longer time periods. When firms adjust pre-set prices in response to exchange rate fluctuations, pass-through approaches the flexible price pass-through from different directions. Pass-through is unity under producer currency pricing if prices are fixed, and falls as price updates become more frequent. The mechanism is reversed under local currency pricing where there is zero pass-through when prices are fixed and higher pass-through when updates are more frequent. We demonstrate that the invoicing currency that minimizes the frequency of price updates also maximizes average profits. If firms choose the optimal invoicing currency, our model therefore predicts that pass-through is high under PCP and low under LCP just as in models with fixed prices. But if the invoicing currency is determined by factors outside the model, this need not be the case. Prices will then be updated frequently and pass-through will be closer to the flexible-price pass-through which is determined by properties of the cost and demand functions.

We have also analyzed if larger fluctuations in the exchange rate lead to higher pass-through than small fluctuations, as well as if there are asymmetric responses in price adjustments depending on if the currency appreciates or depreciates. For large exchange rate innovations, there is a high opportunity cost of not adjusting prices, which results in more frequent price updates. Under PCP, this leads to a lower pass-through than for small exchange rate innovations, while under LCP the more frequent price updating leads to a higher pass-through. Finally, prices respond asymmetrically to appreciations and depreciations of the exporter's currency. In the baseline specification with no inflation, this asymmetry is in general small. But in the presence of inflation in the importing country, prices respond more to appreciations than to depreciations of the exporter's currency.

6. Solution Algorithm

Note that $P(q) \in \left[\underline{P}(q), \overline{P}(q)\right]$, and that

$$V^k(q, P(q)) = V^c(q) + \xi$$

(often referred to as the value matching condition), and

$$V^k(q, \underline{P}(q)) = V^k\left(q, \overline{P}(q)\right) = V^c(q).$$

We use the following algorithm to solve the firm's recursive problem.

(1) Choose evaluation nodes q for the exchange rate and e for the exchange rate shocks.
(2) Set $\xi = 0$ and solve the problem without menu costs. Use the solution as an initial guess for $V^c(q)$ and $P(q)$. Also initially guess that $\underline{P}(q) = \overline{P}(q) = P(q)$. Define $\underline{\zeta}(q) = V_p^k(q, \underline{P}(q))$ and $\overline{\zeta}(q) = V_p^k\left(q, \overline{P}(q)\right)$, and guess that $\underline{\zeta}(q) \equiv \overline{\zeta}(q) \equiv 0$.
(3) Find polynomial approximations of the functions V^c, P, $\underline{P}$, $\overline{P}$, and linear-spline approximations of $\underline{\zeta}$ and $\overline{\zeta}$.
(4) Update the value functions and policy functions at all nodes $q_i \in q$. Use some maximization algorithm to find $p_i^* = P(q)$. To evaluate $EV(q', p')$, we use Gaussian quadrature and evaluate $V(q', p')$ at all nodes $q' = q_i + e$. To evaluate $V(q', p')$, we proceed as follows:
    (a) Evaluate $V^c(q')$, $P(q')$, $\underline{P}(q')$, $\overline{P}(q')$, $\underline{\zeta}(q)$, and $\overline{\zeta}(q)$ using the approximations from step 3.
    (b) If $p' \notin \left[\underline{P}(q'), \overline{P}(q')\right]$ then $V(q', p') = V^c(q')$.
    (c) If $p' \in [\underline{P}(q'), P(q')]$ then $V(q', p')$ is approximated by a cubic spline through $V^c(q')$ and $V^c(q') + \xi$ with slope $\underline{\zeta}(q')$ at $\underline{P}(q')$ and slope zero at $P(q')$.
    (d) If $p' \in \left[P(q'), \overline{P}(q')\right]$, $V(q', p')$ is approximated by a cubic spline through $V^c(q') + \xi$ and $V^c(q')$ with slope zero at $P(q')$ and slope $\overline{\zeta}(q')$ at $\overline{P}(q')$.
(5) Check if the value functions and policy functions have converged. If not, repeat from 3.

7. Estimating Pass-Through

In the empirical literature, pass-through is typically estimated in a regression like

$$\Delta \log p_{t+1} = \gamma_0 + \gamma_1 \Delta \log s_{t+1} + \varepsilon_{t+1} \tag{7.1}$$

or

$$\log p_t = \gamma_0 + \gamma_1 \log s_t + \varepsilon_t \tag{7.2}$$

where γ_1 is the pass-through coefficient. The constant terms in (7.1) and (7.2) typically capture trends in price levels and exchange rates, for example due to inflation. We are typically interested in how a firm's price responds to unanticipated or unusual exchange rate fluctuations. It may therefore be necessary to remove price level and exchange rate trends from the data. Consider defining

$$x_{t+1} = \log \frac{s_{t+1}(1+\pi)}{s_t(1+\pi^E)}$$

and

$$y_{t+1} = \log \frac{p_{t+1}}{p_t(1+\pi)},$$

and regressing

$$y_{t+1} = \hat{\gamma}_0 + \hat{\gamma}_1 x_{t+1} + \varepsilon_{t+1}. \tag{7.3}$$

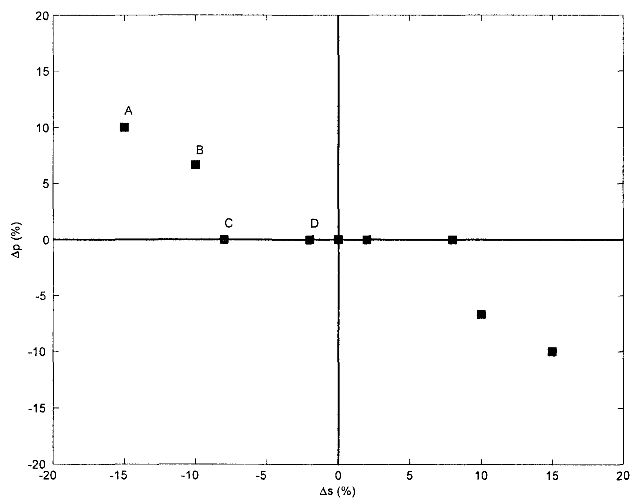
As long as $\hat{\gamma}_0 = 0$, the estimated pass-through in (7.3) will be identical to that estimated in (7.1). But as we demonstrate below, $\hat{\gamma}_0$ will not always equal zero. Estimating the pass-through from (7.1) can then result in a severe bias. We therefore argue that pass-through should be estimated from (7.3) under the restriction that $\hat{\gamma}_0 = 0$, which is the method used in this paper.[20]

When estimating pass-through for the full sample, forcing the constant to equal zero is not important. When conditioning on the direction and size of exchange rate fluctuations, however, the consequences of allowing for a constant term can be dramatic and undesired. To illustrate this problem, Figure B1 displays a hypothetical but realistic relation between prices and the exchange rate where firms only change prices in response to large exchange rate fluctuations. Clearly, there is little or no pass-through in response to small exchange rate fluctuations, and the combined pass-through in points A, B, and C is smaller than the pass-through in points A and B. But if one conditions on large appreciations (points A and B) and allows for a constant term, the estimated pass-through will be small. If also point C is included in a regression the estimated

[20] The empirical literature typically allows for constant terms.

pass-through will be much higher. Such regressions are misleading since they capture additional price changes on the margin in response to additional appreciations on the margin. To find the true pass-through – the price response to the total appreciation – one has to force the regression through the origin.

Figure B1: Example



This turns out to be an important problem also in our simulated data when we condition on exchange rate fluctuations being large. Pass-through is estimated to be much higher when we allow for constant terms. This is explained by a large number of observations similar to point C in Figure B1, i.e. firms that do not change prices in response to exchange rate changes around 10 percent. Table 2 shows that the estimated pass-through is 0.19 conditional on appreciations larger than 10 percent. When including a constant term, the estimate increases to 0.37.

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PAPER 3

Demand and Distance: Evidence of Cross-Border Shopping

Marcus Asplund, Richard Friberg and Fredrik Wilander

ABSTRACT. While many studies have documented deviations from the Law of One Price in international settings, evidence is scarce on the extent to which consumers take advantage of price differentials and engage in cross border shopping. We use data from 287 Swedish municipalities to estimate how responsive alcohol sales are to foreign prices, and relate the sensitivity to the location's distance to the border. Typical results suggest that the elasticity with respect to the foreign price is around 0.4 in the border region; moving 200 (400) kilometers inland reduces it to 0.2 (0.1). Given that cross country price differences for alcohol and other products are often caused by taxes, our evidence has implications for the debate on tax competition/harmonization.

1. Introduction

That prices of many goods differ considerably across countries is well documented[1]. What we know much less about, however, is to what extent consumers actually take advantage of these price differentials and engage in cross border arbitrage. To provide evidence on this, we examine the responsiveness of alcohol sales in Swedish communities to foreign prices, and relate the price sensitivity to a location's distance to the border.

With the deeper integration of the European Union (EU) and its expansion, the effects of cross border trade has become an important policy issue as in many cases the price differences are due to taxes set by individual member states. The resulting price differentials may be so great that consumers in high tax countries do their purchases elsewhere, with important consequences for tax revenues. In fact, it is sometimes argued that countries "compete" by lowering taxes to attract foreign demand leading to an equilibrium with taxes at a lower level than if countries had been able to coordinate;

[0] We thank Peter Davis, Raphael Thomadsen, and seminar participants at the 2005 ENTER Jamboree in Brussels for valuable comments. Anna Ihrfors Wikström at Systembolaget provided the data. Financial support from Vetenskapsrådet (Friberg) and Bankforskningsinstitutet (Wilander) is gratefully acknowledged.

[1] See for instance Engel and Rogers (1996), Goldberg and Knetter (1997), Haskel and Wolf (2001), Anderson and Van Wincoop (2004), Goldberg and Verboven (2005).

see for instance Kanbur and Keen (1993).[2] These issues figure prominently in the ongoing debate on tax harmonization within the EU and can be illustrated with the following quote from a press release regarding taxes on alcohol.[3]

"The Commission concludes that more convergence of the rates of excise duty [on alcohol] in the different Member States is needed so as to reduce distortions of competition and fraud. However, given the widely differing views in the Member States about the appropriate levels of the minimum rates, and given that any change would require unanimous agreement, the Commission is not making a proposal at this time. Instead the Commission wishes to launch a broad debate in the Council, the European Parliament,..." (Press release May 26, 2004).

A key problem in this debate is that little is known about the magnitude of cross border shopping, see Keen (2002) for a discussion. Interview studies indicate that the effects might be substantial. Frequently cited work by Fitzgerald (1992) for instance reports that in 1986 about 25 percent of spirits bought in the Republic of Ireland were bought in Northern Ireland. Campbell and Lapham (2004) examine links between the number of firms along the Canada-US border and the real exchange rate. They find that when prices in the US fall relative to prices in Canada (a real exchange rate depreciation) there is a significant increase in the number of sellers and/or in the average employment on the US side of the border for the four industries they study (food stores, gasoline service stations, drinking and eating places). Their findings are thus consistent with substantial changes in demand as a result of relative price changes and therefore with substantial cross border flows. However, based on an interview study by Ford (1992), they argue that for the industries in question the effects of cross border shopping are confined to border counties. Goldberg and Verboven (2005) report that, despite persistent price differences, cross border shopping of automobiles in Europe is limited. There also exist some papers that examine spillover effects of different sales

[2] Theoretical work using a game theoretic framework was pioneered by Mintz and Tulkens (1986). Kanbur and Keen (1993) examine a tax setting game between two governments. In their model consumers incur a transport cost to shop in the other country such that the closer to the border they live, the less costly is it to go shopping abroad. In their analysis a less densely populated country will set the lower tax rate since it has relatively less to loose from lowering taxes. Wang (1999) shows that this result from Kanbur and Keen is further strengthened if the large country decides on tax first. Nielsen (2001) let countries differ in size rather than in population density, and similarly finds that the smaller country sets the lower tax rate; see Keen (2002) for a survey.

[3] Some recent cuts in alcohol taxation by Denmark (October 2003) and Finland (March 2004) were prompted by concerns over cross border shopping from Germany and Estonia, respectively. This, in turn, caused Sweden to consider the effects of reducing its taxes to limit the price differential with neighbouring Denmark and Finland (SOU, 2004). Britain was recently sued by the European Commission (October 2004) on claims that it tried to hinder high volume cross border shoppers of alcohol in a way that is inconsistent with the common market.

taxes across US states (see e.g. Fox, 1986, and Walsh and Jones, 1988).[4]. This literature suggests that low prices across the border are important for sales in the border counties but it is an open question whether this also has an effect on the interior.

An unusually ambitious interview study by the Centre for Social Research on Alcohol and Drugs provides an indication of the extent of cross border shopping of alcohol. Since 2001, about 18000 randomly selected Swedes per year have been asked about their consumption of alcohol, and also the sources. Figure 1, which is based on data in Table 6.1 in SoRAD (2004), shows the consumption in 2003 from the three main sources of alcohol consumption (the Swedish government retail monopoly, legally imported, illegally imported), measured in liter of pure alcohol.[5]. The data is disaggregated by seven regions. As discussed below, the gateway to lower alcohol prices is in Sweden's south western corner and we measure each region's average distance to Malmö. Bearing in mind the problem with measurement errors[6] with this type of data, the general picture that emerges is that the fraction of imported alcohol is negatively related to the distance to the border. There is, however, only a weak tendency of a negative relationship between the distance and the sum of the three sources. This aggregate data suggests that the prevalence of cross border shopping is related to the distance to the border and that it is roughly replacing domestic sales. However, even with this type of data, a more quantitative analysis is needed in order to disentangle the relationship between demand at the local level, domestic and foreign prices, and distance to the border.

[4] A related literature examines the revenue impact at the state level of taxes in neighbouring states. This literature shows that cross border shopping acts as a constraint on the possibilities to raise state revenue by sales taxes, gasoline taxes or state lotteries. See Garrett and Marsh (2002) for references. Similarly, Beard et al (1997) try to infer the amount of cross border shopping from state level data on alcohol sales. Another somewhat related paper is Goolsbee (2000) who documents more Internet sales in high sales tax locations.

[5] For ease of comparison, we have excluded consumption a) at restaurants and pubs b) of beer and ciders with low alcohol content that can be bought outside Systembolaget, and c) of homemade alcoholic beverages.

[6] The telephone interviews underestimate the true consumption, due primarily to peoples' systematic underreporting of their own consumption (see www.sorad.su.se/alkrapp.pdf). SoRAD has attempted to correct for this in the numbers we use for Figure 2.

Figure 1: Estimated Sources of Alcohol Consumption and Distance to the Danish Border from the approximate Population Center in Different Swedish Regions 2003

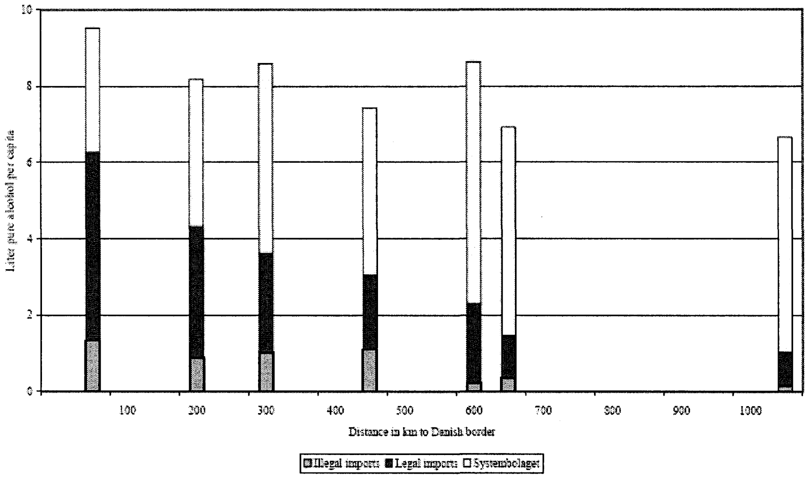
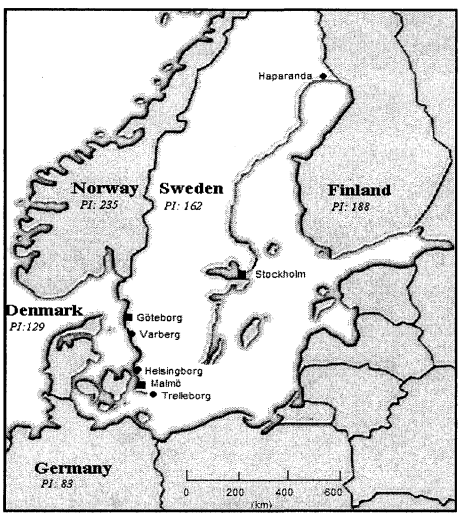


Figure 2: Map with Associated Price Indices



In this paper we use data from the Swedish government retail monopoly to estimate how the sensitivity of sales to foreign prices depends on the distance to the border. A number of features make this an unusually clean case. First, we have monthly data on sales of spirits, wine, and beer over a ten year period for each store that sells alcohol in Sweden. Second, prices are the same across the country. This implies that prices in border areas are not endogenously lower, which in other cases could blur the picture. At the same time, relative prices between countries have varied considerably due both to major tax changes and volatile exchange rates. Third, as seen in the Figure 2, geography suggests that it is easy to measure the distance to the relevant Danish border. The shape of the country (from north to south it is a drive of about 2000 kilometers or 24 straight hours) also gives us substantial variation to exploit.

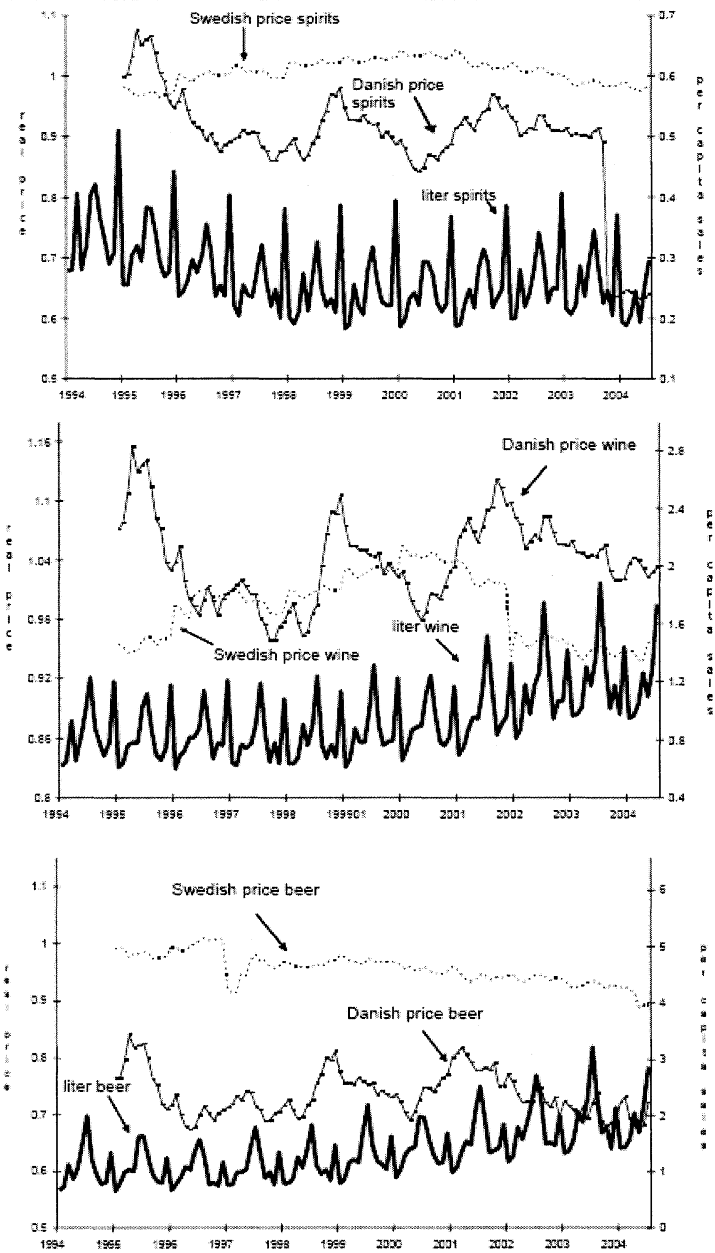
Our findings suggest that distance to the border plays an important role for the extent of cross border arbitrage. Using our estimates from spirits, in a border region the demand elasticity with respect to the foreign price is about 0.4 while moving 200 kilometers inland this elasticity is reduced to 0.2; at 400 kilometers the elasticity is 0.1.

2. Data

The government owned retail monopoly (Systembolaget) made available monthly volume data on sales of spirits, wine, and beer at all its approximately 600 outlets. For the regressions we aggregate the data and use variation in per capita sales across 287 Swedish municipalities over the period January 1995 – July 2004 to estimate demand functions. A great advantage with data from Systembolaget is that it is required to keep the same prices and assortment in all stores (at smaller outlets the customer needs to order some products in advance), which implies that prices are not influenced by local demand conditions. To measure the development of prices, we use price indices from Eurostat for the different product categories[7]. Foreign price indices are converted to Swedish kronor by the corresponding monthly average exchange rate. All prices are deflated by the Swedish Consumer Price Index. Figures 3a-3c show the development of aggregate sales, as well as Swedish and Danish price indices, for the three product categories. Although there is a great deal of seasonal variation, the broad trends with increasing sales of beer and wine, and a steady decline of spirits, are clearly visible. The most drastic price movements are due to tax changes in Sweden (January 1997 for beer and December 2001 for wine) and Denmark (October 2003 for spirits). The floating exchange rate between Swedish kronor and Danish kronor contributes to the comparatively high volatility of the Danish prices when expressed in Swedish kronor.

[7] We use the Harmonized Consumer Price Indices obtained from the Eurostat database for spirits (cp0211), wine (cp0212) and beer (cp0213). These are monthly indices available for all individual member countries.

Figure 3: Per capita sales and real prices of spirits, wine and beer in Sweden.



Note: January 1994–July 2004

The prices are indices and thus do not inform us about differences in the level of prices between countries. However, Horverak and Osterberg (2002) gives us a snapshot, as of June 1999, of the prices of identical baskets in Denmark and Sweden. At that time a basket with beer was 27 percent cheaper and the spirits basket was 10 percent cheaper in Denmark; the basket with wine was 1.5 percent more expensive. We have normalized the price indices in Figures 3a-3c to reflect the difference at this date. While the compositions of these baskets certainly differ from those that form the basis of the price indices, this nevertheless suggest that over essentially the whole time period spirits are cheaper in Denmark, wines are at least as expensive as in Sweden, and beer much cheaper in Denmark.

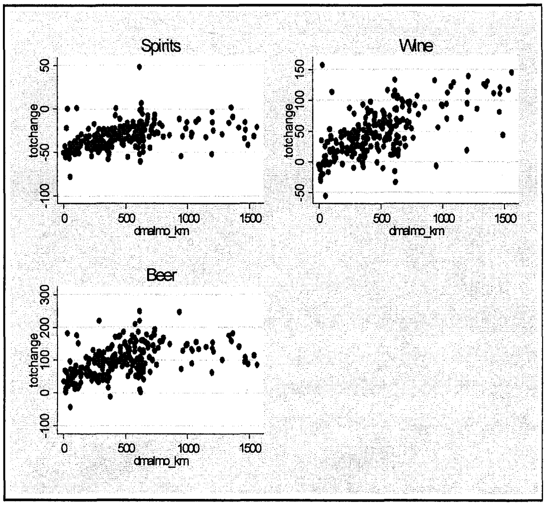
Another way of examining the price levels comes from the Purchasing Power Parity indices of alcoholic beverages that Eurostat calculates on a yearly basis. For each year the average price for the EU-15 is 100.[8] The average of this index over 1995-2003 was 235 for Norway, 188 for Finland, 162 for Sweden, 129 for Denmark and 83 for Germany. Thus, on average a basket of alcohol was some 25 percent more expensive in Sweden than in Denmark, and almost twice as expensive as in Germany. The levels obviously differ over the years but the ranking is consistent. To avoid the influence of Norwegian and Finnish cross border shoppers, we exclude all Swedish municipalities that border Norway or Finland in our regressions. However, we report separate regressions to illustrate the effects in the northern regions when Finland drastically cut the tax on spirits in March 2004.

When Sweden joined the European Union in January 1995 it agreed to gradually loosen the restrictions on the alcohol that could be brought in from other member countries. From December 1994 to July 2004 the legal quota had increased from 1 liter of spirits, 1 liter of wine, and 2 liters of beer to 10 liters of spirits, 90 liters of wine and 110 liters of beer. (The 1994 quotas applied to imports from outside EU throughout the period.) The main gateway to lower alcohol prices is in Sweden's south-west corner (see Figure 2). To Denmark there are quick ferries from Helsingborg, and in July 2000 a toll bridge was opened linking Malmö to Copenhagen, Denmark (before this there were quick ferries linking the two cities). To Germany, there are a number of ferry lines

[8] We use the series for alcohol, "A010201" from the database "Purchasing power parities (PPP) and comparative price level indices for the ESA95 aggregates".

from Trelleborg[9][10]. Our main measure of distance to the border is kilometers by car (by the fastest route) to Malmö; Malmö, Helsingborg, and Trelleborg are very closely situated and the correlation between distance measures to these locations will be very close to one.

Figure 4:. Percentage change in sales per capita, Swedish municipalities



Note: May 1995-May 2004

In Figure 4 we relate the change in per capita sales between May 1995 and May 2004 to the distance to the Malmö. The figures show a striking upward sloping relation between the distance from the border and the growth in sales[11].The regression lines indicate that there is a concave relation between sales growth and distance (results in Table 1). In regressions (not reported) this concave relation was robust to the inclusion

[9] For the different alternatives, the distance in hours (one way) and prices per car with same day return in 2004 were in Swedish kronor (kr) (9kr~1Euro): Malmö-Denmark (bridge) 15minutes, 500kr; Helsingborg-Denmark 20min, 580kr; Trelleborg-Germany 4hours, 650kr. There are also infrequent ferries to Denmark further north: Varberg-Denmark 4 hours, 1195kr and Göteborg-Denmark 3 hours, 745kr.

[10] When Poland and the Baltic States joined the European Union in May 1 2004 additional low price locations became accessible. However, Poland is 8 hours from Ystad (south of Malmö) and Estonia is 15 hours from Stockholm and we have not tried to measure the impact of these improved opportunities to buy cheap alcohol.

[11] There is one particularly large positive outlier close to the border – the municipality of Kävlinge (population 25000). Closer examination of the data shows that a new store was opened right next to the major highway along Sweden's west coast, attracting consumers from other areas. This new store also explains the sharp fall in the neighbouring municipality of Svalöv (population 10000).

of disposable income at the municipality level (data only available until 2002). The relation was also robust to the exclusion of the more northerly ferry ports (Helsingborg, Göteborg and Varberg) and their surrounding municipalities – a finding consistent with our assumption that the Malmö-Trelleborg area was the main gateway.

Table 1: Change in regional sales volume related to Distance to Danish Border.
Dependent Variable is 108-month difference (May 1995 - May2004) in log of sales volume

	Coefficients Robust Standard Errors	Coefficients Robust Standard Errors	Coefficients Robust Standard Errors
	Spirits[a]	Wine[a]	Beer[a]
Dist	0.943*** [0.133]	0.821*** [0.163]	0.855*** [0.144]
Dist^2	−0.464*** [0.091]	−0.258** [0.107]	−0.343*** [0.094]
Constant	−0.793*** [0.040]	−0.093* [0.048]	0.101** [0.040]
Observations	233	233	233
R^2	0.32	0.30	0.24
Test[b]	0.00	0.00	0.00

Notes: ***, **, and * indicate significance at 1, 5, and 10 percent level, respectively
a) Sample excludes municipalities that border to Norway and Finland.
b) Test is the probability that Dist=Dist2=0.

3. Econometric model

That distance to the border seemed to play a role for the development of a region's alcohol sales was shown above. In this section we estimate how sensitive regional sales are to the price across the border, P^F, and the domestic price, P^D[12]. The starting point is that demand per capita for alcohol of type j={spirits,wine,beer} in region i at time t is given by

$$\ln[q_{j,i,t}] = b_{j,0} + b_{j,1}\ln[P^D_{j,t}] + g(\boldsymbol{d}_j, D_i)\ln[P^F_{j,t}] + \boldsymbol{\beta X}_{j,i,t} + u_{j,i} + e_{j,i,t}$$

where X is a vector of other variables, u is unobserved heterogeneity, and e is a standard error term. The own price elasticity is b_1. The elasticity with respect to the foreign price is g(d, D) and thus depends on the distance to the border, D (in 1000 kilometers); d is a vector of parameters to be estimated. The prior is that the influence of the foreign price is decreasing in the distance to the border such that

[12] Demand can in principle be modelled as dependent on prices in several neighbouring countries. In our application, however, the fact that the distances to Denmark and Germany are virtually the same gives rise to a severe multicollinearity problem that we are not able to address with the relatively short time dimension in the data. As a consequence we run separate regressions Danish and German price.

g'(d, D)<0 and g"(d, D)>0. We specify the function g(.,.) as a flexible third order polynomial[13]. Regions differ not only in consumption levels but may also differ in the seasonal purchasing patterns. The first type of heterogeneity is captured by $\mu_{j,i}$ in (1), while the second would be captured in $X_{j,i,t}$ by region specific dummy variables for each calendar month. We use 12-month differences, Δ_{12}, to take out these region specific effects and estimate

$$\Delta_{12}\ln[q_{j,i,t}]=b_{j,0}+b_{j,1}\Delta_{12}\ln[P^{D}_{j,t}]+(d_{j,0}+d_{j,1}D_i+d_{j,2}D_i^2+d_{j,3}D_i^3)\Delta_{12}\ln[P^{F}_{j,t}]+\Delta_{12}\boldsymbol{\beta X}_t+\varepsilon_{j,i,t}$$

In (2) we have omitted the subscripts j and i on X_t to emphasize that it includes no region or type specific variables. The only variable in X_t is the log of the number of Fridays in the month (four or five), to capture that traditionally most of the sales are on Fridays (until 2003, outlets were closed on Saturdays and Sundays).

We estimate (2) as a system of seemingly unrelated equations (SUR) to account for the fact that error terms are correlated (correlation of 0.6-0.8) across equations but treating $\Delta_{12}\ln\left[P^{D}_{j,t}\right]$ and $\Delta_{12}\ln\left[P^{F}_{j,t}\right]$ as uncorrelated with the error terms. The reason for assuming that $\Delta_{12}\ln\left[P^{F}_{j,t}\right]$ is predetermined is that the national price indices of Denmark and Germany are unlikely to be influenced by local Swedish demand shocks[14]. The institutional fact that prices do not vary across Swedish locations and that changing taxes is a very drawn out process are two reasons for why endogeneity of $\Delta_{12}\ln\left[P^{D}_{j,t}\right]$ is not an issue here[15].

4. Results

In the regressions below, we exclude municipalities that border to Norway or Finland. We also report results for the subsample where March and April months are excluded, since sales are greatly influenced by which month Easter falls. We also use a subsample where, in addition, all municipalities more than 1000 kilometers away from Denmark and Germany are excluded.

[13] This is analogous to a parametric version of the model of Pinkse et al (2002).

[14] Given the population sizes of the countries (Denmark, 5.4m, and Germany, 82.8m) it is unlikely that national prices are influenced by demand from Swedish cross border shoppers. The fact that PF is a national average does in itself not rule out the possibility prices just across the border are influenced by local Swedish demand shocks. However, since Copenhagen with a population of 1.7 million is the border town this suggests that changes in prices there are driven by changes in Danish rather than Swedish conditions. The argument also applies to the local prices in Germany.

[15] For instance, in response to concerns about cross border arbitrage following the Danish tax cut in October 2003, a government commission was initiated in January 2004. As of February 2005, their recommendations are still under review and various interested parties can still influence the outcome. Before any new taxes will come into effect, the final proposal will first have to pass parliament and be written into law, something that might take at least another year.

Table 2: Change in regional sales volume.
Dependent variable is 12-month difference in log of sales volume, $\Delta_{12}\ln[\text{qj,i,t}]$.
Foreign price, P^F, is for Denmark, Seemingly Unrelated Regression (SUR)

	Spirits^a	Spirits^b	Wine^a	Wine^b	Beer^a	Beer^b
$\Delta_{12}\ln[P^D]$	-0.784^{***}	-0.858^{***}	-0.188^{***}	-0.237^{***}	-0.781^{***}	-0.880^{***}
	[0.027]	[0.028]	[0.015]	[0.017]	[0.024]	[0.029]
$\Delta_{12}\ln[P^F]$	0.324^{***}	0.400^{***}	0.117^{***}	0.257^{***}	0.445^{***}	0.779^{***}
	[0.011]	[0.014]	[0.025]	[0.032]	[0.035]	[0.051]
$\text{Dist}*\Delta_{12}\ln[P^F]$	-0.939^{***}	-1.342^{***}	-0.870^{***}	-1.733	-0.951^{***}	-2.518^{***}
	[0.069]	[0.120]	[0.157	[0.289]	[0.221]	[0.450]
$\text{Dist}^2*\Delta_{12}\ln[P^F]$	0.864^{***}	1.857^{***}	1.172^{***}	3.336^{***}	0.986^{**}	4.781^{***}
	[0.122]	[0.293]	[0.277]	[0.710]	[0.390]	[1.106]
$\text{Dist}^3*\Delta_{12}\ln[P^F]$	-0.205^{***}	-0.872^{***}	-0.490^{***}	-2.029^{***}	-0.306^{*}	-2.983^{***}
	[0.057]	[0.205]	[0.130]	[0.498]	[0.183]	[0.778]
$\Delta_{12}\ln[\text{Fridays}]$	0.136^{***}	0.192^{***}	0.196^{***}	0.255^{***}	0.251^{***}	0.293^{***}
	[0.005]	[0.005]	[0.006]	[0.006]	[0.006]	[0.007]
Constant	-0.032^{***}	-0.031^{***}	0.031^{***}	0.028^{***}	0.053^{***}	0.052^{***}
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Observations	25603	19305	25603	25603	25603	25603
R^2	0.11	0.19	0.06	0.11	0.05	0.08
Test^c	0.00	0.00	0.00	0.00	0.00	0.00

Notes: [Robust standard errors] ***, **, and * indicate significance at 1, 5, and 10 percent level.
a) Sample excludes municipalities that border to Norway and Finland.
b) Sample excludes; municipalities that border to Norway and Finland, municipalities where Dist>1.00 (1000 kilometers), March and April months.
c) Test is the probability that $\text{Dist}*\Delta_{12}\ln[P^D] = \text{Dist}^2*\Delta_{12}\ln[P^D] = \text{Dist}^3*\Delta_{12}\ln[P^D] = 0$

The results when the foreign price is defined as the price in Denmark and Germany for the three categories are shown in Table 2 and Table 3, respectively. Overall, coefficients are significant with the expected signs and are plausible in magnitude. The effects on demand of changes in foreign prices are quite similar for the two price indices. One might have expected the effect of German prices to be weaker, since it is more costly to go there both in terms of time and outlays. However a counteracting influence may be that German prices are substantially lower than Danish prices. For some consumers, who buy large quantities, the extra distance associated with shopping in Germany rather than in Denmark will be worthwhile.

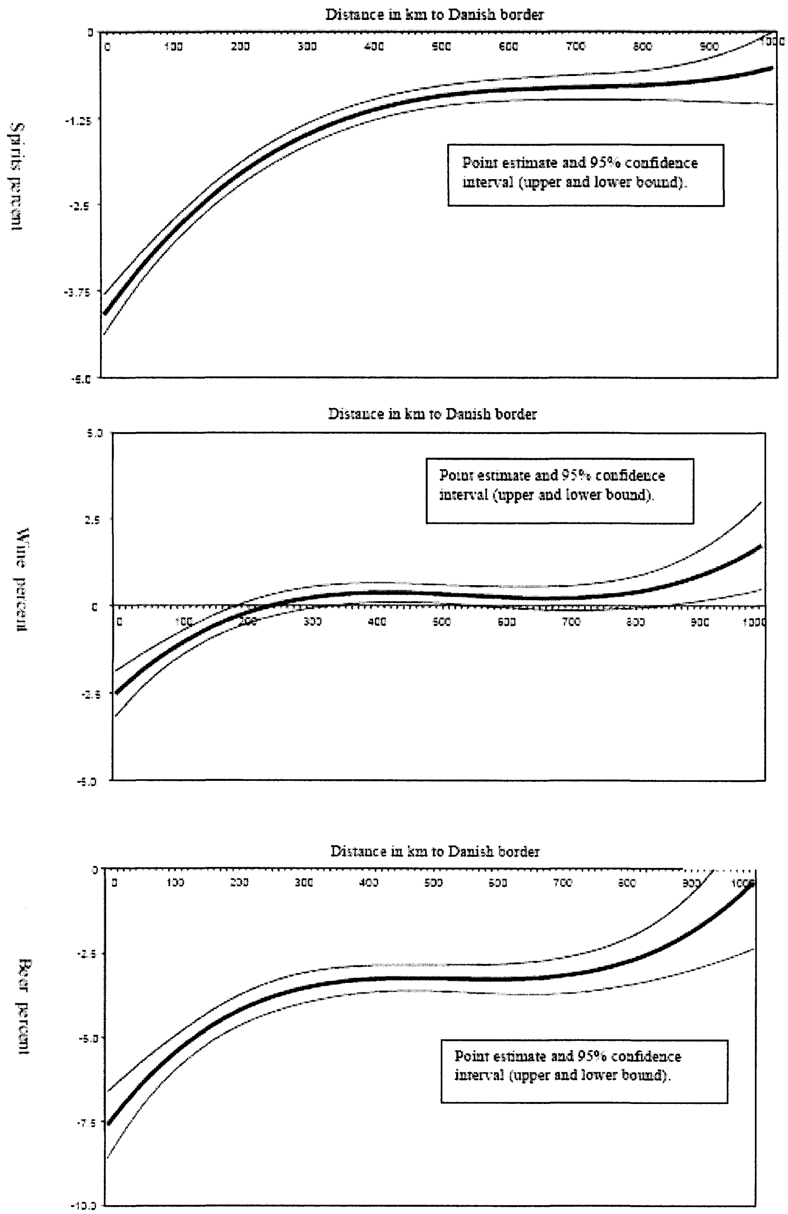
Table 3: Change in regional sales volume.
Dependent variable is 12-month difference in log of sales volume, $\Delta_{12}\ln[qj,i,t]$.
Foreign price, P^F, is for Germany, Seemingly Unrelated Regression (SUR)

	Spirits[a]	Spirits[b]	Wine[a]	Wine[b]	Beer[a]	Beer[b]
$\Delta_{12}\ln[P^D]$	-0.669^{***}	-0.677^{***}	-0.243^{***}	-0.289^{***}	-0.804^{***}	-0.919^{***}
	[0.029]	[0.031]	[0.016]	[0.018]	[0.023]	[0.028]
$\Delta_{12}\ln[P^F]$	0.381^{***}	0.446^{***}	0.229^{***}	0.341^{***}	0.531^{***}	0.688^{***}
	[0.034]	[0.039]	[0.037]	[0.044]	[0.041]	[0.053]
$Dist*\Delta_{12}\ln[P^F]$	-1.466^{***}	-1.770^{***}	-1.491^{***}	-2.275^{***}	-1.411^{***}	-1.856^{***}
	[0.210]	[0.344]	[0.229]	[0.394]	[0.260]	[0.472]
$Dist^2 * \Delta_{12}\ln[P^F]$	1.861^{***}	2.523^{***}	2.149^{***}	4.018^{***}	1.651^{***}	2.579^{**}
	[0.369]	[0.848]	[0.403]	[0.971]	[0.459]	[1.162]
$Dist^3 * \Delta_{12}\ln[P^F]$	-0.676^{***}	-1.020^{*}	-0.954^{***}	-2.189^{***}	-0.640^{***}	-1.273
	[0.174]	[0.597]	[0.190]	[0.682]	[0.216]	[0.818]
$\Delta_{12}\ln[Fridays]$	0.132^{***}	0.192^{***}	0.197^{***}	0.255^{***}	0.250^{***}	0.290^{***}
	[0.005]	[0.005]	[0.005]	[0.006]	[0.006]	[0.007]
Constant	-0.035^{***}	-0.035^{***}	0.030^{***}	0.027^{***}	0.053^{***}	0.052^{***}
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Observations	25603	19305	25603	25603	25603	25603
R^2	0.06	0.10	0.07	0.11	0.07	0.10
Test[c]	0.00	0.00	0.00	0.00	0.00	0.00

Notes: [Robust standard errors] ***, **, and * indicate significance at 1, 5, and 10 percent level.
a) Sample excludes municipalities that border to Norway and Finland.
b) Sample excludes; municipalities that border to Norway and Finland, municipalities where Dist>1.00 (1000 kilometers), March and April months.
c) Test is the probability that $Dist*\Delta_{12}\ln[P^D] = Dist^2 * \Delta_{12}\ln[P^D] = Dist^3 * \Delta_{12}\ln[P^D] = 0$

Instead of focusing on any particular coefficient, we use Figures 5a-5c to illustrate the effect of a hypothetical 10 percent reduction in the price of Danish spirits, wine and beer, respectively. A 10 percent reduction in the Danish price of spirits causes a fall in per capita sales of roughly 4 percent at the border (Malmö). This large cross price elasticity is almost half the own price elasticity. As seen the effect of the tax-cut diminishes gradually as one moves further from the border. The fall in sales is estimated to drop below 1 percent only at 460 kilometer from the border and not until we reach 1000 kilometers can we reject that the effect is zero.

Figure 5:. Estimated effect on sales volumes for spirits, wine and beer in Swedish regions following a 10% reduction in the corresponding Danish price.



For beer the effects again disappear around 1000 kilometers, while for wine the effect tapers off much more rapidly, reaching zero at some 200 kilometers from the border. A likely explanation for this difference is that prices of beer are significantly lower across the border while prices of most medium to high quality wines are about the same. However, in Denmark there exist low quality wines that are cheaper than any that can be found in Sweden. This could give rise to modest amounts of cross border shopping.

Overall, it might be surprising that effects may stretch this far from the border. Note though that these products are easily transported and storable – by driving down to Denmark the price conscious consumer could keep her bar stocked with just one or two yearly trips. Calculations of the cost savings associated by going to Denmark to buy alcohol were particularly common in Swedish press around the time of the Danish tax cut of 2003. One example (from the tabloid Expressen, October 20, 2003) claimed that two persons sharing a car from Stockholm (around 600 kilometers from Malmö) and each buying the full quota at the time would save 3200 kronor (around 350 euros).

Our data set allows another opportunity to relate the effects of lower foreign prices to demand in different locations. Historically beer and wine have been cheaper in Sweden than in Finland, while the prices of spirits have been roughly equal in the two countries[16]. This changed two months before Estonia was due to enter the European Union in May 2004. Finland feared the effects of a very large price differential with its neighbor and therefore reduced the spirits tax by 44 percent resulting in a fall of the spirits price index by 38 percent relative to the previous month. This in turn made spirits prices in Finland very attractive to Swedes in the northern parts of the country[17]. The price indices of wine and beer fell by 7 percent.

In Table 4 we examine the effects on the northern regions. We use the 12-month percentage change in sales in the sparsely populated northernmost 34 municipalities (maximum distance to the Finnish border is 742 kilometers). With only five months of data we have essentially no variation in $\Delta_{12}P^D$ or $\Delta_{12}P^F$ and we therefore estimate a SUR specification with only a third order polynomial of distance, and the percentage change in the number of Fridays, as independent variables[18].

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[16] In June 1999 for instance a basket of beer (wine) was 13 (19) percent more expensive in Finland than in Sweden, while a basket of spirits was some 2 percent cheaper in Finland (Horverak and Osterberg, 2002).

[17] Before the tax cut a liter of Absolute Vodka cost the equivalent of 329 kronor in Finland and after 219 kronor which can be compared to 310 kronor in Sweden.

[18] For spirits, $\Delta_{12}P^F$ ranged from -0.409 to -0.395 and $\Delta_{12}P^D$ between -0.001 and -0.014.

Table 4: Change in regional sales volume.
Dependent variable is 12-month difference[a] in log of sales volume, $\Delta_{12}\ln[qi,t]$. Distance is to the Finnish border.

	Spirits	Wine	Beer
Dist	2.72***	−0.12	0.14
	[0.46]	[0.34]	[0.41]
Dist^2	−6.01***	0.76	0.11
	[1.32]	[0.97]	[1.17]
Dist^3	4.20***	−0.85	−0.32
	[1.11]	[0.81]	[0.98]
$\Delta_{12}\ln$[Fridays]	0.05	−0.03	−0.01
	[0.04]	[0.02]	[0.03]
Constant	−0.44***	−0.01	−0.01
	[0.05]	[0.03]	[0.04]
Observations	164	164	164
Test[b]	0.00	0.17	0.08

[Robust Standard Errors]
a) March 2004-July 2004
b) Test is the probability that Dist=Dist2= Dist3=0.

While the effects of distance on sales of wine and beer are very marginal, spirits sales are highly sensitive[19]. For spirits the point estimate suggests that sales at the border municipalities fell by 44 percent relative to the year before. For the five months in question, $\Delta_{12}P^F$, was about 0.40 which suggest that the cross price elasticity at the border was about unity. Moving 200 kilometers away from the border the elasticity would fall to 0.3 and at 400 kilometers it is around 0.15. The estimated elasticities at the Finnish border are thus even higher than at the Danish border. This is no doubt due to the fact that there is no direct cost of crossing the Finnish border. For instance, from the single Systembolaget store in the border municipality of Haparanda to the Finnish counterpart (Alko) in Tornio there is only a 10 minute drive, which could definitely be worthwhile even for small purchases. As noted in footnote 9, traveling to Denmark by bridge or ferry involves direct costs of at least 500 kronor.

5. Conclusion

Many studies have documented deviations from the Law of One Price in international settings. Our analysis of alcohol sales across Swedish regions offers an indication that the magnitude of cross border arbitrage that these deviations give rise to can be substantial. By estimating demand functions we have shown that the sensitivity of regional sales with respect to foreign prices depends on the distance to the border. The

[19] For wine, distance to the border has no significant effect which might be explained by the fact that wine even after the tax cut remained more expensive in Finland. For beer there is a small but statistically significant effect which could potentially also be due to substitution away from domestically sold beer to spirits bought in Finland.

estimated elasticities are naturally highest at the communities near the border but the effect lingers several hundred kilometers inland.

From a policy perspective, cross border shopping can have a significant effect on a country's tax revenues. Calls for tax harmonization within the European Union have often been accompanied by references to domino effects ("race to the bottom") of differential alcohol taxation. For instance, Denmark and Finland reduced their taxes with reference to cross border shopping in neighboring countries with low prices (Germany and Estonia, respectively); Sweden is currently contemplating the effects of lowering its taxes to get prices closer in line with its closest neighbors. Our estimates suggest that indeed the consequences for tax revenues are non-trivial. Taking the recent Danish spirits tax cut in October 2003 and making a back of the envelope calculation of the effects on Swedish tax revenues suggest a direct loss of about 214 million kronor (some 24 million euro per year or 2.7 euro per capita)[20]. While the tax revenue implications in general will depend on many factors, these numbers nevertheless suggest that the literature on tax competition between governments (Kanbur and Keen, 1993, Wang, 1999 and Nielsen, 2001), have empirical relevance.

[20] We calculate the percentage fall in sales volume that is implied by estimates in column 2 in Table 2 for each municipality. By multiplying these numbers with municipal population and tax revenue per liter of spirits (201 kronor per liter of spirits and an additional 66 kronor in VAT if we use a medium price brand of spirits as a basis for the VAT calculations) we reach the above number. As a comparison, we estimate that the Finnish tax cut in March 2004, which had an effect primarily on the sparsely populated northern regions, lowered Swedish tax revenues by 21.5 million kronor per year.

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PAPER 4

When is a Lower Exchange Rate Pass-Through Associated with Greater Exchange Rate Exposure?

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ABSTRACT. We study the relationship between exchange rate pass-through (how exchange rates affect import prices) and exchange rate exposure (how exchange rates affect profits) under flexible prices. We note that the convexity of costs is an important determinant of both pass-through and exposure, and increasing the convexity of costs usually reduce both pass-through and exposure. Hence, if industries differ in their cost function, then one could see a positive correlation between pass-through and exposure across industries. This effect can be mitigated by the negative correlation between pass-through and exposure induced by changes in the price elasticity of demand.

1. Introduction

Microeconomic theory tells us that exchange rate fluctuations affect the pricing and output decisions of exporting firms, and hence also their profitability. The pass-through of exchange rate changes into import prices, as well as the effect of exchange rate fluctuations on the value of the firm are two closely related topics, yet only one previous paper study their relationship in a theoretical model, namely Bodnar et al. (2002)[1]. They set up a duopoly model with an exporting firm and an import competing foreign firm.[2] They show that exchange rate pass-through and exposure should be negatively correlated across industries. The intuition for their result is that when the substitutability between the domestically produced good and the imported good increases in an industry (which in effect increases the price elasticity of demand for the firms) both firms have greater incentives to stabilize prices, and hence exchange

[0] We thank Richard Friberg for valuable comments.

[1] For a nice survey of studies on exchange rate pass-through, see Pollard and Coughlin (2003). The literature on exchange rate exposure is vast. Previous theoretical papers include, to name a few, the seminal work by Adler and Dumas (1984), Levi (1994) and Marston (1996). Empirical papers include Jorion (1990), Ahimud (1994), Campa and Goldberg (1995), He and Ng (1998), Griffin and Stulz (2001), and lately Dominguez and Tesar (2005).

[2] Other theoretical models of exchange rate exposure in an oligopoly setting include von Ungern-Sternberger and von Weizsacker (1990) and lately Friberg and Ganslandt (2005) who simulate exchange rate exposure for firms in the Swedish bottled water market.

rate pass-through falls. Profits on the other hand become more sensitive to exchange rate changes, so exposure increases. If industries differ mainly in the substitutability between domestically produced and imported goods, one should therefore see a negative relationship between exchange rate pass-through and exposure across industries. The model is tested on Japanese data and is capable of explaining some, but not all of the features of the data. In particular, the estimated pass-through and exposure coefficients do not seem to vary as predictably across industries as their theoretical analysis would suggest.

This is not surprising and does not constitute a critique of the paper itself. First, since the authors only examine eight different industries, the scope for a cross-sectional empirical analysis is limited. Second, in the industrial organization literature, the problems in carrying out empirical inter-industry studies of relations between market structure and firm behavior and performance (commonly referred to as structure-conduct-performance analysis) are well known.[3] Individual industries differ to such a large extent that observable industry characteristics may not be sufficient to explain industry conduct and/or performance. In the case of exchange rate pass-through and exposure, there are many factors besides product substitutability that may vary substantially across industries, and also affect both exchange rate pass-through and exchange rate exposure.

In this paper we study how variation on the supply side across industries will affect the relationship between pass-through and exposure. Nonlinearities in costs act as an incentive for firms to stabilize demand, and hence prices. Since pricing affects profitability, we believe that it is important to allow for the possibility of nonlinearities in the cost function when studying the relationship between exchange rate pass-through and exposure across industries. This is especially so since the degree of scale economies, especially in the short-run, can differ across industries due to for example different labor intensities in production.

We introduce a convex cost function and study the effects of changing the convexity of costs. We do this both in a simple model of monopolistic competition as well as in the oligopoly models used by Bodnar et al. (2002). We find that increasing the convexity of costs reduces both exchange rate pass-through and exposure, both in the case of monopolistic competition as well as in the duopoly price and quantity models. The conclusion is thus that if industries differ mainly on the supply side, this implies a positive correlation between pass-through and exposure. We find that allowing for non-constant marginal costs, the model also fits the data better, both with respect to the estimated elasticities, and their correlation across industries.

[3] See for example Schmalensee (1989) for a discussion on this topic.

In section 2 we define exchange rate pass-through and exposure, while section 3 analyses their relationship in a basic model of monopolistic competition. Section 4 introduces the duopoly model analyzed by Bodnar et al. (2002) allowing for convex costs. In section 5 we examine how the correlation between pass-through and exposure elasticities across industries estimated in Bodnar et al. (2002) are affected by controls for the convexity of the cost function. Section 6 concludes.

2. Pass-through and exposure

Consider an exporting firm that sells to a foreign market but produces domestically.[4] Profits are then

$$\pi = spq - C\left(q\right) \tag{2.1}$$

where s is the exchange rate, measured as the home currency price of one unit of foreign exchange, p is the price in the foreign currency, q is the quantity sold, and $C(q) = q^{\alpha}$ is the cost of producing q units of output. The (constant) elasticity of costs with respect to output is thus α, and we require that costs are (weakly) convex in the quantity, $\alpha \geq 1$. Compared to Bodnar et al. (2002) we have thus relaxed the assumption of linear costs. Demand depends on the market structure and is specified below.

We are interested in how the functional forms of cost and demand functions affect exchange rate pass-through and exposure. Exchange rate pass-through, $\varepsilon_{p,s}$, is defined as the exchange rate elasticity of the price[5],

$$\varepsilon_{p,s} \equiv -\frac{dp}{ds}\frac{s}{p}.$$

Exposure, $\varepsilon_{\pi,s}$, is defined as the exchange rate elasticity of profits,

$$\varepsilon_{\pi,s} \equiv \frac{d\pi}{ds}\frac{s}{\pi}.$$

In the following, we analyze how pass-through and exposure are correlated across industries that differ on the demand or cost side.

3. Monopolistic competition

First consider the firm's optimal strategies when the foreign market is characterized by monopolistic competition.[6] The domestic exporting firm, indexed by $z = 0$, competes with a continuum of foreign producers, indexed by $z \in (0, 1]$. We suppose

[4] Bodnar et al. (2002) allow for imported intermediate inputs in production. To simplify the analysis, we assume that firms only produce in their home countries.

[5] Since $\frac{dp}{ds} < 0$, we follow the usual convention and multiply by minus one to ensure that the expression for elasticity is positive.

[6] This market structure follows Flodén and Wilander (2005).

that the utility function of a representative household is weakly separable (functional separability), so that we can study the consumers' consumption of the differentiated good independent of all other goods. Denoting by $q(z)$ the quantity of the differentiated good z consumed by a household in the foreign market, the household chooses quantities $q(z)$ to solve

$$\max_{q(\cdot)} \left[\int q(z)^{\rho} \, dz \right]^{1/\rho}$$

subject to

$$\int p(z) \, q(z) \, dz = Y$$

where $p(z)$ is the price charged by firm z, and Y is the household's total spending on the differentiated products. The parameter ρ measures the degree of substitutability between the products. The goods are substitutes if $\rho \in (0,1)$ and become perfect substitutes as ρ approaches 1. The goods are compliments for $\rho \in (-\infty, 0)$ and become perfect compliments as ρ approaches $-\infty$. If $\rho = 0$ the goods are independent. For our purposes, we restrict ρ to be between zero and unity.

The household's first order condition implies that

$$q = \theta p^{-\frac{1}{1-\rho}} \tag{3.1}$$

where $\theta = QP^{\frac{1}{1-\rho}}$, $Q \equiv \left[\int q(z)^{\rho} \, dz\right]^{1/\rho}$ is the aggregate quantity consumed, and P is the aggregate price level for the differentiated good defined from $PQ = Y$. The price elasticity of demand is thus constant and equal to $1/(1-\rho) > 1$.

The exporting firm chooses the price p to maximize profits (2.1) subject to the demand function (3.1), resulting in an optimal price

$$p = (ks)^{-\gamma}$$

where $k = \theta^{1-\alpha}\rho/\alpha$ and $\gamma = (1-\rho)/(\alpha - \rho)$. Taking derivatives of this price and the implied optimal profit with respect to the exchange rate, we find that pass-through is

$$\varepsilon_{p,s} = \frac{(1-\rho)}{\alpha - \rho} \tag{3.2}$$

and that exposure is

$$\varepsilon_{\pi,s} = \frac{\alpha}{\alpha - \rho}. \tag{3.3}$$

Proposition 1 shows how changes in product substitutability, ρ, and in the convexity of the cost function, α, affect pass-through and exposure.

PROPOSITION 1. *Under monopolistic competition, if* $\alpha > 1$, *an increase in* ρ *reduces pass-through, but raises exposure. An increase in* α *reduces both pass-through and exposure.*

PROOF. The derivative of (3) with respect to ρ is given by $\frac{1-\alpha}{(\alpha-\rho)^2} < 0$ and the derivative of (4) with respect to ρ is given by $\frac{\alpha}{(\alpha-\rho)^2} > 0$. The derivative of (3) with respect to α is given by $\frac{\rho-1}{(\alpha-\rho)^2} < 0$ while the derivative of (4) with respect to α is given by $\frac{-\rho}{(\alpha-\rho)^2} < 0$. □

The first part of Proposition 1 is just a restatement of Bodnar et al.'s main result (albeit in a different setting) that higher product substitutability raises the price elasticity of demand, which has opposing effects on pass-through and exposure. The second part of Proposition 1 shows that an increase in the convexity of the cost function reduces both exchange rate pass-through and exchange rate exposure. So, if there is large variation across industries on the supply side, so that industries differ mainly in their cost function, we should see a positive correlation between pass-through and exposure across industries. In contrast, when there is variation across industries mainly on the demand side the correlation should be negative, as predicted by Bodnar et al.

To understand the first part of Proposition 1, note that fluctuating production raises average costs if the cost function is convex. Demand fluctuations therefore reduce average profits, and firms then want to stabilize import prices by limiting exchange rate pass-through. Obviously this effect is stronger the more convex are costs. However, given that costs are convex, this effect is also stronger the more price sensitive is demand. An increase in ρ therefore also reduces pass-through.

While higher ρ and α both imply lower pass-through, the impact on exposure is different. Differentiating profits with respect to the exchange rate, we get that (by the envelope theorem) $d\pi/ds = pq$. It follows then that exposure, $\frac{d\pi}{ds}\frac{s}{\pi}$, equals sales divided by profits. Increasing ρ reduces sales, but results in a proportionately larger fall in profits since it also reduces the markup. Exposure then increases. For an increase in α, the opposite occurs. Sales fall, but profits fall proportionately less.[7] Exposure then falls.

4. Oligopolistic competition

Assume now that the foreign market is characterized by oligopolistic competition as in Bodnar et al. (2002). The exporting firm competes with only one foreign firm, and households in the foreign market choose quantity q of the exporting firm's good and q_f of the foreign firm's good to solve

$$\max_{q,q_f} \left[\gamma q^{\rho} + (1-\gamma)\, q_f^{\rho}\right]^{1/\rho}$$

[7] Given the functional forms here, the markup is independent of α.

subject to

$$pq + p_f q_f = Y$$

where $0 < \gamma < 1$ is the relative preference for the exporting firm's good.

The solution to the households' problem can be represented as the direct demand functions

$$q = \frac{Y/p}{1 + \beta^{\frac{1}{\rho-1}} \left(\frac{p_f}{p}\right)^{\frac{\rho}{\rho-1}}} \tag{4.1}$$

$$q_f = \frac{Y/p_f}{1 + \beta^{\frac{-1}{\rho-1}} \left(\frac{p}{p_f}\right)^{\frac{\rho}{\rho-1}}} \tag{4.2}$$

or as the indirect demand functions

$$p = \frac{Y/q}{1 + \beta^{-1} \left(\frac{q_f}{q}\right)^{\rho}} \tag{4.3}$$

$$p_f = \frac{Y/q_f}{1 + \beta \left(\frac{q}{q_f}\right)^{\rho}} \tag{4.4}$$

where $\beta = \gamma / (1 - \gamma)$.

In the following subsections we analyze the equilibrium outcomes under Cournot and Bertrand competition. Since we are interested in how price setting is affected by exchange rate movements, Bertrand competition with price as the strategic variable is the natural starting point. The analysis turns out to be less complicated under Cournot competition, however, so we first examine that market structure.

4.1. Cournot competition. Assume that competition between the exporting firm and the foreign firm is characterized by Cournot competition. The exporting firm then chooses quantity q to maximize profits (2.1), and the foreign firm chooses q_f to maximize $p_f q_f - q_f^{\alpha}$ subject to the indirect demand functions (4.3) and (4.4). We only consider the pure strategy Nash equilibrium, although mixed strategy equilibria may exist. This equilibrium is characterized by the home and foreign firms' first order conditions,

$$\frac{\partial \pi}{\partial q} = s\left(1 + \frac{\partial p}{\partial q}\frac{q}{p}\right) - \frac{\alpha q^{\alpha-1}}{p} = 0 \tag{4.5}$$

and

$$\frac{\partial \pi_f}{\partial q_f} = 1 + \frac{\partial p_f}{\partial q_f}\frac{q_f}{p_f} - \frac{\alpha q_f^{\alpha-1}}{p_f} = 0. \tag{4.6}$$

Let $\lambda = pq/Y$ denote the market share of the exporting firm, and take derivatives of the demand functions to find that $1 + \frac{\partial p}{\partial q}\frac{q}{p} = \rho(1-\lambda)$ and $1 + \frac{\partial p_f}{\partial q_f}\frac{q_f}{p_f} = \rho\lambda$. The Cournot equilibrium quantity for the exporting firm and the associated price is

$$q = \left[\frac{s\rho\lambda Y(1-\lambda)}{\alpha}\right]^{\frac{1}{\alpha}}$$

$$p = \left[\frac{\alpha}{s\rho(1-\lambda)}\right]^{\frac{1}{\alpha}}(\lambda Y)^{\frac{\alpha-1}{\alpha}}$$

and and that the equilibrium market share is $\lambda = \beta s^{\frac{\rho}{\alpha}} / \left(1 + \beta s^{\frac{\rho}{\alpha}}\right)$.

Taking derivatives of the equilibrium price and profits we find that exchange rate pass-through is

$$\varepsilon_{p,s} = \frac{1-\rho(1-\lambda)}{\alpha} + \frac{\rho(1-2\lambda)}{\alpha^2}$$

and that exposure is

$$\varepsilon_{\pi,s} = 1 + \frac{\rho(1-\lambda)}{\alpha} + \frac{\rho^2\lambda(1-\lambda)}{\alpha-\rho(1-\lambda)}.$$

Parts (i) and (ii) of Proposition 2 confirm the main result in Bodnar et al (2002) also when allowing for non-linearity in costs.[8] More interestingly, parts (iii) and (iv) show that an increase in the convexity of the cost function typically reduces both pass-through and exposure. If industries differ mainly on the production side (i.e. have different α, for example because of different labor intensities), theory thus predicts a positive correlation between pass-through and exposure across industries, just as in the case of monopolistic competition.

PROPOSITION 2. *Under Cournot competition, if $s = 1$, (i) an increase in ρ reduces pass-through; (ii) an increase in ρ raises exposure; (iii) an increase in α reduces pass-through unless $\lambda > \frac{2}{3}$ and $\rho > \frac{\alpha}{(4-\alpha)\lambda+\alpha-2}$; and (iv) an increase in α reduces exposure;*

PROOF. Evaluate derivatives of pass-through and exposure with respect to ρ and α at $s = 1$. To show part (i), note that

$$\frac{\partial\varepsilon_{p,s}}{\partial\rho}|_{s=1} = \frac{-(\alpha-1)+(\alpha-2)\lambda}{\alpha^2} < 0$$

where the inequality follows from $\alpha - 1 > (\alpha-2)\lambda$. To show part (ii), note that

$$\frac{\partial\varepsilon_{\pi,s}}{\partial\rho}|_{s=1} = \frac{(1-\lambda)}{\alpha} + \frac{\rho\lambda(1-\lambda)[2\alpha-\rho(1-\lambda)]}{[\alpha-\rho(1-\lambda)]^2} > 0.$$

[8] We only consider the the case when $s = 1$ so that costs in the two countries are symmetric. The equilibrium market share λ is then unaffected by changes in ρ and α. Alternatively we could also consider the case where $s \neq 1$ and holding market share fixed (that is, we ignore $\frac{\partial\lambda}{\partial\rho}$ and $\frac{\partial\lambda}{\partial\alpha}$).

The ambiguous sign in part (iii) follows from

$$\frac{\partial \varepsilon_{p,s}}{\partial \alpha}|_{s=1} = -\frac{\alpha\left[1-\rho\left(1-\lambda\right)\right]+2\rho\left(1-2\lambda\right)}{\alpha^{3}}$$

$$\begin{cases} >0 & \text{if } \lambda > \frac{2}{3} \text{ and } \rho > \frac{\alpha}{(4-\alpha)\lambda+\alpha-2} \geq \frac{1}{2} \\ \leq 0 & \text{otherwise} \end{cases}$$

and part (iv) follows from

$$\frac{\partial \varepsilon_{\pi,s}}{\partial \alpha}|_{s=1} = \frac{-\rho\left(1-\lambda\right)}{\alpha^{2}} - \frac{\rho^{2}\lambda\left(1-\lambda\right)}{\left[\alpha-\rho\left(1-\lambda\right)\right]^{2}} < 0.$$

□

Under monopolistic competition, there was an unambiguous and intuitive result that more convex costs raise the incentives to stabilize production and thus reduces pass-through. For most parameter values, this result also applies under Cournot competition, but if ρ and λ are high and α is low, an increase in α raises pass-through. This result is less intuitive, and is generated by the foreign firm's reaction to the exchange rate shock.[9] When both ρ and λ are large the price response of the foreign firm to output (demand) changes of the exporting firm is high[10] and this effect can dominate for low convexity of the cost function.

The effect on exposure of a higher convexity α is unambiguously negative. Intuitively, the effect is not as obvious. The exposure elasticity can be divided into two parts, $d\pi/ds$ and s/π. When the convexity of the cost function increases, industry profits will go up. This is because higher α reduces competitive behavior in the industry, as the incentives to expand production are lower. Hence, s/π will fall. Unless the sensitivity of profits with respect to the exchange rate, $d\pi/ds$, increases sufficiently when α increases, this implies that the exposure elasticity will fall.

The sensitivity of profits with respect to the exchange rate can be written as

$$d\pi/ds = (\lambda Y)\left(\frac{1-\rho\left(1-\lambda\right)}{\alpha}\right) + sY\left(\frac{\alpha-\rho}{\alpha}\right)\frac{\partial\lambda}{\partial s}. \tag{4.7}$$

Profits thus change due to a valuation effect on the initial net foreign currency position, and as a result of a change in the foreign currency position due to a change in the market share. Substituting for $\frac{\partial\lambda}{\partial s}$ and taking the derivative with respect to α,yield[11]

$$\frac{d^{2}\pi}{dsd\alpha}|_{\lambda=\bar{\lambda}} = -\frac{2\lambda\left(1-\lambda\right)\rho\left(1-\rho\right)}{\alpha^{3}} < 0$$

[9] This is confirmed by deriving the exporting firm's pass-through conditional on the foreign firm's price being fixed, so that the foreign firm does not react to the exchange rate change. Numerical simulations of this expression show that it is decreasing in alpha.

[10] $(\frac{\partial p_f}{\partial q}\frac{q}{p_f} = -\rho\lambda)$

[11] We ignore the effect $\frac{\partial\lambda}{\partial\alpha}$.

Hence also the sensitivity of profits, $d\pi/ds$, falls as the convexity of costs increase, which establishes the result.

4.2. Bertrand competition. Assume now that competition between the exporting firm and the foreign firm is characterized by Bertrand competition. The exporting firm then chooses price p to maximize profits (2.1) and the foreign firm chooses p_f to maximize $p_f q_f - q_f^{\alpha}$ subject to the demand functions (4.1) and (4.2).

The equilibrium price-quantity pairs for the exporter and the foreign firm are given by

$$p=\left[\frac{(\lambda Y)^{\alpha-1}(1-\rho\lambda)\alpha}{s(1-\lambda)\rho}\right]^{\frac{1}{\alpha}},\quad q=\left[\frac{s\rho(1-\lambda)\lambda Y}{(1-\rho\lambda)\alpha}\right]^{\frac{1}{\alpha}} \tag{4.8}$$

and

$$p_f=\left[\frac{((1-\lambda)Y)^{\alpha-1}(1-\rho(1-\lambda))\alpha}{\lambda\rho}\right]^{\frac{1}{\alpha}},\quad q_f=\left[\frac{\rho\lambda(1-\lambda)Y}{(1-\rho(1-\lambda))\alpha}\right]^{\frac{1}{\alpha}} \tag{4.9}$$

where the equilibrium market share for the exporter is

$$\lambda=\frac{\beta(zs)^{\frac{\rho}{\alpha}}}{1+\beta(zs)^{\frac{\rho}{\alpha}}}$$

and $z=[1-\rho(1-\lambda)]/(1-\rho\lambda)$. Note that the expression for λ is an implicit function since z is a function of λ. The equilibrium profits for the exporter are then

$$\pi= s\lambda Y\left[1-\frac{(1-\lambda)\rho}{(1-\rho\lambda)\alpha}\right] \tag{4.10}$$

We show in the appendix that the implied pass-through and exposure elasticities are

$$\varepsilon_{p,s}=\frac{1}{\alpha}\left[1-\frac{\rho(1-\rho+\rho\lambda)[(1-\rho\lambda)(1-\lambda)(\alpha-1)+\lambda(1-\rho)]}{\alpha(1-\rho\lambda)(1-\rho+\rho\lambda)-\rho^2\lambda(1-\lambda)(2-\rho)}\right]$$

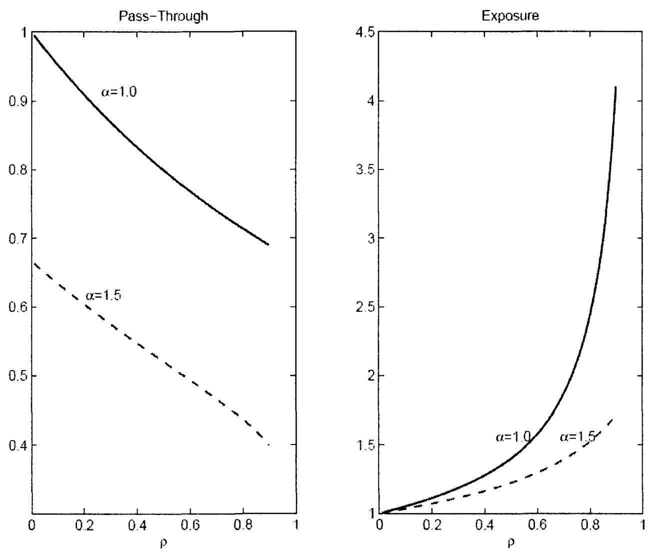
and

$$\varepsilon_{\pi,s}=1+\frac{\rho(1-\lambda)(1-\rho+\rho\lambda)\left[\alpha(1-\rho\lambda)^2-(1-\rho\lambda)(1-\lambda)\rho+\rho\lambda(1-\rho)\right]}{((1-\rho\lambda)\alpha+(\lambda-1)\rho)\left[\alpha(1-\rho\lambda)(1-\rho+\rho\lambda)-\rho^2\lambda(1-\lambda)(2-\rho)\right]}.$$

Note that with $\alpha=1$ these expressions reduce to $\varepsilon_{p,s}=\frac{(1-\rho\lambda)}{1-\rho^2\lambda(1-\lambda)}$ and $\varepsilon_{\pi,s}=1+\frac{(1-\lambda)(1-\rho+\rho\lambda)\rho}{[1-\rho^2\lambda(1-\lambda)](1-\rho)}$ which is identical to the expressions in Bodnar et al. (2002) for the case of no imported intermediate inputs.

It is complicated to analyze analytically how these expressions are affected by the degree of product substitutability and the convexity of costs. Instead we provide numerical examples. Figure 1 plots pass-through and exposure as a function of ρ. The solid line plots the expressions for $\alpha = 1$ and the dotted line for $\alpha = 1.5$. The figure shows that increasing the convexity of costs will generally reduce pass-through, as the line corresponding to $\alpha = 1.5$ is everywhere below the line for $\alpha = 1$. Increasing α also lowers exposure, and this effect is typically stronger when products are closer substitutes. Once again this happens since increasing the convexity of costs reduces competitive behavior in the industry and thus raises profits. Provided that the exporter's market share is not too large, the effect (on industry profits) of increasing α is larger when products are closer substitutes (ρ is high), which is intuitive since it is when products are close substitutes that competition is toughest. Moreover, just as found in the case of Cournot competition, increasing ρ reduces pass-through and raises exposure even in the presence of convex costs.

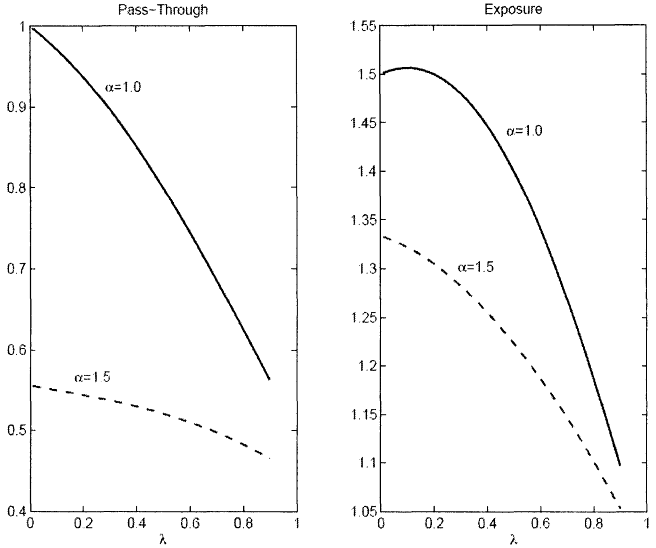
Figure 1: Pass-through and exposure for different degrees of substitutability



Note: The figure plots pass-through and exposure as functions of ρ, holding the market share constant at $\lambda = 0.5$.

A second finding in Bodnar et al. (2002) is the reduction in both pass-through and exposure as the market share of the exporting firm, λ, increases. This holds also in the presence of convex costs, as can be seen from Figure 2.

Figure 2: Pass-through and exposure for different market shares



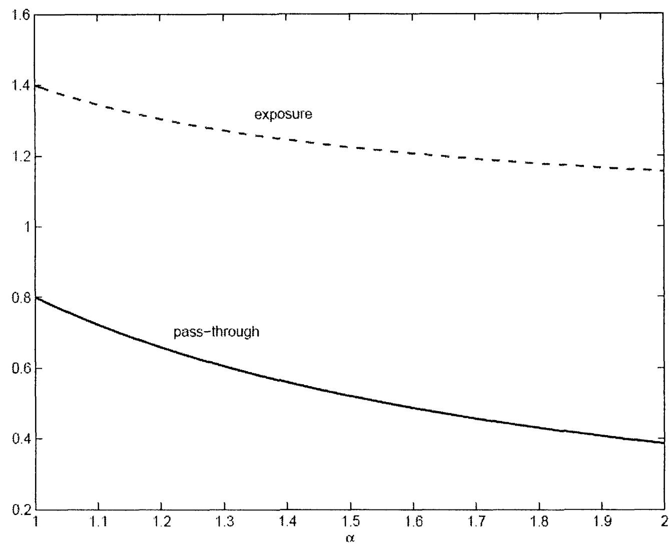
Note: The figure plots pass-through and exposure as functions of λ, holding product substitutability constant at $\rho = 0.5$.

Allowing for convex costs improves the price competition model. One problem with the price competition model under constant marginal costs is that pass-through is generally too high compared to what is estimated from data, unless the market share is close to unity. With convex costs however, the pass-through estimates in the model are typically well below unity when costs are convex, even at lower market shares.

Figure 3 plots pass-through and exposure as functions of α. For the parameter values used, both pass-through and exposure fall as α increases. This finding holds for most parameter values and is once again understood by the incentive to stabilize demand when the cost function is convex. But as under Cournot competition, pass-through is a hump-shaped function of α when both λ and ρ are high. It is then possible that an increase in α raises pass-through and reduces exposure for low values of α.[12]

[12] Once again this is due to the reaction of the foreign firm.

Figure 3: Pass-through and exposure as functions of the convexity of costs



Note: The figure plots pass-through and exposure as functions of the convexity of costs, α, holding ρ and λ constant at $\rho = 0.5$ and $\lambda = 0.5$.

5. A quick look at the data

Bodnar et al. (2002) simultaneously estimate exchange rate pass-through and exposure coefficients for eight Japanese industries, using data from 1986-1995. The cross industry correlation between pass-through and exposure across these industries is $-.0873$. Let us make a back of the envelope check and see if we can control for the convexity of the cost-function. Based on our analysis we expect that the negative correlation would be stronger. The reason is that we would then take into account the effect of a variable that causes the cross-industry correlation to be positive.

We can first note that if the production-function for a fixed level of the capital stock is $y = l^{\frac{1}{\alpha}}$, then $\frac{1}{\alpha}$ will be the labor share in production. The short-run cost function is then $c(y) = y^{\alpha}$, implying that firms/industries with higher labor-intensity (intensity of the flexible production factor), have lower convexity of costs. Firms/industries with different labor intensities may then at least in the short-run also differ in the response of prices and profits to changes in the exchange rate.

Using data from the 1998 Japanese Census of Manufacturers from the Ministry of the Economy, Trade and Industry (METI) we divide the total wage payments and worker compensations by the value of manufactured goods in each industry and uses this as a proxy for labor intensity. The resulting values, along with the coefficients on pass-through and exposure from Bodnar et al. (2002) are shown in Table 1.

Table 1: Pass-through, exposure, and labor intensity in Japanese industries

Industry	Pass-Through	Exposure	Labor intensity
Cameras	.471	.687	.17
Construction	.805	.384	.14
Copiers	.284	1.087	.12
Electronic Parts	.244	1.658	.14
Film	.146	1.494	.23
Magnetic Rec. Products	.218	1.433	.09
Measuring Equipment	.750	2.282	.20
Motor Vehicles	.262	.711	.11

Table 2 shows the partial correlation of exposure with pass-through and labor share as well as the simple correlation coefficients of exposure, pass-through and labor intensity. We would expect that the negative correlation between pass-through and exposure is stronger when we control for labor intensity, and that the correlation between labor intensity and exposure is positive. We would also expect that the correlation between pass-through and labor-intensity is positive, although we know from the theoretical section that for some parameter values an increase in the convexity of the cost function may increase pass-through.

Table 2: Partial and simple correlation coefficients

Partial Correlation	
Exposure with Pass-Through	−.1794
Exposure with Labor Intensity	.4155

Simple Correlation Coefficients	Exposure	Pass-Through	Labor Intensity
Exposure	1.0000		
Pass-Through	−0.0873	1.0000	
Labor Intensity	0.3894	.1922	1.0000

Table 2 confirms our prior in that the partial correlation coefficient between exposure and pass-through is larger than the simple correlation coefficient. Moreover, the correlation between the labor intensity proxy and both exposure and pass-through is positive. Obviously this is a too simple exercise to draw any strong conclusions from. With only eight industries none of the above reported correlations are significant. Nonetheless it is at least comforting that all results go in the direction that our analysis points to.

6. Concluding Remarks

This paper has analyzed the relationship between exchange rate pass-through and exposure under flexible prices. Changes in a firm's or industry's demand and cost structure affects both exposure and pass-through, and we show that increasing the convexity of the cost function usually reduces both pass-through and exposure. This effect is found in a simple model of monopolistic competition, but also in the oligopoly model studied by Bodnar et al. (2002), for a wide range of plausible parameter values.

7. Appendix

7.1. Pass-Through and Exposure under Monopolistic Competition. Let p be the exporter's price in foreign currency. Profits are

$$\pi = \theta s p^{-\frac{\rho}{1-\rho}} - \theta^{\alpha} p^{-\frac{\alpha}{1-\rho}}.$$

The optimal flexible price is then

$$p^*(s) = (ks)^{-\gamma},$$

where $k = \theta^{1-\alpha}\frac{\rho}{\alpha}$ and $\gamma = (1-\rho)/(\alpha-\rho)$. The derivative with respect to s is given by

$$\frac{dp^*(s)}{ds} = -\gamma k (ks)^{-\gamma-1}.$$

Multiplying by $-s$ and dividing by p^* implies that the pass-through elasticity is

$$\varepsilon_{p,s} = -\frac{dp^*(s)}{ds}\frac{s}{p^*(s)} = \gamma = (1-\rho)/(\alpha-\rho).$$

Profits are given by

$$\pi^*(s) = \theta s (ks)^{\frac{\gamma\rho}{1-\rho}} - \theta^{\alpha} (ks)^{\frac{\alpha\gamma}{1-\rho}}.$$

Since $1 + \frac{\gamma\rho}{1-\rho} = \frac{\alpha\gamma}{1-\rho}$, this expression can be simplified to

$$\pi^*(s) = s^{\frac{\alpha\gamma}{1-\rho}} \left[\theta k^{\frac{\gamma\rho}{1-\rho}} - \theta^{\alpha} (k)^{\frac{\alpha\gamma}{1-\rho}}\right].$$

Differentiating the above expression with respect to s, multiplying by s and dividing by $\pi^*(s)$ implies that exposure elasticity is

$$\frac{d\pi^*(s)}{ds}\frac{s}{\pi^*(s)} = \frac{\alpha}{\alpha-\rho}.$$

7.2. Pass-Through and Exposure under Quantity Competition. Under Cournot competition,

$$p = \left[\frac{\alpha}{s\rho(1-\lambda)}\right]^{\frac{1}{\alpha}} (\lambda Y)^{\frac{1-\alpha}{\alpha}}$$

and

$$q = \left[\frac{s\rho\lambda Y(1-\lambda)}{\alpha}\right]^{\frac{1}{\alpha}}$$

and that the equilibrium market share is $\lambda = \beta s^{\frac{\rho}{\alpha}} / \left(1 + \beta s^{\frac{\rho}{\alpha}}\right)$. Substituting p and q into (2.1), using $C(q) = q^{\alpha}$ gives

$$\pi = s\lambda Y \left[1 - \frac{\rho(1-\lambda)}{\alpha}\right]$$

The derivative of π w.r.t. the exchange rate is given by

$$\frac{d\pi}{ds} = \left(sY\frac{d\lambda}{ds} + \lambda Y\right)\left(1 - \frac{\rho(1-\lambda)}{\alpha}\right) - s\lambda Y \frac{\rho}{\alpha}\frac{d\lambda}{ds}.$$

Inserting for $\frac{d\lambda}{ds}$ and multiplying by $\frac{s}{\pi}$yield

$$\varepsilon_{\pi,s} = 1 + \frac{\rho(1-\lambda)}{\alpha} + \frac{\rho^2\lambda(1-\lambda)}{\alpha - \rho(1-\lambda)}.$$

Differentiating p with respect to s we get

$$\frac{dp}{ds} = -\frac{1}{\alpha}s^{-\frac{1}{\alpha}-1}\left(\frac{\alpha}{\rho(1-\lambda)}\right)^{\frac{1}{\alpha}}(\lambda Y)^{\frac{1-\alpha}{\alpha}} + s^{-\frac{1}{\alpha}}(\lambda Y)^{\frac{1-\alpha}{\alpha}}\left(\frac{\alpha}{\rho(1-\lambda)}\right)^{\frac{1}{\alpha}}\left(\frac{1}{\alpha(1-\lambda)} + \frac{1-\alpha}{\alpha\lambda}\right)\frac{d\lambda}{ds}$$

Multiplying $\frac{dp}{ds}$ by $-\frac{s}{p}$ and using $\frac{d\lambda}{ds} = \frac{\rho}{\alpha}\frac{\lambda(1-\lambda)}{s}$, the expression for pass-through is

$$\varepsilon_{p,s} = \frac{1-\rho(1-\lambda)}{\alpha} + \frac{\rho(1-2\lambda)}{\alpha^2}.$$

7.3. Pass-Through and Exposure under Price Competition. In order to derive the pass-through elasticity under Bertrand competition, we totally differentiate the equilibrium price

$$p=\left[\frac{(\lambda Y)^{\alpha-1}(1-\rho\lambda)\,\alpha}{s\,(1-\lambda)\,\rho}\right]^{\frac{1}{\alpha}}$$

with respect to the exchange rate, s, taking into account the fact that the market share, λ, depends on s. By the chain rule the pass-through elasticity is given by

$$\varepsilon_{p,s}\equiv-\frac{dp}{ds}\frac{s}{p}=-\left[\frac{d\left((\lambda Y)^{\frac{\alpha-1}{\alpha}}\right)}{ds}\left(\frac{(1-\rho\lambda)\,\alpha}{s\,(1-\lambda)\,\rho}\right)^{\frac{1}{\alpha}}+\frac{d\left(\left(\frac{(1-\rho\lambda)\alpha}{s(1-\lambda)\rho}\right)^{\frac{1}{\alpha}}\right)}{ds}(\lambda Y)^{\frac{\alpha-1}{\alpha}}\right]\frac{s}{p}$$

which is equal to

$$s\left[\frac{\alpha-1}{\alpha\lambda}\frac{d\lambda}{ds}-\frac{1}{\alpha s}\right]+s\left[\frac{1}{\alpha}\frac{(1-\lambda)\,\rho}{(1-\rho\lambda)\,\alpha}\frac{\alpha\,(1-\rho)\,\frac{d\lambda}{ds}}{(1-\lambda)^2\,\rho}\right].$$

It then remains to solve for $\frac{d\lambda}{ds}$. Under price competition, the exporting firm's market share is given by $\lambda=\frac{\beta(zs)^{\frac{\rho}{\alpha}}}{1+\beta(zs)^{\frac{\rho}{\alpha}}}$, where $z=[1-\rho\,(1-\lambda)]\,/\,(1-\rho\lambda)$. Totally differentiating λ with respect to s, and solving for $\frac{d\lambda}{ds}$ yields

$$\frac{d\lambda}{ds}=\frac{\rho\lambda}{\alpha s}\frac{(1-\lambda)\,(1-\rho\lambda)\,(1-\rho+\rho\lambda)}{(1-\rho+\rho\lambda)\,(1-\rho\lambda)-\frac{\rho\lambda}{\alpha}\,(1-\lambda)\,(2\rho-\rho^2)}$$

Substituting for $\frac{d\lambda}{ds}$ in the above expression and simplifying yields the pass-through elasticity

$$\varepsilon_{p,s}=\frac{1}{\alpha}-\frac{(1-\rho+\rho\lambda)\,\rho\,[(1-\rho\lambda)\,(1-\lambda)\,(\alpha-1)+\lambda\,(1-\rho)]}{\left(\alpha^2\,(1-\rho\lambda)\,(1-\rho+\rho\lambda)-\rho\lambda\,(1-\lambda)\,\left(2\rho-\rho^2\right)\alpha\right)}$$

Using the expression for profits, (4.10), we get

$$\frac{d\pi}{ds}=\left[\lambda Y+sY\frac{d\lambda}{ds}\right]\left[1-\frac{(1-\lambda)\,\rho}{(1-\rho\lambda)\,\alpha}\right]+s\lambda Y\left[\frac{\rho\,[(1-\rho\lambda)-(1-\lambda)\,\rho]\,\frac{d\lambda}{ds}}{(1-\rho\lambda)\alpha(1-\rho\lambda)}\right]$$

Inserting for $\frac{d\lambda}{ds}$ and multiplying by $\frac{s}{\pi}$ yields the exposure elasticity

$$\varepsilon_{\pi,s}=1+\frac{\frac{\rho}{\alpha}\,(1-\lambda)\,(1-\rho+\rho\lambda)\,\left[(1-\rho\lambda)^2\,\alpha-(1-\rho\lambda)\,(1-\lambda)\,\rho+\rho\lambda\,(1-\rho)\right]}{((1-\rho\lambda)\,\alpha+(\lambda-1)\,\rho)\,\left[(1-\rho\lambda)\,(1-\rho+\rho\lambda)-\frac{\rho\lambda}{\alpha}\,(1-\lambda)\,\left(2\rho-\rho^2\right)\right]}$$

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PAPER 5

Common Currencies and Equity Prices - Evidence from a Political Event

Fredrik Wilander

ABSTRACT. This paper uses an event, the Swedish EMU- referendum, to study the relationship between exchange rate risk and the market capitalization of exporting companies. Using event-study methodology, we examine how firms on the Swedish stock market were affected by the decision not to join the European Monetary Union, which would to a have eliminated exchange rate risk for many companies. We find evidence of statistically significant negative abnormal returns on the trading day after the election for two out of fifteen examined industry indices, but no effects in a sample of publicly traded exporting firms.

1. Introduction

Recent empirical research has demonstrated that sharing a common currency with major trading partners significantly increases the level of trade between countries[1]. Currency unions seem to act like "trade boosters", increasing trade between member countries without diverting trade away from non-member countries. What has been much less studied is to what extent currency unions, which would mean a reduction of exchange rate risk and transaction costs, benefit exporting companies. In this paper we will use a political event, the Swedish referendum on whether or not to join the European Monetary Union (EMU), as a natural experiment to examine the relationship between introduction of a common currency and the market capitalization of exporting firms. If Sweden would have voted to join the EMU, exchange rate uncertainty and transaction costs associated with the use of both multiple currencies and hedging instruments would have been greatly reduced for many exporting companies. Prior to the election, the potential gain of removing exchange rate uncertainty (adjusted for the probability of a favorable outcome) should have been included in equity prices. The day after the election the probability of a favorable outcome was zero and one would expect a decline in equity prices of exporting firms. Using event study methodology, we

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[1] See for example Rose (2000), Persson (2001), Tenreyro (2001) and Micco et al. (2003).

perform an analysis on three levels, the aggregate stock-market, individual industries, as well as a sample of 33 firms traded on the Stockholm Stock Exchange with high exports to sales ratios. We find evidence of statistically significant negative abnormal returns on the trading day after the election for two out of fifteen examined industry indices, but no significant negative effect on the aggregate stock market or individual firms. The results are in line with earlier empirical work which finds at best a weak relationship between exchange rate volatility and the market value of firms. The results also indicate that the increases in bilateral trade that come from countries sharing a common currency may not necessarily benefit exporting companies to the same extent.

Section 2 discusses related literature, section 3 explains the methodology used in the paper, section 4 summarizes the data, 5 gives the estimation results and section 6 concludes.

2. Related Literature

The issue of how exchange rate fluctuations affect the international firm's profits has been extensively examined both theoretically and empirically. The studies can broadly be divided into two areas; one that analyzes the sensitivity of profits with respect to exchange rate changes (so called exchange rate exposure), and one that analyzes how the level of prices and profits are affected by exchange rate uncertainty. In a seminal paper, Adler and Dumas (1980) defined exchange rate exposure as the partial sensitivity of the value of the firm with respect to the exchange rate. Since then a vast number of studies have analyzed exchange rate exposure by utilizing the fact that the measure of exposure proposed by Adler and Dumas can be estimated by a regression of the market value of the firm (proxied by the price of the firm's equity) on exchange rates, bilateral or effective[2]. In a recent paper[3], Dominguez and Tesar employ the regression-based methodology in a cross-country, cross-industry analysis. They find that on average 12 percent of firms and 22 percent of industries included had significant and robust exposure using weekly returns data. While exceeding what would have been found by pure chance, it is still a modest number, indicating that the covariance between exchange rates and equity prices is likely to be rather weak[4].

[2] Jorion (1990), Bodnar and Gentry (1993) and Amihud (1994), fail to find a significant exposure to exchange rate variability for many firms and industries. More recent studies focusing on small open economies find stronger effects. Nydahl (1999) examine Swedish firms and find significant exposure for around 40% of the surveyed firms, after controlling for movements in the market portfolio, while de Jong et al (2003) examine Dutch corporations. In their survey, over 50% of firms exhibited exchange rate exposure.

[3] "Exchange Rate Exposure", forthcoming Journal of International Economics.

[4] One possible explanation could be that the costs of exchange rate uncertainty are not well understood by many corporations. Loderer and Pichler (2000) survey Swiss corporations about their

The theoretical literature on how exchange rate uncertainty affect the level of the firm's exports and profits is also vast, but in general, conclusions are sensitive to assumptions. In the early models, such as Clark (1973), exchange rate uncertainty tend to reduce the level of exports and profits for risk averse exporters. In these models the crucial assumptions beside risk aversion is that no inputs are imported, hedging is limited and output is constant over the planning horizon[5]. Moreover, exchange rate risk is the only source of uncertainty, a stark assumption for larger diversified firms. Relaxing any or several of these assumptions imply that the effect of exchange rate uncertainty is ambiguous, and can very well be positive. For example, relaxing the assumption that capacity decisions have to be made prior to exchange rate is known, exchange rate fluctuations can also create profit opportunities. Exporting can be seen as an option, an option that increases in value when the volatility of the exchange rate is high. In this case the value of the firm increases when exchange rate volatility increases. This is the case in both Franke (1991) and Sercu and Vanhulle (1992).

Studies on the effect of exchange rate volatility on the level of aggregate trade has been numerous, but often inconclusive[6]. For example, Frankel and Wei (1993) examine annual data of 63 countries between 1980 and 1990 and find generally small effects, and also changing coefficients for different parts of the sample. Interestingly, much larger effects have been found when analyzing the effect of sharing a common currency. Rose (2000) incorporates a common currency dummy variable in a gravity-equation framework to study the effects on bilateral trade. The finding is that countries with a common currency trade up to three times as much as countries that do not. Persson (2001) and Tenreyro (2001) both criticize this finding due to the non-random selection problem (countries that trade extensively may be more likely to also form a currency union). However, using various methods to control for this, such as propensity score matching, the common currency effect is still 50-65%. Micco, Stein and Ordonez (2003) study the effect of currency unions on the countries that form it, a somewhat different question (and perhaps more interesting from a policy point of view). Using data from 1999-2002 they study the effect of EMU and already after four years find a common currency effect of at least 10%. Moreover, there is no evidence of trade diversion

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currency risk profile, and while many claim using financial instruments to hedge short-term transactions, few are able to quantify their economic currency risk exposure, or even cash-flow exposure. Moreover, when they do know, not even publicly listed companies do usually reveal this information to investors, creditors and financial analysts. If firms have difficulties to quantify their exposure, one should not be surprised if the stock market also faces difficulties.

[5] Risk aversion is not sufficient to conlude that exchange rate uncertainty reduce the overall volume of exports and firm profits, see for instance Dellas and Zilberfarb (1993).

[6] For a nice survey of the many empirical papers covering the early period of floating exchange rates, see Coté (1994).

from non-member countries, so that the net benefit of sharing a common currency is positive. The question we ask in this paper is if these apparently large gains from sharing a common currency also benefit individual exporting companies.

3. Methodology

If market participants believed that joining the EMU was beneficial for Swedish exporting companies, then this potential gain, adjusted for the probability of a favorable election outcome, should have been included in the capitalized values of exporting companies prior to the election. In this paper we will use two different approaches to detect potential effects of the referendum. For both approaches the first objective is to identify an event period, the period over which the security prices of the firms involved will be examined. The referendum was held 14th September 2003, which was a Sunday. As argued in the introduction, all possibility of reducing exchange rate uncertainty had vanished on September the 15th, the day after the election day. Being the first trading day after the election, we limit the event window to this day, as information about the election result should be incorporated into equity prices over that day.

To be able to say something about the effects of the referendum, we need that the probability of a favorable outcome was non-zero, otherwise we will not be able to detect any effect on the event day. We will argue that in fact there was a great deal of uncertainty about the election outcome. For example, the day prior to the election, the main newspaper in Sweden, Dagens Nyheter, published results from four polls. One poll predicted a positive outcome, two polls predicted a negative outcome and one poll predicted a tie. This indicates that there essentially was a dead race between the two sides, perhaps with a slight favor for the "no-side"[7].

We now turn to explain the two different approaches used in this paper. We will start with the classical event study methodology explained in MacKinlay (1997), and then explain a regression-based approach, used by for example Schipper and Thompson (1985) and Chevalier (1995).

3.1. The Classical Approach. To estimate the impact of the event requires a measure of abnormal returns. We start by defining the abnormal return for security i as

[7] Another indication of the fact that the election outcome was far from certain can be found by examining the odds given by betting companies. For one large internet betting company from which the author received odds for the last trading day prior to the election (Friday the 12th September), these were set so that the implied probability of a favorable outcome was roughly 30%. An additional factor of uncertainty was the attack on the Swedish foreign minister Anna Lindh, an advocate of EMU, on Thursday the 11th of September and her death the day after. As a result of the murder, there was a discussion in the press about political motives behind the attack and how it would affect the election outcome.

$$AR_{it} = R_{it} - E\left[R_{it} \mid X_t\right] \tag{3.1}$$

where R_{it} is the actual observed continuously compounded daily return, and $E\left[R_{it} \mid X_t\right]$ is the normal return where X_t is the conditioning information for the normal return model. We will use a simple market model to estimate normal returns. We posit that there is a linear relationship between the daily return, R_{it}, and the market daily return, R_{mt}, so that

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it} \tag{3.2}$$

with $E\left[\varepsilon_{it}\right] = 0$ and $Var\left[\varepsilon_{it}\right] = \sigma_{\varepsilon}^2$. The parameters of the market model, α_i, β_i and σ_{ε}^2 are then estimated using OLS during an estimation window, which is non-overlapping with the event window. The abnormal return on the event day can then be calculated as

$$AR_{it} = R_{it} - \left[\widehat{\alpha_i} + \widehat{\beta}_i R_{mt}\right] \tag{3.3}$$

where $\widehat{\alpha_i}$ and $\widehat{\beta}_i$ are the estimates of α_i,and β_i respectively. Finally, the estimate of σ_{ε}^2, s_{ε}^2 can be calculated as $\frac{1}{L-2}\sum\left(AR_{it} - \overline{AR_{it}}\right)^2$ where $\overline{AR_{it}}$ is the mean abnormal return over the estimation window and L is the length of the estimation window, which in our case is 150 trading days. The standardized abnormal return, SAR_{it} is calculated as

$$SAR_{it} = \frac{AR_{it}}{\sqrt{s_{\varepsilon}^2}}$$

For $L > 30$ SAR_{it} is approximately normally distributed.

The classical approach will be used when measuring the impact of the event on the aggregate stock market, and also when examining individual industry indices.

3.2. The Regression Approach. Given that the event day is the same for all industries and firms, this is likely to lead to correlation in the residual returns of the examined securities. This problem of event day clustering can be overcome by estimating the impact of the event jointly for all securities and allowing for residual return correlation. We posit that the return of security i at date t is given by

$$R_{it} = \alpha_i + \beta_i R_{mt} + \gamma_i D_t + \varepsilon_{it} \tag{3.4}$$

where R_{it} is once again the actual observed continuously compounded daily return of security i, R_{mt} is the corresponding market return and D_t is a dummy variable taking the value of one on the event date and zero otherwise. The coefficient γ is then the event-day effect. Finally, ε is the error term which is assumed serially independent but may be contemporaneously correlated with the error term for other securities. Equation (4) is therefore estimated jointly for all securities as a system of seemingly unrelated regressions[8]. We can then test two hypotheses concerning the impact of the referendum; that either the sum of event parameters is zero, or that individual parameters are zero. This approach will be used when analyzing the effects on individual industries as well as individual firms.

4. Data

4.1. Aggregate Stock Market. For the analysis two value weighted stock market indices, the Stockholm All Share Index (SAX) and Affärsvärdens Generalindex (AFGX), were used. The benchmark against which normal performance is estimated is the Dow Jones World Stock Index (DJWSI). The estimation window is 150 trading days, and is nonoverlapping with the event window by 30 trading days. All data is from the Ecowin database.

4.2. Industry Analysis. We are also interested if there are any cross-sectional differences on the industry level. We therefore extend the analysis to incorporate a set of 15 industry indices. These are Affärsvärdens Industry Indices for 15 industries. While these are not the only indices available, we exclude the financial sector and real estate as well as indices that to some extent overlap with those included.

Table 1: Included indices in the industry analysis

1	Basic Materials	9	Health Care Providers
2	Biotechnology	10	Metals and Mining
3	Construction	11	Information technology
4	Chemicals	12	Internet consulting
5	Consumer Goods	13	Pharmaceuticals
6	Forestry	14	Telecommunications
7	Hardware Manufacturing	15	Transportation
8	Medical Technology		

As a market proxy we use AFGX. Once again the estimation window is 150 trading days, and is nonoverlapping with the event window by 30 trading days. All data is obtained from Ecowin database.

[8] In this case, when the regressors are identical, the parameter estimates are identical to equation by equation OLS, see Greene (2000).

4.3. Individual Securities. We finally estimate the effects on individual securities in a sample óf 30 public firms traded on the Stockholm Stock Exchange (SSE). The sample includes the traded firms that appear in the Sveriges Största Företag yearbook (Sweden's largest companies yearbook) rankings of top exporters as measured by export to sales ratios, plus additional firms that are traded on the SSE with export to sales ratios of 60% or higher. An additional requirement is also that the trading is frequent enough so that it is possible to estimate the parameters of a market model[9]. The included firms are presented in table A1 in the appendix. Summary statistics of the sample is presented in Table 2. Company information is taken from Sveriges Största Företag 2003-2004 Yearbook, the Osiris database and is in some cases supplemented by individual financial statements. Stock price data is from Datastream.

Table 2: Summary Statistics of Firm Sample

	Mean	Max	Min
Sales$^{\text{in million SEK}}$	26900	186000	8.738
Employees	18800	203070	20
Exports to Sales	82%	100%	59.6%

Note: 2002 numbers

5. Estimation and Results

5.1. Aggregate Stock Market Analysis. We will firstly examine if the outcome of the referendum affected the stock market on an aggregate level. The overall economic benefits of joining the EMU were debated intensely prior to the referendum. The removal of exchange rate uncertainty and lower interest rates were two arguments in favor of joining the EMU, while fear of sudden price increases and the abolishment of sovereign monetary policy were two arguments against joining. For our study it is also important to investigate if the event had an aggregate impact. If that is the case, we cannot use the Swedish stock market as a proxy for the market return. We estimate the parameters of the market model by the following linear projections

$$SAX_{rt} = \alpha + \beta \left(DJWSI_{rt} \right) + \epsilon_t \tag{5.1}$$

[9] Thin trading can result in a downward bias in estimated betas. While one can correct for this using lagged values of the return of market portfolio the differences are usually small. In fact, it is not clear that downward bias in betas necessarily implies misspecification in an event study, see Brown and Warner (1985). However, for some of the smaller firms with high export to sales ratios, the trading is so infrequent that it is not possible to estimate the market model and these firms are hence excluded.

as well as

$$SAX_{rt} = \alpha + \beta_1 (DJWSI_{rt}) + \beta_2 (DJWSI_{rt-1}) + \epsilon_t \tag{5.2}$$

where SAX_r and $DJWSI_r$ are the continuously compounded returns on the SAX and the DJWSI. In a second step we use (4) to estimate AR and SAR. Results are reported in Table A2 in the appendix.

For the event to have a statistically significant impact at the 5%-level, the standardized abnormal return should have an absolute value exceeding 2. This is not the case. The results remain unchanged when replacing SAX with AFGX. They also remain unchanged when we include the daily return of a trade weighted exchange rate index (TCW), or the return on bilateral exchange rates. We take this as evidence that we can use the Swedish stock market as a benchmark in our industry and firm analysis below, as there was no noticeable effect of the referendum.

5.2. Industry Analysis. In a second step we examine if any particular industries were affected by the referendum. We estimate the effect of the election both using the classical approach as well as the regression approach. We start by presenting the results from the former.

Table 3 below show the return and the standardized abnormal returns for each industry on the event day, ranked by negative abnormal performance (actual continuously compounded return on event day in parenthesis). The estimates from the market model using AFGX as a market proxy are shown in Table A3 in the appendix.

Table 3: Indices included in the industry analysis

	Industry	SAR_i (R_i)		Industry	SAR_i (R_i)
1	Internet consulting	-2.042* (−.0284)	9	Biotechnology	.3828 (.0117)
2	Information technology	-1.7586* (−.0187)	10	Metals and Mining	.5818 (.0073)
3	Telecommunications	-.9577 (−.0131)	11	Construction	.6896 (.0089)
4	Transportation	-.9196 (−.0176)	12	Medical Technology	.6637 (.0095)
5	Pharmaceuticals	-.6014 (−.0073)	13	Forestry	.7907 (.0087)
6	Hardware Manufacturing	-.5402 (−.0104)	14	Basic Materials	.7947 (.0076)
7	Health Care Providers	-.4389 (−.0023)	15	Consumer Goods	.8964 (.0093)
8	Chemicals	.2143 (.0032)			

Note: SAR is the standardized abnormal return.

Two industries had statistically significant negative abnormal returns at the 10% level, information technology and internet consulting (also significant at the 5% level). The return on the AFGX on the event day was .23%. No industries had significant positive abnormal performance on the event day. It is hard to find any reason for why information technology and internet consulting companies should be especially affected. It could be that these indices are comprised of firms that would have gained a lot from an introduction of the euro in Sweden, for example due to necessary changes in computer systems, which would have increased the demand for information technology products and services. Due to the dollar dominance in invoicing in some industries, most notably raw materials and wood products, it is perhaps not so surprising that these industries were not affected.

We also check the results by comparing them to the regression based approach. We thus estimate (4) for all industries simultaneously. The results are reported in Table 4 where we rank industries according to the t-value associated with the estimated event day parameter $\widehat{\gamma}$, in ascending order.

Table 4: SUR estimation of equation (4) with standard errors in parenthesis

Industry	$\widehat{\alpha}$	$\widehat{\beta}$	$\widehat{\gamma}$	$t-stat$
Internet consulting	.0005852 (.000917)	1.205976 (.0770923)	−.0318073 (.0142519)	−2.23
Information technology	.0010156 (.0007311)	1.070959 (.0614579)	−.0222332 (.0113616)	−1.96
Telecommunications	.0000855 (.0007429)	1.558607 (.0624497)	−.0165363 (.0115449)	−1.43
Transportation	.0007417 (.0012834)	.781015 (.1078931)	−.0201204 (.019946)	−1.01
Hardware Manufacturing	.0029982 (.0014457)	.5681654 (.1215333)	−.0146879 (.0224676)	−0.65
Pharmaceuticals	−.0001647 (.00097)	1.04242 (.0815421)	−.0094762 (.0150745)	−0.63
Health Care Providers	−.0001411 (.0010997)	.7647401 (.0924495)	.0021576 (.0170909)	0.13
Construction	−.0013059 (.0007892)	1.099374 (.0663412)	.0077622 (.0122644)	0.21
Chemicals	−.0001517 (.0006994)	.3500348 (.0587978)	.002571 (.0108698)	0.24
Biotechnology	.0018157 (.0012899)	.8294304 (.1084335)	.0079769 (.0200459)	0.40
Metals and Mining	.0003124 (.0006002)	.6007657 (.0504565)	.0056334 (.0093278)	0.60
Medical Technology	.0010997 (.0006366)	.5663374 (.0535187)	.0071441 (.0098939)	0.72
Forestry	−.0006018 (.000567)	.7578327 (.0476662)	.0075458 (.008812)	0.86
Basic Materials	−.0003352 (.0004836)	.65756 (.0406566)	.0065014 (.0075161)	0.87
Consumer Goods	−.0002458 (.0005292)	.6171358 (.0444891)	.0081516 (.0082246)	0.99

The results in Table 4 confirm those in Table 3. Two industries had significant negative abnormal returns on the event day, while none had significant positive abnormal returns. It is also interesting to note the similarities in the results from the two approaches.

5.3. Security Analysis. We finally estimate (4) simultaneously for the 30 exporting firms in our sample. Table 5 below summarizes the SUR estimation.

Table 5: Summary of SUR estimation of equation (4).

	Min.	Max.	Mean	Number of positive coefficients	Average T-ratio
α	−0.0070	0.0044	−0.0003	16	−0.1303
β	0.2035	2.4226	0.7854	30	10.1200
γ	−0.0786	0.0333	-0.0017	16	0.1126

While several firms had rather large negative event-day effects, no negative effects were statistically significant. The reason is the high residual variance, especially for many of the smaller firms. If one instead formed an equally weighted portfolio of the smaller firms with high export to sales ratios, then the event day effect when using the classical approach is borderline significant and negative. The intuitive explanation for this result is a diversification effect, the variance of the portfolios residual return is lower than that of the individual firms. For one firm the estimate of γ was both positive and statistically significant.

6. Concluding Remarks

This paper has used event study methodology to estimate the effect of common currencies on the capitalized values of exporting companies. We find generally small effects. On the aggregate level, the outcome of the EMU-referendum was not reflected in significant abnormal returns for the stock market. This is consistent with the broad market index including many firms with relatively little exposure to foreign currency risk. It is also consistent with earlier empirical and theoretical research in which the impact of exchange rate volatility on the level of firm profits is ambiguous.

On the industry level, the study examined 15 individual industries and found that 2 out of the 15 industries had statistically significant negative abnormal returns while no industries had statistically significant positive abnormal returns. On the firm level we found no statistically significant negative event day effects.

Given the large positive effects of a common currency on the level of aggregate trade, the lack of significant effects in this study is interesting. One potential explanation is that while there are positive effects for individual firms in sharing a common currency with major trading partners, there are also negative aspects. If the large increases in bilateral trade found in earlier studies is not only due to existing exporters increasing sales, but instead that firms that previously did not export now find it worthwhile (for example due to the reduction in transaction costs), then this would lead to increased competition in export markets and thus lower markups and profits for existing exporting firms. In a recent paper by Baldwin et al (2005), the authors show theoretically that the increases in bilateral trade found in the empirical literature can very well stem from both existing firms increasing their exports and that the number of firms that export increases. However, even if the increases in bilateral trade is partly due to existing firms increasing exports, can these exports on the margin be sold at the average markup? The results found in this study indicate that while sharing a common currency may act as a "trade booster", it is not certain that exporting companies will benefit to the same extent.

7. Appendix

Table A1: List of exporting firms included in sample

1	Alfa Laval	16	Nobia
2	Atlas Copco	17	Ortivus
3	Aspiro	18	Precise Biometrics
4	Astra Zeneca	19	Qmed
5	Axis	20	Rottneros
6	Billerud	21	Saab
7	Boliden	22	Securitas
8	Ericsson	23	Skanditek
9	Hennes & Mauritz	24	Skanska
10	Holmen	25	SKF
11	Höganäs	26	Ssab
12	Karo Bio	27	Syngenta
13	Klippan	28	Swedish Match
14	Micronic	29	Trelleborg
15	Net Insight	30	Volvo

Table A2: Estimation of Abnormal Returns for SAX Index

	$\widehat{\alpha}$ (Std. Errors)	$\widehat{\beta_1}$ (Std. Errors)	$\widehat{\beta_2}$ (Std. Errors)	R^2	$\sqrt{s_\varepsilon^2}$
(4)	.0000188 (.0007604)	1.027407 (.0804697)	-	.52	.0081
(5)	-.0002039 (.0007243)	1.01192 (.07653)	.3142216 (.0761548)	.57	.0081
	R_{it}	AR_{it}	SAR_{it}		
(4)	.0019	.0036	.4456		
(5)	.0019	.0024	.2962		

Table A3: Industry Estimates from the Market Model

Industry	$\widehat{\alpha}$ (Standard Errors)	$\widehat{\beta}$ (Standard Errors)	R^2	$\sqrt{s_\varepsilon^2}$
Basic Materials	−.0003982 (.0006755)	.6146666 (.050367)	.50	.0083
Biotechnology	.0020503 .0016594	.7983203 .1237393	.22	.0204
Construction	−.0024283 .0010628	1.062424 .0792479	.55	.0130
Chemicals	−.0003490 .0010131	.3993598 .075541	.16	.0124
Consumer Goods	−.0001267 .0007337	.6184556 .0547075	.46	.0090
Forestry	−.0004922 .0007677	.7035888 .0572438	.50	.0094
Hardware Manufacturing	.0018243 .0020067	.4714162 .1496308	.06	.0246
Medical Technology	.0011618 .0008284	.5597746 .0617743	.35	.0107
Health Care Providers	.0003265 .0009905	.9648739 .0738578	.53	.0122
Metals and Mining	.0000467 .0008428	.5613738 .0628416	.35	.0103
Information technology	.0005206 .0010027	1.023756 .0747704	.56	.0123
Internet consulting	.0010422 .001278	1.145312 .0952997	.49	.0157
Pharmaceuticals	.0001605 .001353	1.073416 .1008883	.43	.0167
Telecommunications	−.0002824 .0013109	1.149638 .0977502	.48	.0161
Transportation	−.0003676 .0016912	.8311538 .1261049	.22	.0208

Table A4: SUR Estimates for Individual Firms

Industry	$\widehat{\alpha}$ (Standard Errors)	$\widehat{\beta}$ (Standard Errors)	$\widehat{\gamma}$ (Standard Errors)
Alfa Laval	.0003788	.7807999	−.0171048
	.001515	.0929577	.0293756
Atlas Copco	.0003801	1.323429	.0033298
	.0010006	.0613932	.0194009
Aspiro	.0044023	1.193624	.0202786
	.0139881	.8582982	.2712308
Astra Zeneca	−.0003230	.7966574	−.0070228
	.001101	.0675591	.0213493
Axis	−.0000311	.6378242	−.0270314
	.0018055	.1107848	.0350091
Billerud	.0005073	.5863705	.0322903
	.0008675	.0532292	.0168209
Boliden	−.0000972	.9136376	.0287593
	.0015936	.0977827	.0309003
Ericsson	.0003581	2.422606	−.0277659
	.0019019	.1166986	.0368779
Hennes & Mauritz	−.0003059	.808937	.0210727
	.000789	.0484148	.0152996
Holmen	.0001415	.620485	.0119005
	.0006816	.0418213	.0132159
Höganäs	−.0007480	.5351752	−.0003047
	.0009167	.0562448	.0177739
Karo Bio	−.0043082	.5473859	.0032315
	.0020331	.1247481	.0394217
Klippan	−.0012960	.3391896	.0006289
	.0015245	.0935416	.0295601
Micronic	−.0015011	1.104992	−.0324211
	.0019844	.1217589	.038477
Net Insight	−.0003063	1.260146	−.0133457
	.0027206	.1669331	.0527525
Nobia	.0001370	.5189065	−.0011577
	.0011922	.0731503	.0231162
Ortivus	.0014723	.3273824	.0046865
	.0021717	.1332542	.0421097
Precise Biometrics	−.0070285	.6446865	−.0776212
	.0046157	.2832122	.0894979
Qmed	.0004258	.5445792	−.0153523
	.0017847	.1095099	.0346062
Rottneros	−.0003924	.615343	.0152743
	.0010978	.067362	.0212871
Saab	−.0002035	.3366276	.0125334
	.0009348	.0573599	.0181263
Securitas	−.0018945	1.257963	.0042057
	.001331	.0816699	.0258085
Skanditek	.0001317	.787375	−.0087979
	.0022187	.1361399	.0430216
Skanska	−.0000183	.9249758	.0074956
	.0008605	.0528025	.0166861
SKF	.0006560	.8976745	.0138787
	.0007938	.0487044	.0153911
SSAB	.0002386	.6143426	−.0014471
	.0008124	.0498488	.0157527
Syngenta	−.0003910	.3273128	−.0091025
	.001156	.0709285	.0224141
Swedish Match	.0000387	.2034651	−.0004389
	.0010095	.0619429	.0195746
Trelleborg	.0007130	.6824388	.0024032
	.000746	.0457745	.0144652
Volvo	.0002317	1.007903	.0051478
	.0007984	.0489903	.0154814

Note: Breusch-Pagan test of independence: chi2(435) = 990.206, Pr = 0.0000

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