ELSEVIER

Journal of International Economics 45 (1998) 59–76

Journal of INTERNATIONAL ECONOMICS

In which currency should exporters set their prices?

Richard Friberg*

Stockholm School of Economics, P.O. Box 6501, S-113 83 Stockholm, Sweden

Received 6 February 1997; accepted 17 August 1997

Abstract

This paper studies the choice of price setting currency for an exporter faced with the choice of setting price in his own, in the importers' or a third currency under exchange rate uncertainty. We establish that sufficient conditions on demand and cost functions for exchange rate pass-through to be less than unity under certainty are also sufficient conditions for price setting in the importer's currency to yield the highest expected profit under exchange rate uncertainty. Under the same conditions on demand and cost functions, setting price in the importer's currency maximizes expected utility when risk aversion and forward currency markets are introduced. © 1998 Elsevier Science B.V.

Keywords: Exchange rate fluctuations; Invoicing; Pricing of exports

JEL classification: F14; F23

1. Introduction

In this paper we study the choice of what currency to set price in from the viewpoint of an exporter. On a micro level the issue is interesting as we may learn much about the connections between the currency denomination of trade on the one hand, and exchange rate pass-through and exchange rate exposure on the other hand. Understanding the micro-foundations for the choice of currency denomination of trade is important for several macro issues. The choice of what currency to use in international trade will affect demand for different currencies and will

*Tel.: +46 8 736 96 45; fax: +46 8 31 32 07; e-mail:nerf@hhs.se

PII S0022-1996(97)00035-4

influence how the trade balance responds to an exchange rate change[1] as long as prices are not fully flexible. One recent article that explores macro-economic implications of pre-set prices in international trade is Betts and Devereux (1996) which studies exchange rate determination and volatility when a share of traded goods have prices that are pre-set in the importer's currency. Another example is Feenstra and Kendall (1997) who study how the price setting currency chosen determines the nature of deviations from Purchasing Power Parity.

The empirical relevance of any pre-set pricing analysis will of course be dependent on how long prices are fixed. As a floating exchange rate fluctuates literally by the minute it could be very costly to reoptimize offer prices every time the exchange rate changes. The study of pre-set prices will therefore perhaps be more interesting than in a domestic economy setting since exchange rates generally fluctuate much more than domestic price levels.

We model a situation where an exporter sets a price in some currency under exchange rate uncertainty. The exporter commits to sell the demanded quantity at the ex post realized price that importers face[2] and has the choice of what currency to set price in. We will call the currency chosen for this the price setting currency. Fig. 1 presents a stylized version of an international trade transaction to clarify the focus of this paper. Typically international trade involves a lag between the determination of quantities and the actual payment taking place. The currency used for the trade contract is denoted the invoicing currency and the currency used for the actual payment is referred to as the currency of payment.[3] In theory different currencies could be used for the different stages but with few known exceptions the same currency is used for all three purposes.

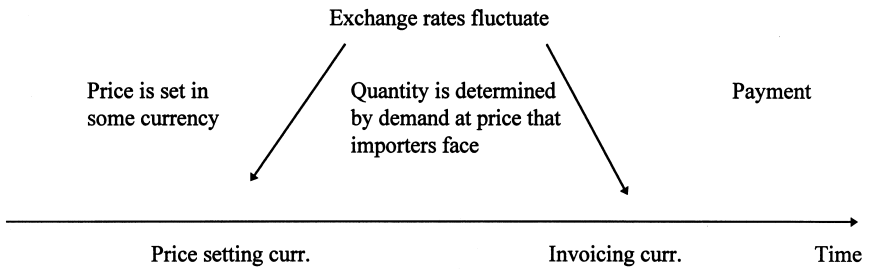

Fig. 1. A stylized international trade transaction.

[1] See, e.g., Magee (1974).

[2] Donnenfeld and Zilcha (1991) claim that the typical international transaction takes this form: first capacity is decided by the producer, new information arrives about the exchange rate, price is set and, finally, after the exchange rate is known, orders from buyers arrive and the goods are shipped.

[3] These roles also correspond to the different roles of money – price setting relates to the unit of account function, invoicing relates to the store of value function and the currency of payment fulfils the medium of exchange function.

In focusing on one of the roles of trade currency (price setting) while neglecting the other roles, this paper follows the tradition of previous work in the field.[4] Baron (1976), Giovannini (1988) and Donnenfeld and Zilcha (1991) study the pre-set pricing aspect. The shape of demand and cost functions will determine which price setting currency yields the highest expected profits. Baron (1976) found that, for a demand curve that is linear in price and constant marginal costs, setting price in the importer's currency yields the highest expected profits.

The novelty of this paper is to show that the choice of price setting currency is determined by similar conditions on the demand and cost functions to those that govern exchange rate pass-through (how much import prices change when the exchange rate changes). Specifically, we show that sufficient conditions for exchange rate pass-through to be less than unity (in the absence of uncertainty) are also sufficient conditions for price setting in the importer's currency to yield the highest expected profits under exchange rate uncertainty. The intuition behind this result lies in recognizing that both less than full exchange rate pass-through and price-setting in the importer's currency are ways of stabilizing demand.

Another contribution is to extend the analysis on pre-set prices to a third currency, a currency that is neither that of the exporter nor importer. The issue is empirically important as use of a third currency is common in international trade – an illustration of this is that 50% of world trade is invoiced in U.S. dollars[5] while the United States' share of world trade in manufactured goods is 14%.[6]

We also extend the literature by ranking the choice of price setting currency when there is risk aversion and forward currency markets. The extension is interesting since there is much evidence that firms do indeed use the forward market to hedge exchange rate exposure.[7]

A criticism waged against the literature in the pre-set pricing tradition is that it does not explain the empirical evidence on currency use in international trade. A number of papers have found that trade in manufactured goods between developed countries is mainly invoiced in the exporter's currency.[8] This finding is often referred to as ''Grassman's law'' following seminal work by Grassman (1973a), (1973b). Grassman studied the currency denomination of Swedish exports and

[4]There exists some related theoretical work that studies the invoicing currency alone, as separate from the pre-set pricing aspect that we are interested in, e.g. Magee and Rao (1979), Bilson (1983) and Viaene and De Vries (1992). There has also been some work focusing on the currency of payment (medium of exchange) role of money. See Krugman (1980) and Rey (1996).

[5]The Economist (1996).

[6]US exports and imports as share of world exports and imports 1994. For services the US share is somewhat higher. Source: World Trade Organization.

[7]See, for instance, the Wharton/CIBC Wood Gundy (1995) study of derivatives usage by U.S. non-financial corporations. Of the responding firms that do use derivatives, 91% hedge anticipated foreign exchange transactions within one year or less (''sometimes'' or ''frequently''). Forward/future currency contracts are reported as the most commonly used instrument for this purpose.

[8]See, e.g., Page (1981) and Carse and Wood (1979). See Bilson (1983) for a summary of ''stylized facts''.

imports using data from 1968. In Grassman's sample, 66% of Swedish exports, but only 26% of imports, were invoiced in Swedish kronor. 12% of exports were invoiced in U.S. dollars in Grassman's sample. By 1995[9] the share of exports invoiced in Swedish kronor had decreased to 43.8% and the share of exports invoiced in U.S. dollars had increased to 18.4%. There had been no corresponding increase in the share of the United States as a Swedish export market (7.9% in 1995).

These observations on Swedish invoicing practices point to the need for newer evidence on invoicing practices. We know of very little survey evidence using data from the 1980s or later.[10] For instance, the figures on Sweden in Page (1981) are taken from Grassman (1973a), (1973b). We should be cautious of discarding theoretical explanations of current or future choice of price setting currency based on evidence from a previous institutional setup (fixed exchange rates, less developed forward currency markets, exchange restrictions).

Section 2 presents our model and Section 3 discusses the choice of price setting currency. In Section 3.1 we discuss the choice of price setting currency under risk neutrality. In Section 3.2 we discuss the choice of price setting currency under risk aversion and with forward currency markets. Section 4 concludes.

2. The model

The firm studied is an exporter who sells in a single foreign market. The exporter is a monopolist (or more generally we may think of it as a firm whose residual demand curve expressed in the importers' currency is not affected by exchange rate surprises). The exporter has the choice between setting the export price in his own, in the importers' or in a third currency. We assume that the exporter is constrained to produce in his home country. The exporter's objective is to maximize the expected utility of profits in his home currency. *The central assumptions are that the exporter has to set price before the exchange rate is known and that demand is a function of the price that importers face after exchange rate uncertainty is resolved*. Let e, the stochastic nominal exchange rate, denote units of the exporters' currency needed to buy one unit of the importers' currency. A higher value of e thus implies a depreciation of the exporter's currency. Let e^o denote units of third country currency needed to buy one unit of the importer's currency. The exchange rate between the exporter's and the third country's currency is given by the relation e/e^o. Let $E(e) = \bar{e} = 1$ and $E(e^o) = \bar{e^o} =$

[9]The data are taken from the settlement reports of Sveriges Riksbank (the Swedish Central Bank). All payments through Swedish banks above a threshold of SEK 75 000 (about U.S.$ 10 000) are reported. Friberg and Vredin (1997) give a more detailed account of the currency use in Swedish foreign trade.

[10]Black (1991) is one exception. He reports data for Germany, France, Italy and Japan from 1987.

1 and assume that e and e^{o} are uncorrelated, which greatly simplifies calculations.[11] The analysis is partial equilibrium and exchange rates are exogenous. The exporter has access to a forward currency market. The forward rate of e is given by β and the forward rate of $e/e^{o} = \beta^{o}$. Assume that international financial markets are efficient such that the forward rate is equal to the expected spot rate. Let h and h^{o} respectively denote the size of the forward currency contract.

Let the markup and the support of the exchange rate be such that it will always be optimal for the exporter to satisfy ex post demand. Quantity demanded, Q, is a decreasing function of the price that importers face (in their own currency) once the exchange rate is known. Assume that costs are incurred in the exporter's currency and are given by $C(Q)$. Let subindexes denote partial derivatives. U is a Von Neumann–Morgenstern utility function, $U_{\Pi} > 0$, $U_{\Pi\Pi} < 0$. Let $U(\Pi) = \Pi$ under certainty. Let * denote a price that has been denominated in the importer's currency and ^{o} a price that has been set in the third country currency. When pricing in the exporter's currency no super-index is used. The super-indexes are also used to denote profits under the different pricing strategies. A *hat* is used to denote a variable that has been pre-set at the ex ante optimal level.

2.1. Price is set in the importers' currency

When the firm *sets price in the importers' currency* the firm's maximization problem is given by

$$\max_{p^{*},h} EU(\Pi^{*}) = E[U(ep^{*}Q(p^{*}) - C(Q(p^{*})) - h(e - \beta))] \tag{1}$$

The associated first order conditions are

$$E[U_{\Pi^{*}}((e)(p^{*}Q_{p^{*}} + Q) - C_{Q}Q_{p^{*}})] = 0 \tag{2}$$

$$E[U_{\Pi^{*}}(-e + \beta)] = 0 \tag{3}$$

Rearranging and substituting condition (3) into condition (2) we get

$$\beta(p^{*}Q' + Q) = C_{Q}Q_{p^{*}} \tag{4}$$

We see that the optimal price is not dependent on the shape of the utility function or the stochastic properties of the exchange rate. This is a version of the ''separation theorem'' that is normally derived in a price taking framework (see, e.g., Ethier, 1973; Kawai and Zilcha, 1986). Exchange rate uncertainty does not influence prices and hence traded quantities. We also note from Eq. (3) that

[11] It would clearly be preferable to relax this assumption. For now we note that the higher the positive correlation between e and e^{o} in our model, the less difference there will be between pricing in the exporter's and the third currency.

efficient forward markets imply that the exporter will hedge fully, set $h = p^*Q$. This follows by rewriting Eq. (3) as

$$(E[U_{\Pi *}]E[-e + \beta] + \text{cov}[U_{\Pi *}, -e]) = 0 \tag{5}$$

When the expected exchange rate equals the forward rate the condition holds only for $\text{cov}[U_{\Pi *}, -e] = 0$, which is achieved by full hedging. Profits are linear in exchange rate surprises – hedging does not lower expected profits – and it is therefore optimal for a risk averse exporter to hedge fully.

2.2. Price is set in the exporter's currency

When the price is set in the exporter's currency before the exchange rate is known the firm's maximization problem is given by:

$$\max_p EU(\Pi) = E\left[U\left(pQ\left(\frac{p}{e}\right) - C\left(Q\left(\frac{p}{e}\right)\right)\right)\right] \tag{6}$$

The associated first order condition is given by

$$E[U_{\Pi}(pQ_p + Q - C_Q Q_p)] = 0 \tag{7}$$

Here risk aversion will affect the optimal price, which will be higher than under risk neutrality. This is discussed by Baron (1976). By setting a higher price the exporter lowers the demand elasticity, thereby reducing the sensitivity of profits to exchange rate surprises. Traded quantities will thus be lower on average and the ''separation theorem'' does not hold.[12]

2.3. Price is set in the third country currency

When the exporter sets price in the third currency the maximization problem is given by

$$\max_{p^o, h^o} EU(\Pi^o) = E\left[U\left(\frac{e}{e^o} p^o Q\left(\frac{p^o}{e^o}\right) - C\left(Q\left(\frac{p^o}{e^o}\right)\right) - h^o\left(\frac{e}{e^o} - \beta^o\right)\right)\right]$$

The associated first order conditions are given by

$$E\left[U_{\Pi^o}\left(\frac{e}{e^o}(p^o Q_{p^o} + Q) - C_Q Q_{p^o}\right)\right] = 0 \tag{8}$$

[12]This builds on an implicit assumption that the exporter does not hedge the demand risk by buying forward contracts in his own currency. For the specific demand function used in Feenstra and Kendall (1997) it is possible to achieve a perfect hedge and the separation theorem will hold. We do not include hedging when price setting in the exporter's currency for simplicity and since we observe relatively little short selling of currencies that are not matched by any flows in that currency (see, e.g., Wharton/CIBC Wood Gundy, 1995).

$$E\left[U_{\Pi^o}\left(-\frac{e}{e^o}+\beta^o\right)\right]=0 \tag{9}$$

We are not able to determine the optimal size of the forward contract without further assumptions. We note however that the exporter will not be able to insulate himself fully from risk by using the forward currency market since demand will be affected by surprises in e^o, which implies that the exposure to be hedged is uncertain. As the exporter is not insulated from risk, the curvature of the utility function will influence the optimal price and traded quantities will, on average, be different than under certainty; the ''separation theorem'' will not hold.

3. The choice of price setting currency

3.1. Risk neutrality

Which price setting currency gives the ex ante highest expected utility depends on how profits are affected by exchange rate surprises. We will first compare the choice of setting price in the importer's or exporters' currency under risk neutrality. This gives us a problem of the type analyzed by Baron, Giovannini and Donnenfeld and Zilcha. When *setting price in the importers' currency* the first order condition is a linear function of the exchange rate, *e*. The price that is set will be dependent only on the expected value of *e*. The above implies that

$$E(\Pi^*(\hat{p}^*,e))=\Pi^*(\hat{p}^*,\bar{e})=\max_{p^*}\Pi^*(p^*,\bar{e}) \tag{10}$$

Expression (10) tells us that when the exporter sets his price in the importers' currency, the expected profits under a fluctuating exchange rate are equal to realized profits with pre-set price when the exchange rate is equal to its mean. Profits are then equal to optimal ex post profits when the exchange rate is equal to its mean.

When price is *set in the exporter's currency* profits will typically *not* be a linear function of exchange rate surprises. Which price setting currency gives the highest expected profits depends on the curvature of profits – if profits when pricing in the home currency are a concave or convex function of exchange rate surprises.

Before turning to the comparison of price setting currencies we note that *if* prices could be set *after* the exchange rate were known, both price setting currencies would yield the same profit. All variables are then known and the exporter can set p/e fully by choosing p

$$\max_{p^*}\Pi^*(p^*,\bar{e})=\max_{p}\Pi(p,\bar{e}) \tag{11}$$

After the last paragraph's detour we again turn to the study of pre-set prices. *If*

profits are a concave function of surprises in the exchange rate then Eqs. (10) and (11) combined with the definition of profit maximization (profits when price is set at an ex post optimal level must be at least as high as profits under pre-set prices) and concavity imply that the following inequality holds:

$$E(\Pi^*(\hat{p}^*,e)) = \max_p \Pi(p,\bar{e}) \geq \Pi(\hat{p},\bar{e}) \geq E(\Pi(\hat{p},e)). \tag{12}$$

Thus if profits are a concave function of exchange rate surprises when setting price in the exporter's currency, expected profits for the exporter are higher when he sets price in the importers' currency. Suppressing arguments we note that the first and second partial derivative of profits with respect to exchange rate surprises when setting price in the exporter's currency are given by

$$\Pi_e = (\hat{p} - C_Q)Q_e \tag{13}$$

$$\Pi_{ee} = (\hat{p} - C_Q)Q_{ee} - C_{QQ}(Q_e)^2 \tag{14}$$

The first derivative is positive, a depreciation of the exporter's currency will lead to higher demand and higher profits. The function is concave if the second derivative (Eq. (14)) is negative.[13] Given standard assumptions on the cost function (increasing and convex in quantity produced) a sufficient condition for concavity of profits is that the demand function is concave in the exchange rate.

3.1.1. Relationship to the exchange rate pass-through literature

The literature on exchange rate pass-through studies how much import prices change when exchange rates change.[14] Analyses of exchange rate pass-through and the closely related phenomenon of pricing-to-market (market specific markup adjustment when exchange rates change) have typically ignored issues of what currency prices are set in since it is usually assumed that price is set after the exchange rate is known. The dominating empirical finding in this literature is that of a pass-through elasticity that is less than unity and of ''local currency price stability'' (see, e.g., Knetter, 1993). Import prices change less than the exchange rate.

Knetter (1992) (p. 16) notes that the ''Choice of invoice currency should depend on the same factors that determine exchange rate pass-through''. We will show that this is indeed the case in our framework. Both depend on the curvature of demand and cost functions.

Proposition 1. *Sufficient conditions on the demand and cost functions for the*

[13]Note that for small changes in e we would get the same effects on profits without assuming pre-set prices. The envelope theorem implies that for a marginal change in e the only effect on profits would be the direct effect since the price is already set at the optimal level.

[14]See, for instance, Feenstra (1989) or Menon (1995) for a survey.

pass-through elasticity to be less than unity (under certainty) are also sufficient conditions for price setting in the importers' currency to yield higher expected profits under exchange rate uncertainty.

Proof. In Appendix A it is shown that a sufficient condition for less than full pass-through if $C_{QQ} \geq 0$ is that

$$1 > -\frac{Q_{pp}}{Q_p} p. \tag{15}$$

Sufficient conditions for setting price in the importer's currency to yield higher expected profits are, from Eqs. (12) and (14), that $C_{QQ} \geq 0$ and $Q_{ee} < 0 \Leftrightarrow 2 > -(\hat{p}/e)[\partial^2 Q/\partial(\hat{p}/e)^2]/[\partial Q/\partial(\hat{p}/e)]$. Use $\hat{p}/e = p$, where p is defined as the price that importers face. We then write $Q_{ee} < 0 \Rightarrow 2 > -(Q_{pp}/Q_p)p$. ■

The same condition is found in Donnenfeld and Zilcha (1991) but they do not relate it to the exchange rate pass-through literature. Even though limited exchange rate pass-through may depend on issues not directly related to the curvature of demand or cost functions (e.g., market share considerations as in Froot and Klemperer, 1989), the common empirical finding of less than full exchange rate pass-through indicates that setting price in the importers' currency is often optimal.

Some intuition for why demand would be concave in exchange rate surprises comes from a comparison with the second order condition for profit maximization under certainty. A necessary condition for profit maximization is that profits are concave in the price, that

$$(p - C_Q)Q_{pp} - C_{QQ}(Q_p)^2 + 2Q_p e < 0 \tag{16}$$

A sufficient condition for the second order condition to hold if $C_{QQ} \geq 0$ is thus that

$$2 > -(p - C_Q)\frac{Q_{pp}}{Q_p e} \tag{17}$$

Profit maximization thus implies that demand not be too convex in price, that the sensitivity of demand does not decrease too much as the price is increased. The same mechanism drives the concavity of profits in exchange rate surprises in Proposition 1. Only if demand is sufficiently convex in price will demand increase at a sufficiently increasing rate when the exchange rate depreciates for profits to be convex in exchange rate surprises. The difference between the two stems from that whereas a change in price will affect marginal revenue both through the change in price and the change in demand, an exchange rate change will affect only demand if price is fixed in the exporter's currency.

In the analysis above it was assumed that costs are incurred in the exporter's currency. One could create a setup where imported inputs priced in a foreign

currency would affect how marginal costs were affected by exchange rate surprises. The curvature of marginal costs could also be affected and thus change the conditions on the demand function under which profits would be concave in exchange rate surprises. The basic flavor of the above analysis would not change however, the curvature of profits in exchange rate surprises would determine the profit maximizing price setting currency.

3.1.2. On the choice of setting price in a third currency

If the exporter sets price in a third currency both demand and the price that the exporter receives will be uncertain. Donnenfeld and Zilcha (1991) (p. 1009) note that ''Typically it was assumed that exchange rate uncertainty resulted in commodity price uncertainty because prices were quoted in [a third currency]''. Commodity price uncertainty in the sense of Oi (1961) implies that profits will be convex in price (exchange rate) fluctuations. Expected profits will thus be an increasing function of price volatility. This, together with the observation that the share of Swedish trade invoiced in dollars has increased, motivates our interest in third currency pricing.

In our framework price setting in the importer's currency will yield higher expected profits than price setting in a third currency under the same conditions on demand and costs as in Proposition 1. The exporter will prefer pricing in a currency with low variance relative to the importers' currency if profits are a concave function of exchange rate surprises that affect demand. The difference relative to commodity price uncertainty is explained by that under the assumptions of Oi (1961) the firm is a price taker and determines quantity after the price (exchange rate) is known. In Oi's framework profits are convex in price fluctuations since when prices are high the firm receives a higher price *and* sells more output. Conversely, when prices are low the firm will reduce output and limit the reduction in profits. In our pre-set price framework quantity is demand determined and output is expanded when the price that the exporter receives is low (a depreciation of e^o).

Proposition 2. *Assume that demand and cost functions fulfil sufficient conditions as in Proposition 1. Then: (i) setting price in the importers' currency yields highest expected profits; (ii) for low enough variance of e^o relative to e, setting price in the third currency will yield higher expected profit than setting price in the exporter's currency; (iii) for high enough variance of e^o relative to e, setting price in the exporter's currency yields higher expected profits than setting price in the third currency.*

Proof. See Appendix B. Setting price in the importers' currency yields higher expected profits than price setting in the exporter's or a third currency under sufficient conditions on the demand and cost functions as in Proposition 1.

According to this model a Swedish monopolist exporter would want to set price on exports to the Netherlands in Dutch guilders. The ranking of price setting in the exporter's or third currency depends on the relative variance of these currencies. The exporter would prefer to set price on exports to the Netherlands in German marks over setting price in Swedish kronor (the Dutch guilder being tied to the German mark). In the proof we use that when the variance of $e^o = 0$, setting price in the third currency is equivalent to setting price in the importer's currency. The intuition being that there is no difference in expected profits from exports to England between setting prices in Scottish pounds or in English pounds.

3.2. Risk aversion

The optimality of setting price in the importer's currency when profits are concave in ex post exchange rate surprises holds also under risk aversion and efficient forward markets.

Proposition 3. *With $U_{II} > 0$, $U_{III} < 0$, efficient forward currency markets and demand and cost functions that fulfil sufficient conditions as in Proposition 1 then: (i) setting price in the importers' currency yields higher expected utility than setting price in the exporter's currency; (ii) under the assumption that the firm sells an amount $\hat{h}^o \geq 0$ on the forward currency market, setting price in the importers' currency yields higher expected utility than setting price in the third currency.*

Proof. See Appendix C. The intuition for Proposition 3 is that by using the forward market and setting price in the importers' currency the exporter fully avoids risk and achieves the same (certain) profits as he would under certainty. Both the price that the exporter receives and the quantity to be exported are certain. Utility is then higher than with concave profits evaluated using a concave utility function (as is the case with setting price in the exporter's or third country currency). Selling the third currency forward makes profits *more* concave in e^o for a given price. The intuition for profits becoming more concave can be seen by noting that the price that the exporter receives, $[(e/e^o)\hat{p}^o)]$, is convex in surprises in e^o. Selling e^o forward diminishes this effect without alleviating the effect on profits due to the concavity of demand in exchange rate surprises. Note, however, that selling an amount $\hat{h}^o$ of the third currency forward lowers the first order effect on profits from an exchange rate surprise. Selling $\hat{h}^o > 0$ forward thus constitutes a hedge and the assumption is therefore not very restrictive.

Before concluding we will note the close connection between the above analysis and the financial literature on exchange rate exposure. Exchange rate exposure is defined as the current expectation of the sensitivity of the value of the firm to

future exchange rate surprises.[15] In the framework presented above the firm's ex ante choice of currency denomination of prices determines how it will be affected by ex post exchange rate surprises. The resulting exposure when pricing in the importer's currency is the equivalent of what the financial literature has called transaction exposure. A certain revenue in foreign currency whose value in the home currency is uncertain. This exposure is easily hedged since the amount to be hedged is certain. When the exporter sets price in his own currency there is no transaction exposure but as we have seen above that does not mean that total exchange rate exposure is lower. Setting price in the exporter's own currency does not mean that risk is avoided – in fact, in our framework the opposite is true.

4. Concluding remarks

This paper has demonstrated the attractiveness of setting price in the importer's currency in a price setting framework. How can we reconcile this with the common finding in the empirical literature reported in the Introduction that trade between developed countries in manufactured goods is predominantly invoiced in the exporter's currency?

Part of the explanation no doubt rests with the fact that we have neglected transaction cost/medium-of-exchange and ''invoicing''/store-of-value roles of currency. Part of the explanation may be that the empirical evidence stems from older institutional setups. The shift away from invoicing in kronor is what our model would predict given that Sweden has had a floating exchange rate since November 1992. We note that in our framework the existence of a forward currency market makes price setting in the importers' currency even more attractive. The development of forward markets and spreading understanding of how they work should lead to more goods being priced in the importers' currency.[16] In most developed countries there are also much fewer exchange restrictions now than during the period when most empirical studies of invoicing currencies were made.[17]

We must of course recognize that the aggregate figures on trade currencies include both intra-firm transactions (where currency choice should be ruled by other considerations than those in this paper) and transactions where nominal

[15] Adler and Dumas (1984).

[16] Grassman (1973b) (p. 70) points to the difficulties of using the forward currency market at the time: ''The market for forward exchange is relatively thin and tends, moreover to disappear in acute currency crises, i.e. when it is most needed...they are considered technically complicated and that firms have only a limited knowledge of the foreign exchange market...all forward transactions require the permission of the Bank of Sweden, and this may also have restricted the scope of forward transactions in Sweden''.

[17] See Carse and Wood (1979) for a discussion of far-reaching exchange restrictions in Great Britain at the time of their survey.

rigidities play a very small role, so that the choice of price setting currency is of little consequence. The above points out that more empirical knowledge of current price setting and invoicing practices is desirable. This applies both to surveys of invoicing currency use as well as to careful studies of price setting in different national markets, such as Knetter's study of the prices of *The Economist* (Knetter, 1997). This paper has emphasized that we should not take for granted that empirical results on price setting from one institutional setup will hold under another setup.

Acknowledgements

I wish to thank Karl Jungenfelt, Carsten Kowalczyk, Oz Shy, Patrik Säfvenblad, Anders Vredin, the editor of this journal, two anonymous referees and seminar participants at the Stockholm School of Economics as well as at the 1996 EEA and ESEM conferences for helpful comments and suggestions. All remaining errors are mine. Financial support from Bankforskningsinstitutet is gratefully acknowledged.

Appendix A

In this appendix we derive sufficient conditions for the pass-through elasticity to be less than unity under certainty. The result is due to Feenstra (1989) and this exposition is a somewhat simplified version of that work. First define $e^* \equiv 1/e$. Under certainty the exporter's maximization problem is given by

$$\max_p \; pQ(p) - C(Q)e^* \tag{A.1}$$

the first order condition is

$$Q + Q_p p - C_Q Q_p e^* = 0 \tag{A.2}$$

Define $\eta = -Q_p p/Q$, the (positive) price elasticity of demand. We rewrite Eq. (A.2) as

$$\text{Marginal revenue (MR)} \equiv p\left(1 - \frac{1}{\eta}\right) = C_Q e^* \tag{A.3}$$

Total differentiation of Eq. (A.3) yields

$$\left[\left(1 - \frac{1}{\eta}\right) + p\frac{\eta_p}{\eta^2} - C_{QQ}Q_p e^*\right]\mathrm{d}p - C_Q \,\mathrm{d}e^* = 0 \tag{A.4}$$

Divide by C_Q and e^* and multiply by p to reach

$$\frac{\mathrm{d}p}{\mathrm{d}e^*}\frac{e^*}{p}=\frac{1}{\left(1+(p^2\eta_p/(\eta^2 MR))+(C_{QQ}/C_Q)Q\eta\right)}. \tag{A.5}$$

Eq. (A.5) is the pass-through elasticity; the percentage change in import price due to a percentage change in the exchange rate (expressed as units of importers' currency needed to buy a unit of the exporter's currency). $[(C_{QQ}/C_Q)Q]$ is the elasticity of marginal costs with respect to output, this has the same sign as C_{QQ}. The term $[1+(p^2\eta_p/(\eta^2 MR))]$ is the elasticity of marginal revenue w.r.t. price, this is >1 (<1) as $\eta_p>0$ $(\eta_p<0)$. This establishes that if $C_{QQ}\geq 0$ a sufficient condition for $0<(\mathrm{d}p/\mathrm{d}e^*)(e^*/p)<1$ is that

$$\eta_p>0 \tag{A.6}$$

$$-\left(Q_{pp}\frac{p}{Q}+Q_p\frac{1}{Q}\right)>0 \tag{A.7}$$

$$-\frac{Q_{pp}}{Q_p}p-1<0 \tag{A.8}$$

$$-\frac{Q_{pp}}{Q_p}p<1 \tag{A.9}$$

■

Appendix B

Proof of Proposition 2. (i) Setting price in the importers' currency yields higher expected profits than setting price in the exporter's currency. This follows from Eqs. (12) and (14). Now compare price setting in the third currency with price setting in the exporter's currency.

$$\begin{aligned}E(\Pi^*(\hat{p}^*,e))-E(\Pi^{\mathrm{o}}(\hat{p}^{\mathrm{o}},e,e^{\mathrm{o}}))=E(e)E\left(\hat{p}^*Q(\hat{p}^*)-\frac{\hat{p}^{\mathrm{o}}}{e^{\mathrm{o}}}Q\left(\frac{\hat{p}^{\mathrm{o}}}{e^{\mathrm{o}}}\right)\right)\\ +\mathrm{cov}\left(e,\hat{p}^*Q(\hat{p}^*)-\frac{\hat{p}^{\mathrm{o}}}{e^{\mathrm{o}}}Q\left(\frac{\hat{p}^{\mathrm{o}}}{e^{\mathrm{o}}}\right)\right)\\ -E(C(Q(\hat{p}^*)))+E\left(C\left(Q\left(\frac{\hat{p}^{\mathrm{o}}}{e^{\mathrm{o}}}\right)\right)\right).\end{aligned} \tag{B.1}$$

e and e^{o} are uncorrelated which implies that the covariance term is 0 (no correlation between e and the difference in revenue measured in the importer's

currency under the two price setting practices). Also use that $E(e) = 1$ to express Eq. (B.1) as

$$= E(\hat{p}^{*}Q(\hat{p}^{*}) - C(Q(\hat{p}^{*}))) - E\left(\frac{\hat{p}^{o}}{e^{o}}Q\left(\frac{\hat{p}^{o}}{e^{o}}\right) - C\left(Q\left(\frac{\hat{p}^{o}}{e^{o}}\right)\right)\right), \tag{B.2}$$

$$= \max_{p^{*}} \Pi^{*}(p^{*},\bar{e}) - E\left(\frac{\hat{p}^{o}}{e^{o}}Q\left(\frac{\hat{p}^{o}}{e^{o}}\right) - C\left(Q\left(\frac{\hat{p}^{o}}{e^{o}}\right)\right)\right), \tag{B.3}$$

$$= \max_{p^{o}} \Pi^{o}(p^{o},\bar{e^{o}},\bar{e}) - E\left(\frac{\hat{p}^{o}}{e^{o}}Q\left(\frac{\hat{p}^{o}}{e^{o}}\right) - C\left(Q\left(\frac{\hat{p}^{o}}{e^{o}}\right)\right)\right). \tag{B.4}$$

Expression (B.4) will be positive if profits when setting price in the third currency (measured in the importers' currency) are concave in $e^{o} \Leftrightarrow$ if

$$\frac{2}{e^{o2}}\left(\frac{\hat{p}^{o}}{e^{o}}Q - \hat{p}^{o}Q_{e^{o}}\right) + \left(\frac{\hat{p}^{o}}{e^{o}} - C_{Q}\right)Q_{e^{o}e^{o}} - C_{QQ}(Q_{e^{o}})^{2} < 0. \tag{B.5}$$

The last two terms in Eq. (B.5) are the equivalent of Eq. (14) and the sum of these two is negative following Proposition 1. We can rewrite the first term as $2(\hat{p}^{o}/e^{o3})Q + 2(\hat{p}^{o2}/e^{o4})Q_{\hat{p}^{o}}$. This is positive if $1 - (\eta/e^{o})$ is positive, where $\eta = -Q_{\hat{p}^{o}}(\hat{p}^{o}/Q)$ is defined as the (positive) price elasticity of demand evaluated at the ex ante optimal price. This implies that the first term will be negative in expectation since the exporter would not set price where demand is inelastic. Thus for $Q_{e^{o}e^{o}} < 0$ and convex marginal costs the second derivative will be negative, establishing that $E(\Pi^{*}(\hat{p}^{*},e)) > E(\Pi^{o}(\hat{p}^{o},e^{o},e))$. ■

(ii) From Eqs. (12) and (14) and monetary neutrality we know that

$$E(\Pi^{*}(\hat{p}^{*},e)) = E(\Pi^{o}(\hat{p}^{o},\bar{e^{o}},e)) > E(\Pi(\hat{p},e)).$$

If the variance of $e^{o} = 0$, setting price in the importers' and third currency imply equal expected profits. The inequality is strict implying that

$$E(\Pi^{*}(\hat{p}^{*},e)) > E(\Pi^{o}(\hat{p}^{o},e^{o},e)) > E(\Pi(\hat{p},e))$$

for small enough variance of e^{o} relative to the variance of e. ■

(iii) From (i) and monetary neutrality we know that

$$E(\Pi^{*}(\hat{p}^{*},e)) = E(\Pi(\hat{p},\bar{e})) > E(\Pi^{o}(\hat{p}^{o},e^{o},\bar{e})).$$

If the variance of $e = 0$ setting price in the importers' and exporter's currency implies equal expected profits. The inequality is strict implying that

$$E(\Pi^{*}(\hat{p}^{*},e)) > E(\Pi(\hat{p},e)) > E(\Pi^{o}(\hat{p}^{o},e^{o},e))$$

for small enough variance of e relative to the variance of e^{o}. ■

Appendix C

Proof of Proposition 3. (i) Show that the following chain of inequalities hold to establish that expected utility when setting price in importer's currency is higher than expected utility when setting price in the exporters' currency

$$E(U(\Pi^*(\hat{p}^*,\hat{h},e))) \geq U(\Pi^*(\hat{p}^*,h=p^*Q)), \tag{C.1}$$

$$=\max_{p^*} \Pi^*(p^*,\bar{e}), \tag{C.2}$$

$$=\max_{p} \Pi(p,\bar{e}), \tag{C.3}$$

$$> E(U(\Pi(\hat{p},e))). \tag{C.4}$$

Expected utility when pricing in the importers' currency when using the forward market optimally is at least as high as utility with full hedging (as seen in Section 2.1 the two are equal in our setup). When hedging fully profits are non-stochastic; use this and the assumption that $U(\Pi)=\Pi$ under certainty to establish Eq. (C.2). Profit when hedging fully is equal to profits with optimally set price (ex post) when the exchange rate is equal to its mean. Monetary neutrality establishes Eq. (C.3). Under conditions on demand and costs as in Proposition 1 profits are concave in exchange rate fluctuations when price is pre-set in the exporter's currency. The utility function is assumed to be concave and increasing in profit. We can then use the result that if $f(x)$ is concave and $F(z)$ is concave and increasing, then $F(f(x))$ is concave to establish the Proposition. ■

(ii) Show that the following chain of inequalities holds to establish that expected utility when setting price in the importers' currency is higher than when setting price in the third currency

$$E(U(\Pi^*(\hat{p}^*,e,\hat{h}))) \geq U(\Pi^*(\hat{p}^*,h=p^*Q)) \tag{C.5}$$

$$=\max_{p^*} \Pi^*(p^*,\bar{e}) \tag{C.6}$$

$$=\max_{p^o} \Pi^o(p^o,\bar{e}^o,\bar{e}) \tag{C.7}$$

$$> E(U(\Pi^o(\hat{p}^o,e^o,e,\hat{h}^o))) \tag{C.8}$$

The equality in Eq. (C.7) is analogous to Eq. (C.3).

As discussed in Section 3.2 we were not able to determine the optimal hedge when the firm sets price in the third currency. We will instead analyze how a hedge affects the behavior of ex post realized profits. We noted that the exposure to be hedged is uncertain since quantities and hence revenues are uncertain. Assume that

the exporter has sold an amount $\hat{h}^{o}$ on the forward currency market. Expected profits will then be given by

$$E\left(\frac{e}{e^{o}}\hat{p}^{o}Q\left(\frac{\hat{p}^{o}}{e^{o}}\right)-C\left(Q\left(\frac{\hat{p}^{o}}{e^{o}}\right)\right)-\hat{h}^{o}\left(\frac{e}{e^{o}}-\beta^{o}\right)\right)=E(e)\left(\frac{\hat{p}^{o}}{e^{o}}Q\left(\frac{\hat{p}^{o}}{e^{o}}\right)-\frac{\hat{h}^{o}}{e^{o}}\right)+\operatorname{cov}\left(e,\frac{\hat{p}^{o}}{e^{o}}Q\left(\frac{\hat{p}^{o}}{e^{o}}\right)-\frac{\hat{h}^{o}}{e^{o}}\right)-E\left(C\left(Q\left(\frac{\hat{p}^{o}}{e^{o}}\right)\right)+\hat{h}^{o}\beta^{o}\right) \tag{C.9}$$

e and e^{o} are uncorrelated which implies that the covariance term is 0 (no correlation between e and revenue measured in the importers' currency). Also use that $E(e)=1$ to express Eq. (C.9) as

$$E\left(\frac{\hat{p}^{o}}{e^{o}}Q\left(\frac{\hat{p}^{o}}{e^{o}}\right)-C\left(Q\left(\frac{\hat{p}^{o}}{e^{o}}\right)\right)-\hat{h}^{o}\left(\frac{1}{e^{o}}-\beta^{o}\right)\right) \tag{C.10}$$

If Eq. (C.10) is concave in surprises in e^{o} the inequality (C.8) holds. The second partial derivative of Eq. (C.10) w.r.t. e^{o} is given by

$$\frac{2}{e^{o2}}\left(\frac{\hat{p}^{o}}{e^{o}}Q-\hat{p}^{o}Q_{e^{o}}\right)+\left(\frac{\hat{p}^{o}}{e^{o}}-C_{Q}\right)Q_{e^{o}e^{o}}-C_{QQ}(Q_{e^{o}})^{2}-\frac{2}{e^{o3}}\hat{h}^{o} \tag{C.11}$$

The sum of the first three terms is negative in analogy with Proposition 2. $\hat{h}^{o}\geq 0$ by assumption which establishes that expected profits are concave in exchange rate surprises. The utility function is assumed to be concave and increasing in profit. We can then use the theorem that if $f(x)$ is concave and $F(z)$ is concave and increasing, then $F(f(x))$ is concave to establish the Proposition. ■

References

Adler, M., Dumas, B., 1984. Exposure to currency risk: Definition and measurement. Financial Management 13, 41–50.

Baron, D.P., 1976. Fluctuating exchange rates and the pricing of exports. Economic Inquiry 14, 425–438.

Betts, C., Devereux, M.B., 1996. The exchange rate in a model of pricing-to-market. European Economic Review 40, 1007–1021.

Bilson, J., 1983. The choice of an invoice currency in international transactions. In: Bhandari, J., Putnam, B. (Eds.), Economic Interdependence and Flexible Exchange Rates. MIT Press, Cambridge, MA, pp. 384–401.

Black, S.W., 1991. Transactions costs and vehicle currencies. Journal of International Money and Finance 10, 512–526.

Carse, S., Wood, G., 1979. Currency of invoicing and forward covering: Risk-reducing techniques in British foreign trade. In: Martin, J., Smith, A. (Eds.), Trade and Payments Adjustment under Flexible Exchange Rates. The Macmillan Press, London, pp. 174–196.

Donnenfeld, S., Zilcha, I., 1991. Pricing of exports and exchange rate uncertainty. International Economic Review 32, 1009–1022.

The Economist, 1996. The euro and the dollar: Strut your stuff. The Economist, October 19, pp. 87–88.

Ethier, W., 1973. International trade and the forward exchange market. The American Economic Review 63, 494–503.

Feenstra, R.C., 1989. Symmetric pass-through of tariffs and exchange rates under imperfect competition: An empirical test. Journal of International Economics 27, 25–45.

Feenstra, R.C., Kendall, J.D., 1997. Pass-through of exchange rates and purchasing power parity. Journal of International Economics 43, 237–261.

Friberg, R., Vredin, A., 1997. Exchange rate uncertainty and the microeconomic benefits of EMU. Swedish Economic Policy Review (forthcoming).

Froot, K.A., Klemperer, P., 1989. Exchange rate pass-through when market share matters. American Economic Review 79, 637–654.

Giovannini, A., 1988. Exchange rates and traded goods prices. Journal of International Economics 24, 45–68.

Grassman, S., 1973a. A fundamental symmetry in international payment patterns. Journal of International Economics 3, 105–116.

Grassman, S., 1973b. Exchange Reserves and the Financial Structure of Foreign Trade. Saxon House, Farnborough.

Kawai, M., Zilcha, I., 1986. International trade with forward-futures markets under exchange rate and price uncertainty. Journal of International Economics 20, 83–98.

Knetter, M.M., 1992. Exchange rates and corporate pricing strategies. NBER Working Paper No. 4151.

Knetter, M.M., 1993. International comparisons of pricing-to-market behavior. The American Economic Review 83, 473–486.

Knetter, M.M., 1997. The segmentation of international markets: Evidence from *The Economist*. NBER Working Paper No. 5878.

Krugman, P.R., 1980. Vehicle currencies and the structure of international exchange. Journal of Money, Credit and Banking 12, 513–526.

Magee, S.P., 1974. U.S. import prices in the currency-contract period. Brookings Papers on Economic Activity 1, 117–168.

Magee, S.P., Rao, R.K.S., 1979. The currency of denomination of international trade contracts. In: Levich, R.M., Wihlborg, C.G. (Eds.), Exchange Rate Risk and Exposure. Lexington Books, Lexington, MA, pp. 61–86.

Menon, J., 1995. Exchange rate pass-through. Journal of Economic Surveys 9, 197–231.

Oi, W.Y., 1961. The desirability of price instability under perfect competition. Econometrica 29, 58–64.

Page, S.A.B., 1981. The choice of invoicing currency in merchandise trade. National Institute Economic Review 98, 60–71.

Rey, H., 1996. International trade and currency exchange, manuscript. London School of Economics and Political Science, London.

Viaene, J-M., De Vries, C., 1992. On the design of invoicing practices in international trade. Open Economies Review 3, 133–142.

Wharton/CIBC Wood Gundy, 1995. 1995 survey of derivatives usage by U.S. non-financial firms. The Weiss Center for International Financial Research, the Wharton School of the University of Pennsylvania.