Which currency to set price? A model of multiple countries and risk averse firm

Jian Wang*

The Department of Economics

University of Wisconsin, Madison

June 2004

Key words: pricing to market; local currency pricing; producer currency pricing; risk averse; multinational companies

JEL Classification: F10, F23, F30

---

* jwang25@wisc.edu. Office address: 6443 Social Science Building, 1180 Observatory Drive, University of Wisconsin, Madison, WI 53706-1393 Phone: (608) 265-4833.
I am indebted to Charles Engel for his continuous support and encouragement from the beginning of this project. I am also graceful to Min Shi for her insightful comments. This paper has benefited from the discussions with Robert Staiger, Scott Taylor, Jianfeng Liu, Homing Tang, Zhiguo Xiao and all other seminar participants at the University of Wisconsin, Madison. This latest version was finished while I worked as a research intern at the Bank of England, whose hospitality is gracefully acknowledged. Remaining errors are mine only.

Which currency to set price? A model of multiple countries and risk averse firm

Abstract: A crucial question centering many recent debates in the international macroeconomics is under which currency the price is sticky. This paper provides a micro-foundation to study the firm's choice of price setting currency in the sticky price model. I first prove that the risk preference is a secondary consideration in the choice of the price setting currency. This result questions the claim that the currency forward market can change the currency choice of risk averse firms. Then I extend the discussion to a model with multiple importing countries. Unlike the single-importing-country model, the optimal choice of the price setting currency also depends on the variance and covariance of the log exchange rates. This result connects the firm's currency choice to the macro variables. This interaction should be endoginized in the open macroeconomic models when studying some important questions like the choice of optimal exchange rate regime.

1. Introduction

In the international trade, exporting firms have to decide in which currency to set prices for their products. The exporters can set price either in their home currency (also known as producer currency pricing or PCP) or in the importer's currency (also known as local currency pricing or LCP). Due to the volatility of the exchange rate, it is prohibitively costly for the firms to adjust their prices whenever the exchange rate changes. Therefore, the prices in reality are much stickier than the exchange rates.[1] Under a sticky price setting, the choice of price setting currency determines the short run exchange rate pass-through and therefore how significant the expenditure switching effect is. With the traditional assumption of PCP, the short run exchange rate pass-through is unity and therefore the expenditure switching effect should be a major consideration when making the exchange rate policy. However, when the price is sticky in the importing country's currency, there is no short run expenditure switching effect and many well established theories have to be re-considered[2]. Therefore it is very important to study the micro-foundation for the firm's behavior of the price setting currency choice.

There are two major limitations in the prior studies on this topic. The first one lies in the way how they connect the risk averse and risk neutral firms. When a firm is risk averse and maximizes the expected value of a concave utility function, the solution is generally too complicated to draw some interesting conclusions. So the previous studies

[1] For empirical evidence, see Mussa (1986), Baxter and Stockman (1989), Flood and Rose (1995) and Obstfeld (1998).
[2] For instance, it is related to the problems of the optimal exchange rate regime, the cost of currency union and the economic stability under the foreign monetary shocks.

(with quite few exemptions[3]) either totally ignored the case of risk averse firms or resorted to an efficient currency forward market to connect these two types of firms (for example, see Ethier (1973), Kawai and Zilcha (1986) and Friberg (1998)). Intuitively, the currency forward market can help the firms fully cover their foreign exchange exposure. Therefore, they will behave in exactly the same as the risk neutral firms. However, the existence of a perfect currency forward market seems too strong in reality.

Most newly industrializing countries just start to build their financial market, but at a very slow pace[4]. In the emerging forward exchange markets of developing countries, the forward covers provided by banks are normally subject to many official restrictions[5]. This makes it very difficult for a firm to take currency forward contacts as an effective weapon to hedge against exchange rate uncertainty. It is necessary for us to study the behavior of the risk averse firms when the currency forward market is absent.

There are many more reasons for the assumption of risk aversion. Among them is the validity of the assumption that the manager will behave at the best of the shareholder's benefit. In reality, it is costly and difficult for the shareholders to monitor the manager due to the imperfect information. To some extent, the manager's attitude towards risks depends on the internal organization of the firm.[6] If the manager's major incomes are from his/her salary which is contingent on the performance of the firm, it is

[3] Giovannini (1988) and Devereux, Engel and Storgaard (2003) consider a case where the firms maximize discounted expected profit. Depending on the assumption of the random discount factor, the firms could exhibit any risk preference. However, the stochastic discount factor is taken as exogenous in their models. Though this assumption is not strong for the economy with diversified assets, there are plentiful reasons for us to think about the undiversified shareholders. For example, as noted by Bascom (1994), the portfolio choices are very limited in most developing countries due to the reasons like the high and unstable inflation, the absence of an organized securities market, government controlled financial sectors etc.

[4] See Eiteman et al for more details. (1998)

[5] See page 146 of Bascom (1994) for some examples of these restrictions and in which countries they are applied.

[6] For example, see Friberg (1999) for comments on the case of risk-seeking manager after being offered stocks purchase option.

reasonable to believe that the manager is risk averse. So even when the shareholders are risk neutral, the manager will operate the company in a risk averse way. Kumar (1988) provides more details in a game between the risk-averse manager and the risk neutral shareholders.

Therefore it is interesting for us to consider a risk-averse firm when studying the choice of price setting currency, but prior studies just connect it to the risk neutral firm in an unrealistic way. In this paper, we connect these two types of firms by comparing the necessary and sufficient condition for LCP to be a dominant strategy. Under the second order Taylor expansion around the mean of the log exchange rate[7], we prove that the decision rule of choosing price setting currency is identical for these two types of firms. Therefore, the existence of a hedging market is not a necessary condition to connect the risk neutral and risk averse firms in the problem of currency choice.

The second limitation of the prior studies is that they only focused on the situation with a single importing country and ignored the potential interactions between the exchange rates of importing countries. In the previous studies, the optimal currency to set price only depends on the properties of the firm's demand and cost functions[8]. However, when the exporter's trade partners come from two or more countries, the variance of the total profit will also be affected by the correlation of the exchange rates. The correlation of the exchange rates could increase or decrease the variance of the profit in different ways for LCP and PCP. Therefore the choice of which currency to set price is more complicated than in the situation with a single importing country.

---

[7] Though the exchange rate is volatile, the change in the log exchange rate is relatively small. So we can use the second order approximation around the mean of the log exchange rate.

[8] For example, see Baron (1976), Donnenfeld and Zilcha (1991) and Engel (2003).

Inspired by the rapid development of the multi-national companies, I extend the discussion of the price setting currency choice to a multiple importing countries case. With the same second order Taylor expansion, we provide the necessary and sufficient condition for LCP to be a dominant strategy. In contrast to the single importing country case, this condition also depends on the variance and covariance of the log exchange rates. A major contribution for this result is that we connect the firm's behavior of choosing price setting currency with the macro variables. As we have mentioned, the firm's choice of the price setting currency determines the short run exchange rate pass through and therefore the monetary policy's impacts on the macroeconomic variables. Our result here suggests that the monetary policies in return will also affect the firm's choice between PCP and LCP through the macroeconomic variables. This interaction is missing from the prior micro-foundation literature and deserves more attention in the future macroeconomic models.

The remaining of this paper is organized in the following way: section 2 provides a brief literature review. In section 3, we study the model with a single importing country and make connections between the risk neutral and risk averse firms. Section 4 extends the model to a multi-currency setting. The necessary and sufficient condition is also provided in this section for LCP to yield higher expected profit. We show that this condition also depends on the variance and covariance of the log exchange rate. Section 5 concludes, summarizes major results and discusses future research directions.

2. Literature Review

The question of in which currency to set price is trivial when the price is flexible or the exchange rate is fixed. Hence all the discussions on the price setting currency choice are under the sticky price and flexible exchange rate models. The literature studies in which currency a monopolistic supplier presets price when the price can not be altered in the short run in responding to the exchange changes. The choice of price setting currency determines how firms handle the exchange rate risk. When the firms set prices in their home currency (PCP), they can totally avoid the price uncertainty caused by the exchange rate fluctuations. However, the demand will change with the ex post realization of exchange rates. In contrast, if the firms take the strategy of LCP, they can fix the demand, but the final price they receive will vary with exchange rates. Without a forward market to lock the future price or demand, the firms have to bear either the price or demand risk.

Financial risk management is a big concern for the firms.[9] A large body of research has been done to explore the firm's choice of the invoicing currency. Meanwhile, the choice of price setting currency also has substantial impacts on many macro-economic issues. Therefore the research on this topic is numerous. The review here is only limited to the research closely related to this paper.

The study on the pricing currency choice started at the early 1970's when many industrial countries switched from the fixed to flexible exchange rate regime. An important regularity at that moment is the exports were generally invoiced at the

[9] In a survey conducted by Rawls and Smithson (1990), financial risk management was ranked as one of the primary corporate objectives.

producer's currency[10]. Ethier (1973) has considered a case where the importers have to decide the level of foreign currency invoiced imports before the realization of the exchange rate. The setup of such models is based on the belief that the final prices are more flexible than the prices of imports (or intermediate goods). Intuitively most of the exporter's predetermined costs are denominated in its home currency. In response to an exchange rate shock, it is hard for the exporters to cut the cost as to maintain their profit margin. However, it should be easier for importers to pass on exchange-rate fluctuations to the final consumers. So the importers are more likely to take the exchange rate risk in the international trade.

In contrast, Clark (1973) has studied the problem from the view of an exporter—the exporter has to bear the exchange rate risk by pre-setting a price denominated by the importer's currency. From the customs questionnaire and interviews, Grassman (1973) concludes, "Formally, it is the seller who takes the initiative and decides what the invoice currency is to be..." Based on this fact, all the following studies built their models on the exporter's problem. Baron (1976) finds that when the demand, cost and utility functions are linear, the local currency pricing (LCP) yields higher expected profit than the producer currency pricing (PCP). In a partial equilibrium mode, Giovannini (1988) studies the choice of the invoicing currency for a monopolist who sells products to both domestic and foreign market. Donnenfeld and Zilcha (1991) examine a similar model and derive a sufficient condition for LCP to yield a higher expected profit.

The research on the choice of price setting currency is reheated recently due to its interesting implication on the exchange rate pass through. When the LCP is predominant, the short run exchange rate pass through is zero and therefore the well known

[10] It is known as Grassman's Law. This law particularly applied to manufactured products.

“expenditure switching effect” does not hold and many well established macroeconomic theories have to be reconsidered. Betts and Devereux (1996) first introduced PTM *cum* LCP into a model based on Obstfeld and Rogoff’s famous “Redux model” (1995). They have examined the impacts of degree of PTM-LCP on the macro variables and the potential of the model to replicate some striking international business cycle regularities. Devereux and Engel (1998, 1999) study how an economy can be insulated from foreign monetary shocks when LCP is a prevalent practice. All of these macro-models take LCP as exogenous.

In a recent paper, Devereux, Engel and Storgaard (2003) have proposed a general equilibrium model in which they endogenize the choice of price setting currency. By exploring the interaction of pricing currency choice and exchange rate fluctuation, they connect the exchange rate pass through and exchange rate volatility. A major result of their paper is that pass-through rate is related to the relative stability of monetary policy.

Fribreg (1998) has connected the exchange rate pass-through and the choice of pricing currency in another way. He establishes that the sufficient condition for the exchange rate pass-through rate to be less than unity is also sufficient for LCP to yield higher expected utility. With a perfect currency forward market, he extended this result to the case with risk-averse firms. Engel (2003) improves the results in a more general model. He finds that the necessary and sufficient condition of low pass through in the flexible price setting is also necessary and sufficient for LCP to yield higher expected discounted profit when the price is sticky.

Feenstra and Kandell (1997) derive and test a model of purchasing power parity from the optimal pricing behavior of exporting firms. Although they test both PCP and

LCP, the choice of pricing currency is not a major concern in their paper. An interesting empirical comparison between PCP and LCP is recently done by Koren, Szeidl and Vincze (2004). They examine the prevalence of PCP and LCP by estimating a structural pricing model with disaggregate data. Their results support PCP in a wide range of product categories. The results provide some very useful empirical evidence for the current policy making. However, like Feenstra and Kandell, they do not study the firm's choice of price setting currency either.

3. The model with single importing country

In this section, we study which currency a risk averse firm will use to set price when it only exports to a single foreign country. Under the second order approximation around the log exchange rate[11], we find that the currency choice problem is the same for the risk neutral and risk averse firms.

Suppose we have two countries, Home and Foreign and let S be the exchange rate between these two countries. S is defined as the home currency denominated price for one unit of foreign currency. The logarithm of the exchange rate, s is a random variable with the mean $\bar{s}$ and variance σ^2. A firm from Home country only sells its products to the Foreign market[12]. We follow the standard assumption of monopolistic competition in the new open macroeconomic literature and assume the firm can set its price either in the

[11] Though the exchange rate is volatile, the change in the logarithm of exchange rates is small. This validates our approximation. The advantage of this method is that it allows us to find explicitly the sufficient and necessary condition for LCP to dominate.
[12] This assumption is just for convenience. See Giovannini (1988) for the impacts of the domestic market on the firm's pricing behavior.

home currency (PCP) or foreign currency (LCP)[13]. The firm has the perfect information about the demand and cost functions when setting the price. However, the price must be set before the exchange rate is revealed and the firm is supposed to fulfill the demand under any ex post realization of the exchange rate[14].

We first consider the case of PCP. Let P be the price set by the firm and $D\left(Pe^{-s}\right)$ be the corresponding demand function. The firm is supposed to use both home and foreign factors in the production. With this setup, the model can be applied to both the exporters who use imported factors in the production and the multi-national companies that produce in more than one country. We classify the factor inputs into two categories: the factors priced in the home currency and those in the foreign currency.

So the cost function we employ throughout this paper takes the form of $C\left(D\left(Pe^{-s}\right)\right)H\left(W_1,\ W_2^* e^s\right)$, where W_1 is the price of the factors denominated in the home currency and W_2^* is the price of the factors denominated in the foreign currency. The function $H\left(W_1,\ W_2^* e^s\right)$ is assumed to be homogenous of degree one. All other variables except for the exchange rate are non-stochastic.

With this setup, it is easy for us to find the firm's profit function as in equation (1).

$$\begin{aligned} \pi &= PD\left(\frac{P}{S}\right) - C\left(D\left(\frac{P}{S}\right)\right)H\left(W_1,\ W_2^* S\right) \\ &= PD\left(Pe^{-s}\right) - C\left(D\left(Pe^{-s}\right)\right)H\left(W_1,\ W_2^* e^s\right) \end{aligned} \tag{1}$$

[13] Here I exclude the case where the firm sets price with third country currency. Friberg (1998) provides a sufficient condition for the third country currency strategy to be dominated by PCP. For simplicity, I just assume that exporters cannot use third country currency to price their products in this paper.

[14] It is also assumed implicitly that the change in log exchange rate s is small such that the firm's profit margin is large enough to make it profitable for any realization of s. Therefore, the firm will not default from satisfying the market demand.

Similarly, if we use asterisk to denote the strategy of LCP, the firm's profit function becomes

$$\begin{aligned}\pi^* &= P^* SD(P^*) - C(D(P^*))H(W_1,\ W_2^* S) \\ &= P^* e^s D(P^*) - C(D(P^*))H(W_1,\ W_2^* e^s)\end{aligned} \tag{2}$$

In this paper, we assume that the firm is risk averse and maximizes its expected utility of profit. With two potential currencies to set the price, the firm solves the following problem.

$$Max\{\overline{U},\ \overline{U}^*\}$$

where $\overline{U} = Max_{P}\ E_s[U(\pi(P))]$ and $\overline{U}^* = Max_{P^*}\ E_s[U(\pi^*(P^*))]$.

$U(\cdot)$ is a concave function and E_s is the expectation operator with respect to the log exchange rate s. The firm solves this problem by comparing optimal expected utilities of PCP and LCP ($\overline{U}$ and $\overline{U}^*$).

Equation (3) and (4) are the second order Taylor expansions of the profit function around $\bar{s}$ for PCP and LCP respectively.

$$\begin{aligned}&E[U(\pi)] \approx U(\pi(\bar{s})) \\ &+\frac{1}{2}\left[\frac{d^2U}{d\pi^2}(\pi(\bar{s}))\left(\frac{d\pi}{ds}(\bar{s})\right)^2 + \frac{dU}{d\pi}(\pi(\bar{s}))\frac{d^2\pi}{ds^2}(\bar{s})\right]\sigma^2\end{aligned} \tag{3}$$

$$\begin{aligned}&E[U(\pi^*)] \approx U(\pi^*(\bar{s})) \\ &+\frac{1}{2}\left[\frac{d^2U}{d\pi^{*2}}(\pi^*(\bar{s}))\left(\frac{d\pi^*}{ds}(\bar{s})\right)^2 + \frac{dU}{d\pi^*}(\pi^*(\bar{s}))\frac{d^2\pi^*}{ds^2}(\bar{s})\right]\sigma^2\end{aligned} \tag{4}$$

We find two effects on the firm's expected utility from a change in the exchange rate. The first effect is from $\frac{d^2U}{d\pi^2}(\pi(\bar{s}))\left(\frac{d\pi}{ds}(\bar{s})\right)^2$, which is negative from the assumption of risk aversion ($\frac{d^2U}{d\pi^2}(\pi(\bar{s}))<0$). $\frac{d\pi}{ds}(\bar{s})$ measures the exchange rate risk on the profit, that is, how much the profit will change with a change in the log exchange rate. Since the firm is risk averse, the foreign exchange risk brings a negative effect to the expected utility. The second effect comes from $\frac{dU}{d\pi}(\pi(\bar{s}))\frac{d^2\pi}{ds^2}(\bar{s})$. It is positive for LCP because π^* is convex in the log exchange rate, s. But from the equation (1), we know the profit function of PCP, π could be either convex or concave in s.

To compare these two strategies, we need to approximate the **optimal** expected utility, which yields from the optimal price chosen by the firm. For PCP, the optimal expected utility can be written as

$$E\left[U\left(\pi\left(P^{opt};s\right)\right)\right]\approx U\left(\pi\left(P^{opt};\bar{s}\right)\right) + \frac{1}{2}\begin{bmatrix}\frac{d^2U}{d\pi^2}\left(\pi\left(P^{opt};\bar{s}\right)\right)\left(\frac{d\pi}{ds}\left(P^{opt};\bar{s}\right)\right)^2 \\ +\frac{dU}{d\pi}\left(\pi\left(P^{opt};\bar{s}\right)\right)\frac{d^2\pi}{ds^2}\left(P^{opt};\bar{s}\right)\end{bmatrix}\sigma^2 \tag{5}$$

where P^{opt} solves the problem of $\underset{P}{Max}\ E_s\left[U(\pi(P))\right]$ and $\bar{U}=E\left[U\left(\pi\left(P^{opt};s\right)\right)\right]$.

Following a similar argument as in Engel (2003), we can use P^{app} to substitute P^{opt} in the above approximation.[15] P^{app} is the price that solves the utility maximization problem when s is fixed at its mean ($s=\bar{s}$). That is, $P^{app}=\arg\max\{U(\pi(\bar{s}))\}$. Substitute this to the equation 5, we obtain the approximated optimal expected utility for PCP in the equation (6).

[15] The approximation is good up to the second order terms. For more details see appendix 1.

$$E\left[U\left(\pi\left(P^{opt};s\right)\right)\right] \approx U\left(\pi\left(P^{app};\bar{s}\right)\right) + \frac{1}{2}\left[\begin{array}{l} \frac{d^2U}{d\pi^2}\left(\pi\left(P^{app};\bar{s}\right)\right)\left(\frac{d\pi}{ds}\left(P^{app};\bar{s}\right)\right)^2 \\ + \frac{dU}{d\pi}\left(\pi\left(P^{app};\bar{s}\right)\right)\frac{d^2\pi}{ds^2}\left(P^{app};\bar{s}\right) \end{array}\right]\sigma^2 \qquad (6)$$

By the same token, we can approximate the optimal expected utility of LCP as

$$E\left[U\left(\pi*\left(P*^{opt};s\right)\right)\right] \approx U\left(\pi*\left(P*^{app};\bar{s}\right)\right) + \frac{1}{2}\left[\begin{array}{l} \frac{d^2U}{d\pi*^2}\left(\pi*\left(P*^{app};\bar{s}\right)\right)\left(\frac{d\pi*}{ds}\left(P*^{app};\bar{s}\right)\right)^2 \\ + \frac{dU}{d\pi*}\left(\pi*\left(P*^{app};\bar{s}\right)\right)\frac{d^2\pi*}{ds^2}\left(P*^{app};\bar{s}\right) \end{array}\right]\sigma^2 \qquad (7)$$

When the log exchange rate is fixed at its mean ($s = \bar{s}$), it is easy to check that PCP and LCP yield the same profits. That is, $P^{app} = e^{\bar{s}} P*^{app}$ *and* $\pi\left(P^{app}\right) = \pi*\left(P*^{app}\right)$. Intuitively, when the exchange rate is fixed, the problem of currency choice becomes trivial: in which currency to set price does not matter at all since the price under one currency can always be converted to another one at the fixed rate. Therefore, from the equations (6) and (7), the necessary and sufficient condition for LCP to be dominant ($E\left[U\left(\pi*\left(P^{*opt};s\right)\right)\right] > E\left[U\left(\pi\left(P^{opt};s\right)\right)\right]$) reduces to

$$R\left[\left(\frac{d\pi*}{ds}\left(P*^{app};\bar{s}\right)\right)^2 - \left(\frac{d\pi}{ds}\left(P^{app};\bar{s}\right)\right)^2\right] < \left[\frac{d^2\pi*}{ds^2}\left(P*^{app};\bar{s}\right) - \frac{d^2\pi}{ds^2}\left(P^{app};\bar{s}\right)\right] \qquad (8)$$

where $R = -\frac{d^2U}{d\pi*^2}\left(\pi*\left(P*^{app};\bar{s}\right)\right) \Big/ \frac{dU}{d\pi*}\left(\pi*\left(P*^{app};\bar{s}\right)\right)$ is the absolute risk averse coefficient.

It seems from (8) that this condition is contingent on how much the firm dislikes the foreign exchange risk. However, in the appendix 1, we show that at the point of expansion, the marginal profit over the exchange rate is identical for LCP and PCP ($\frac{d\pi*}{ds}\left(P*^{app};\bar{s}\right) = \frac{d\pi}{ds}\left(P^{app};\bar{s}\right)$)[16]. This makes the risk-averse coefficient canceled out and the condition (8) boils down to a much simpler form

$$\frac{d^2\pi*}{ds^2}\left(P*^{app};\bar{s}\right) - \frac{d^2\pi}{ds^2}\left(P^{app};\bar{s}\right) > 0 \qquad (9)$$

If we follow the same second order Taylor expansion for a risk neutral firm, we will find that the same condition as (9) for LCP to be a dominant strategy. So under the second order Taylor expansion, the currency choice problem for a risk averse firm is actually identical to the one faced by a risk neutral firm. Therefore the existence of a currency forward market is not a necessary condition for us to extend the result of currency choice for a risk neutral firm to a risk averse one. This is consistent with the result of Devereux, Engel and Storgaard (2003) and Engel (2003). They find that the choice of price setting currency is independent of the stochastic discount factors in their models. As we have mentioned, the firm's risk preference depends on the assumptions about the discount factor in their papers. Therefore their result also implies that the choice is not contingent on the firm's risk preference. However, our result here is more general and can be applied to the case when the assets are not fairly diversified.

[16] Generally the marginal profit over the exchange rate differs for LCP and PCP. The equation holds only at the point where the log exchange rate is equal to its mean.

Devereux and Engel (1998, 1999) show that the economy can be insulated from the foreign monetary shocks if the most exporting firms set prices in the local currency. Therefore, it is desirable for the policy makers to encourage the practice of LCP. An efficient currency forward market is able to help the risk averse firms to hedge their exchange rate risk. So it sounds intuitive that the development of such a market could promote the practice of LCP. However, this seemingly intuitive result is questionable under the setup of this paper. It is easy to check that in this paper, the risk neutral firm does not hedge its foreign exchange exposure[17]. From the above result, we know that under the second order approximation, the price setting currency choice problem is exactly the same for risk neutral and risk averse firms. That is, the impact of the currency forward market is small and only exists in the higher order terms in the problem of currency choice[18]. Therefore the development of a currency forward market should not change the currency choice of the risk averse firms even though it may affect the prices charged by them. The policy makers should be cautious in taking the currency forward market as their first priority to encourage the practice of LCP. To understand the impacts of a currency forward market on the firm's choice of pricing currency, we have to first study the incentive for a risk neutral firm to hedge its foreign exchange exposure and how the forward market affects its currency choice behavior.

In the appendix 1, we also find the necessary and sufficient condition for LCP to yield higher expected profit than PCP:

$$(*) \qquad \gamma - \varepsilon - \delta\gamma(\gamma - 1) - 2(1-\omega)(\gamma - 1) < 1 .$$

[17] With the setup of this paper, the risk neutral firm has no incentive to hedge its exchange rate exposure. However, if we consider other effects like differentiated taxation in the model, even the risk neutral firm will have incentive to hedge.

[18] However, it is worth of noticing that we are not claiming the impact of hedging market on the utility is small. I thank Menzie Chinn for pointing out this for me.

where $\gamma\left(Pe^{-s}\right) = -\frac{Pe^{-s}D'}{D}$ is the elasticity of the demand function. $\frac{1}{\eta} = \frac{C'(D)D}{C(D)}$ is the elasticity of the cost function. $\varepsilon = \frac{\gamma' P e^{-s}}{\gamma}$ is the elasticity of the demand elasticity. $\delta = \frac{C''(D)D}{C'(D)}$ is the elasticity of the marginal cost and $\omega = \frac{W_1 H_1(W_1,\ W_2)}{H(W_1,\ W_2)}$. From the fact that H is HD1, it is easy to check that $1-\omega = \frac{W_2 H_2(W_1,\ W_2)}{H(W_1,\ W_2)}$. From this condition, we know that only the demand and cost functions determine the firm's decision in the single importing country model.

This condition is also consistent with the prior studies. The condition (*) is precisely the same one as in Engel (2003) when the only uncertainty comes from the exchange rate. This result can also be easily connected to Friberg's sufficient condition we mentioned before. We have noticed that the profit function of LCP is always convex in the log exchange rate s, which implies $\frac{d^2\pi^*}{ds^2}\left(P^{*app};\bar{s}\right) > 0$. Therefore, a sufficient condition for (9) to hold is $\frac{d^2\pi}{ds^2}\left(P^{app};\bar{s}\right) < 0$, that is, the profit function of PCP is concave in s. Friberg (1998) proves that when the cost function is convex ($\delta > 0$), a sufficient condition for π to be concave in s is $\varepsilon > \gamma$. It is easy to check that this condition is also sufficient for the condition we found in the appendix 1 (Friberg considers a special case when $\omega = 1$ and $\gamma > 1$.) Friberg extended this sufficient condition to the model with risk averse firms by assuming a perfect currency forward market. Here we find a more general condition and also show that under the second order Taylor expansion around the mean of log exchange rate $\bar{s}$, the currency forward market is not necessary to extend the decision rule of the currency choice from the risk neutral to the risk averse firms.

Before moving to the next section, it is helpful to elaborate a little on why the firm's choice of price setting currency simply depends on the demand and cost functions. At the point of our expansion (when the log exchange rate is fixed at its mean), the profit is the same for LCP and PCP. In LCP, the profit function is always convex in the log exchange rate s. A simple application of Jensen's inequality tells us the expected profit of LCP is higher than the profit when s is fixed at its mean. PCP is preferable only when its profit function is even more convex in s than that of LCP. So in which currency to set price just depends on under which currency the profit function is more convex in s. The curvature of the profit function is fully determined by the demand and cost functions under this single importing county setup. Therefore none of the stochastic property of the exchange rate enters the condition we found. The condition (*) is exactly the same condition under which the profit function is more convex for LCP than that for PCP. However, in the next section we will show you that the condition also depends on the variance and covariance of log exchange rates when the firm exports to multiple countries.

4. Model with multiple importing countries

Now, we extend our discussion to the case with multiple importing countries.[19] We follow a similar setup as in the last section with the modification that the firm now exports its products to two foreign countries: foreign country 1 and 2. The two foreign

[19] In this section, we only discuss the case of a risk neutral firm. However, following a similar process as in the single importing country case, we can prove that the risk preference does not affect the decision on the price setting currency choice under the assumption that foreign countries are symmetric.

countries are assumed to be symmetric and have the same demand function. The exporting firm is still a monopolist and is able to segment these two foreign markets.

Equations (10) and (11) are the profit functions for PCP and LCP respectively

$$\pi = P_1 D_1\left(P_1 e^{-s_1}\right) + P_2 D_2\left(P_2 e^{-s_2}\right) - C\left(D_1\left(P_1 e^{-s_1}\right) + D_2\left(P_2 e^{-s_2}\right)\right) H\left(W,\ W_1^* e^{s_1},\ W_2^* e^{s_2}\right) \tag{10}$$

$$\pi^* = P_1^* e^{s_1} D_1\left(P_1^*\right) + P_2^* e^{s_2} D_2\left(P_2^*\right) - C\left(D_1\left(P_1^*\right) + D_2\left(P_2^*\right)\right) H\left(W,\ W_1^* e^{s_1},\ W_2^* e^{s_2}\right) \tag{11}$$

We follow the same definitions for the parameters as in the last section and use the subscript 1 and 2 to distinguish the two foreign countries. More details about the second order Taylor expansion of these two equations are provided in the appendix 2. Here we just use the result directly and focus on the condition for the strategy LCP to be dominant. The expected optimal profit for PCP is

$$E[\pi] \approx CH\left[\begin{array}{l} \frac{\gamma}{\eta(\gamma-1)} - 1 + \frac{1}{2}\left(\frac{\gamma^2(\gamma-\varepsilon)}{\eta(\gamma-1)} - \frac{\gamma^2\delta + \gamma(\gamma-\varepsilon) + 2\gamma\omega_1}{\eta} - \zeta_1(1+\omega_1)\right)(VAR(s_1) + VAR(s_2)) \\ -\left(\frac{\delta\gamma^2 + 2\omega_1}{\eta} + \omega_{12}\omega_1\right) COV(s_1,\ s_2) \end{array}\right] \tag{12}$$

γ, ε, η and δ follow the same definitions as before. The new parameters are defined as

$$\omega = \frac{WH_1\left(W,\ W_1^* e^{s_1},\ W_2^* e^{s_2}\right)}{H\left(W,\ W_1^* e^{s_1},\ W_2^* e^{s_2}\right)}$$

$$\omega_1 = \frac{W_1 H_2\left(W,\ W_1^* e^{s_1},\ W_2^* e^{s_2}\right)}{H\left(W,\ W_1^* e^{s_1},\ W_2^* e^{s_2}\right)}$$

$$\omega_{12} = \frac{W_2 H_{23}\left(W,\ W_1^* e^{s_1},\ W_2^* e^{s_2}\right)}{H_2\left(W,\ W_1^* e^{s_1},\ W_2^* e^{s_2}\right)}$$

$$\zeta_1 = \frac{W_1^* e^{s_1} H_{22}\left(W,\ W_1^* e^{s_1},\ W_2^* e^{s_2}\right)}{H_2\left(W,\ W_1^* e^{s_1},\ W_2^* e^{s_2}\right)}$$

In the above equation, all the variables are evaluated at the point of $P = P^{app}; s = \bar{s}$.

If we follow the similar steps for LCP, we will obtain that

$$E\left[\pi^*\right] \approx CH\begin{bmatrix} \dfrac{\gamma}{\eta(\gamma-1)} - 1 + \dfrac{1}{2}\left(\dfrac{\gamma}{\eta(\gamma-1)} - \zeta_1(1+\omega_1)\right)(VAR(s_1) + VAR(s_2)) \\ -\omega_{12}\omega_1 COV\left(s_1,\ s_2\right) \end{bmatrix} \tag{13}$$

Comparing equation (12) and (13), it is easy to find the necessary and sufficient condition for LCP to yield higher expected profit as[20]

$$\begin{aligned} &(\gamma - 1 - \varepsilon - \delta\gamma(\gamma-1) - (1-\omega)(\gamma-1))(VAR(s_1) + VAR(s_2)) \\ &< (\gamma-1)(\gamma\delta + (1-\omega))COV\left(s_1,\ s_2\right) \end{aligned} \tag{14}$$

If we set the covariance of the log exchange rates to zero ($COV\left(s_1,\ s_2\right) = 0$), the condition (14) reduces to $\varepsilon - (\gamma-1) > -\gamma\delta(\gamma-1) - (1-\omega)(\gamma-1)$. We are left with the same condition as in the single importing country case. This result is intuitive. Since the firm can segment these two markets perfectly, if the exchange rates are also uncorrelated, these two markets are just two independent markets for the firm. Choosing currency for two totally independent markets is of no difference from choosing currency one by one for each market. So the condition for the single importing country model is just a special

---

[20] We need to notice $2\omega_1 = \omega_1 + \omega_2 = 1 - \omega$, which is from the symmetry between the two foreign countries and the homogeneity of degree one for the function H.

case of the model with multiple importing countries. In this more general condition, the variance and covariance of the exchange rates also affect the firm's choice of price setting currency along with the demand and cost functions.

In the condition (14), the effect of the covariance of the log exchange rates depends on the sign of $(\gamma-1)(\gamma\delta+(1-\omega))$. γ is the demand elasticity evaluated at the optimal price. Since the firm is a monopolist in our model, γ is greater than 1. It is also easy to see that $1-\omega$ is always positive by the homogeneity of degree one for the function of $H\left(W,\ W_1^* e^{s_1},\ W_2^* e^{s_2}\right)$. The sign of δ, however, is ambiguous and depends on the property of the cost function. From the definition that $\delta=\frac{C''(D)D}{C'(D)}$, δ is positive under the usual assumption that the cost function is convex.

In this case, $(\gamma-1)(\gamma\delta+(1-\omega))$ is positive. And it is easy to check from the condition (14) that the condition for LCP to yield higher expected profit in the single importing country case ($\gamma-\varepsilon-\delta\gamma(\gamma-1)-2(1-\omega)(\gamma-1)<1$), is a sufficient condition for LCP to yield higher expected profit in the two importing county case if the covariance of log exchange rates is positive. That is, the positively correlated exchange rates will encourage the firm to take LCP.

This result is very intuitive. When the strategy of LCP is dominant in the single importing country case, the profit function of LCP must be more convex in log exchange rate than that of PCP. Therefore, the increase in the variance of log exchange rate promotes the popularity of LCP. In the two importing country case, the positive correlation of log exchange rates increases the overall variability of log exchange rates and make LCP more favorable than before. At the same time, the increased exchange rate volatility also decreases the relative expected cost for LCP against PCP. Under the assumption of convex cost function, the increase in the variance of overall exchange rate increases the expected cost for PCP, but does not affect the cost of LCP since the demand and therefore the cost has been fixed when the price is denominated in the local currency.

The policy implication for this result is that the positively correlated exchange rates may encourage the practice of LCP for the multinational companies. Recent years observe an increase in the practice of LCP[21]. It is interesting to see if this increase is caused by the development of the multi-national companies that export to multiple countries with positively correlated log exchange rates. Due to the lack of the appropriate micro data, we are not able to test this result in this paper. But we are looking forward to the future empirical research for this test. However, an important contribution for this result is that we show the macroeconomic variables, like exchange rates determine the firm's choice of price setting currency. Meanwhile, the currency choice in return has important implication for these variables in the macroeconomic models as we have mentioned before. Therefore it is necessary to capture this interaction in the macroeconomic model in the future research.

5. Conclusion

The exporters have to decide in which currency to preset their prices when facing the exchange rate uncertainty. In the prior studies, the firm is either assumed to be risk neutral or there is a perfect currency forward market for the risk averse firm to fully hedge the exchange rate risk. However, the development of currency forward markets is very limited, especially for the developing countries. In this paper, I connect these two

[21] See ECU Institute (1995).

types of firms in a more realistic way. Under the second order Taylor expansion around the mean of the log exchange rate, the risk averse firm actually solves the same problem as the risk neutral one. That is, when the change in the logarithm of exchange rate is small (this condition is more realistic than a perfect currency hedging market), the risk preference is irrelevant in the problem of currency choice. The policy maker should be cautious in the claim that the currency forward market will encourage risk averse firm to employ LCP.

The second contribution of this paper is that we extend the discussion to a multi-currency setting. Though the macro variables like exchange rate are irrelevant in the case with a single importing country, they are crucial for the firm's choice of price setting currency when the firm's trading partners are from more than one country. Usually multinational corporations (MNC) produce and trade simultaneous with multiple countries. This paper provides a micro-foundation to analyze the interaction between the macroeconomic variables and the MNC's pricing currency choice.

However, we have to admit that the model studied in this paper is a very simple one with many restrictions. For example, in this paper, we limit our attention to the case where only exchange rate is stochastic. Though this assumption significantly simplifies our discussion and makes it easier for us to focus on the major points we want to deliver, a more general model is desirable and may generate more interesting results.

As mentioned in the last section, the risk neutral firms have no incentive to hedge foreign exchange risk in this paper since the profit is a linear function of exchange rate when setting price in the foreign currency. Many other factors, such as taxes, affect the shape of the profit function and may affect the firm's hedging behavior. The inclusion of these factors in the model is also desirable in the future research.

More importantly, in this paper the length of the price stickiness is taken as exogenous. It is more reasonable for us to believe that the firm's decision on how long to fix its price is determined by the macroeconomic variables like the inflation rate, exchange rate, etc[22]. At the same time, the choice of price setting currency and the stickiness of the price have significant impacts on these macroeconomic variables in return. The endoginization of the choice on price setting currency has generated some very interesting results in the paper of Devereux, Engel and Storgaard (2003). From my opinion, it is also desirable to endogenize the length of the price stickiness and explore how it interacts with the above macro variables. The research on the micro-foundations of the firm's decision on the price stickiness and its implication on the monetary policy in the general equilibrium models should be fruitful in the future research.

[22] Here we follow the literature in which the price adjustment is time contingent. However, it is worth of noticing that both the time and state contingent price adjustments are documented in the empirical studies.

Appendix 1

We follow the similar second order Taylor expansion as Engel(2003) and extend it to the case with risk averse firm. By the second order Taylor expansion,

$$E[U(\pi)] \approx U(\pi(\bar{s}))$$
$$+\frac{1}{2}\left[\frac{d^2U}{d\pi^2}(\pi(\bar{s}))\left(\frac{d\pi}{ds}(\bar{s})\right)^2 + \frac{dU}{d\pi}(\pi(\bar{s}))\frac{d^2\pi}{ds^2}(\bar{s})\right]\sigma^2$$

To compare PCP and LCP, we need to approximate optimal expected profit, that is, the profit when price equals to P^{opt}.

P^{opt} is the optimal solution to firm's problem, that is

$P^{opt} = \arg\max(E[U(\pi)])$. The close form of P^{opt} is usually complicated and not available for our approximation. Instead, Engel (2003) uses P^{app} in the second order approximation.

P^{app} is the solution to firm's problem when log exchange rate is fixed at its mean. That is, $P^{app} = \arg\max\{\pi(\bar{s})\}$. We can follow a similar argument to prove that this approximation is also valid here at least to the order of our approximation.

When $s = \bar{s}$, $P^{app} = \arg\max\{\pi(\bar{s})\} = \arg\max\{U(\pi(\bar{s}))\}$. Therefore, $P^{app} = P^{opt}(1 + o(\sigma^2))$, as $E[U(\pi)] = U(\pi(\bar{s}))$ up to the second order terms. From the first order condition of P^{opt}, we know $E[U(\pi(P^{opt};s))] = E[U(\pi(P^{app};s))]$ to the second order approximation as $\lim_{P^{app}\to P^{opt}}\{E[U(\pi(P^{opt};s))] - E[U(\pi(P^{app};s))]\} = 0$

With the above second order approximation, we can prove that $\frac{d\pi^*}{ds}(P^{*app};\bar{s}) = \frac{d\pi}{ds}(P^{app};\bar{s})$.

The profit for PCP and LCP is respectively

$$\left.\begin{aligned}\pi &= PD\left(\frac{P}{S}\right) - C\left(D\left(\frac{P}{S}\right)\right)H\left(W_1,\ W_2^* S\right) = PD\left(Pe^{-s}\right) - C\left(D\left(Pe^{-s}\right)\right)H\left(W_1,\ W_2^* e^s\right)\\ \pi^* &= P^* SD(P^*) - C(D(P^*))H\left(W_1,\ W_2^* S\right) = P^* e^s D(P^*) - C(D(P^*))H\left(W_1,\ W_2^* e^s\right)\end{aligned}\right\} \quad (A.1)$$

Take derivative of profit with respect to s, we have marginal profit with respect to exchange rate.

$$\frac{d\pi}{ds} = -PD'\left(Pe^{-s}\right)Pe^{-s_1} + HC'\left(D\left(Pe^{-s}\right)\right)D'\left(Pe^{-s}\right)Pe^{-s} - CH_2 W_2^* e^s$$
$$= PD\gamma - CH\left(\frac{\gamma}{\eta} + 1 - \omega\right)$$

where $\gamma\left(Pe^{-s}\right) = -\frac{Pe^{-s}D'}{D}$ is the elasticity of demand function.

$\frac{1}{\eta} = \frac{C'(D)D}{C(D)}$ is the elasticity of cost function. $H_2 = \frac{\partial H\left(W_1,\ W_2\right)}{\partial W_2}$ and

$\omega = \frac{W_1 H_1\left(W_1,\ W_2\right)}{H\left(W_1,\ W_2\right)}$. From the fact that H is HD1, we know $1 - \omega = \frac{W_2 H_2\left(W_1,\ W_2\right)}{H\left(W_1,\ W_2\right)}$

$$\frac{d\pi^*}{ds} = P^* e^s D(P^*) - CH_2 W_2^* e^s$$

When $P = P^{app}$, $P^* = P^{*app}$, from the first order condition,

$$P^{*app}\ D = \frac{CH\gamma e^{-\bar{s}}}{\eta(\gamma - 1)} \quad \text{(A.2)}$$

$$P^{app} D = \frac{CH\gamma}{\eta(\gamma - 1)}$$

Substitute them to the above equation, we have

$$\frac{d\pi^*}{ds}\left(P^{*app}; \bar{s}\right) = \frac{d\pi}{ds}\left(P^{app}; \bar{s}\right) = \frac{CH\gamma}{\eta(\gamma - 1)} - (1 - \omega)CH$$

All the variables in the above equation are evaluated at P^{app} and $\bar{s}$.

Next, we derive the necessary and sufficient condition for LCP to yield higher expected profit than PCP.

Apply the second order Taylor expansion to expected value of the profit functions in (A.1)

$$E\left[\pi^{PCP}\right] \approx P^{PCP} D\left(P^{PCP} e^{-\bar{s}}\right) - C\left(D\left(P^{PCP} e^{-\bar{s}}\right)\right) H\left(W_1,\ W_2^* e^{\bar{s}}\right) + \frac{1}{2}\left[P^{PCP} D\left(P^{PCP} e^{-\bar{s}}\right)\gamma(\gamma-\varepsilon) - \frac{CH}{\eta}\left[\gamma^2\delta + \gamma(\gamma-\varepsilon) + (1-\omega)(2\gamma+\eta+\eta\zeta)\right]\right] VAR(s) \qquad \text{(A.3)}$$

$\varepsilon = \dfrac{\gamma' P e^{-s}}{\gamma}$ is the elasticity of elasticity.

$\delta = \dfrac{C''(D)D}{C'(D)}$ is the elasticity of marginal cost.

$$\zeta = \frac{H_{22}\left(W_1,\ W_2\right)W_2}{H_2\left(W_1,\ W_2\right)}$$

Substitute A.2 to the above equation, we will have

$$E\left[\pi^{PCP}\right] \approx C\left[\frac{\gamma}{\eta(\gamma-1)} - 1 + \frac{H}{2}\left(\frac{\gamma^2(\gamma-\varepsilon)}{\eta(\gamma-1)} - \frac{\gamma^2\delta + \gamma(\gamma-\varepsilon) + (1-\omega)(2\gamma+\eta+\eta\zeta)}{\eta}\right) VAR(s)\right] \qquad \text{(A.4)}$$

Following the same steps for the case of LCP, we have

$$E\left[\pi^{LCP}\right] \approx C\left[\frac{\gamma}{\eta(\gamma-1)} - 1 + \frac{H}{2}\left(\frac{\gamma}{\eta(\gamma-1)} - (1-\omega)(1+\zeta)\right) VAR(s)\right] \qquad \text{(A.5)}$$

A simple comparison between A.4 and A.5 gives us the necessary and sufficient condition for LCP to yield higher expected profit is

$\gamma - \varepsilon - \delta\gamma(\gamma-1) - 2(1-\omega)(\gamma-1) < 1$.

Appendix 2

Second order Taylor expansion of expected profit under Multi-currency setting

The profit function for PCP is

$$\pi^{PCP} = P_1^{PCP} D_1\left(\frac{P_1^{PCP}}{S_1}\right) + P_2^{PCP} D_2\left(\frac{P_2^{PCP}}{S_2}\right) - C\left(D_1\left(\frac{P_1^{PCP}}{S_1}\right) + D_2\left(\frac{P_2^{PCP}}{S_2}\right)\right) H\left(W,\ W_1^* e^{s_1},\ W_2^* e^{s_2}\right)$$

$$= P_1^{PCP} D_1\left(P_1^{PCP} e^{-s_1}\right) + P_2^{PCP} D_2\left(P_2^{PCP} e^{-s_2}\right) - C\left(D_1\left(P_1^{PCP} e^{-s_1}\right) + D_2\left(P_2^{PCP} e^{-s_2}\right)\right) H\left(W,\ W_1^* e^{s_1},\ W_2^* e^{s_2}\right)$$

In the following equations we suppress augments of the functions when we believe no confusion will arise.

The first derivative of profit over s is

$$\frac{d\pi}{ds_1} = -P_1^{PCP} D_1' P_1^{PCP} e^{-s_1} - \left[-C' D_1' P_1^{PCP} e^{-s_1} H + CH_2 W_1^* e^{s_1}\right]$$

We can obtain the second derivative of profit over s as

$$\frac{d^2\pi}{ds_1^{\ 2}} = P_1 D_1\left[\frac{P_1 e^{-s_1} D_1'}{D_1} + \frac{P_1 e^{-s_1} D_1'}{D_1} \times \frac{P_1 e^{-s_1} D_1''}{D_1'}\right]$$

$$-CH\left[\begin{array}{l}\frac{P_1 e^{-s_1} D_1'}{D_1} \times \frac{C' D_1}{C} + \left(\frac{P_1 e^{-s_1} D_1'}{D_1}\right)^2 \times \frac{C'' D_1}{C'} \times \frac{C' D_1}{C} + \frac{C' D_1}{C} \times \frac{P_1 e^{-s_1} D_1'}{D_1} \times \frac{P_1 e^{-s_1} D_1''}{D_1'} \\ -2 \times \frac{C' D_1}{C} \times \frac{P_1 e^{-s_1} D_1'}{D_1} \times \frac{H_2 W_1^* e^{s_1}}{H} + \frac{H_2 W_1^* e^{s_1}}{H} \times \frac{H_{22} W_1^* e^{s_1}}{H_2} + \frac{H_2 W_1^* e^{s_1}}{H}\end{array}\right]$$

$$= P_1 D_1 \gamma(\gamma - \varepsilon) - \frac{CH}{\eta}\left[\gamma(\gamma - \varepsilon) + \gamma^2 \delta + 2\gamma(1-\omega) + \zeta_1(1+\omega_1)\right]$$

whwhere D is the total demand faced by the firm. $D = D_1 + D_2 = 2D_i$ since we assume that the two countries are symmetric.

$\gamma\left(P_1 e^{-s_1}\right) = -\frac{P_1 e^{-s_1} D_1'}{D_1}$ is the elasticity of demand function.

$\varepsilon\left(P_1 e^{-s_1}\right) = \frac{\gamma'\left(P_1 e^{-s_1}\right) P_1 e^{-s_1}}{\gamma\left(P_1 e^{-s_1}\right)}$ is the elasticity of elasticity.

$\frac{1}{\eta} = \frac{C'(D) D}{C(D)}$ is the elasticity of cost function.

$\delta = \frac{C''(D)D}{C'(D)}$ is the elasticity of marginal cost.

$$\frac{d^2\pi}{ds_1 ds_2} = -\begin{bmatrix} C'' D_1' P_1 e^{-s_1} D_2' P_2 e^{-s_2} H - C' D_1' P_1 e^{-s_1} H_3 W_2^* e^{s_2} - C' D_2' P_2 e^{-s_2} H_2 W_1^* e^{s_1} \\ + CH_{23} W_2^* e^{s_2} W_1^* e^{s_1} \end{bmatrix}$$

$$= -\frac{CH}{\eta}\left[\delta\gamma^2 + \gamma(1-\omega) + \eta\omega_1\omega_{12}\right]$$

Approximate the expected profit around the mean of log exchange rate.

$$E\left[\pi^{PCP}\right] \approx P_1^{PCP} D_1\left(P_1^{PCP} e^{-\bar{s}_1}\right) + P_2^{PCP} D_2\left(P_2^{PCP} e^{-\bar{s}_2}\right) - C\left(D_1\left(P_1^{PCP} e^{-\bar{s}_1}\right) + D_2\left(P_2^{PCP} e^{-\bar{s}_2}\right)\right)$$
$$+\frac{1}{2}\left[P_1 D_1 \gamma(\gamma-\varepsilon) - \frac{CH}{\eta}\left[\gamma(\gamma-\varepsilon) + \gamma^2\delta + 2\gamma(1-\omega) + \zeta_1(1+\omega_1)\right]\right](VAR(s_1) + VAR(s_2))$$
$$-\frac{CH}{2\eta}\left[\delta\gamma^2 + \gamma(1-\omega) + \eta\omega_1\omega_{12}\right]COV\left(s_1, s_2\right)$$

Let $P_i^{app} = \arg\max \pi^{PCP}\left(\bar{s}_1, \quad \bar{s}_2\right)$ and $\pi^{app} = E\pi^{PCP}\left(P_i^{app}; s_1, \quad s_2\right)$

Where $\pi^{PCP}\left(\bar{s}_1, \quad \bar{s}_2\right)$ is the profit function when the exchange rates are fixed at their means.

From the first order condition, we know

$$P_1^{app} D_1\left(P_1^{app} e^{-\bar{s}_1}\right) = \frac{\gamma CH}{2\eta(\gamma-1)}$$

Let $P_i^{opt} = \arg\max\left(E\left[\pi\left(s_1, \quad s_2\right)\right]\right)$ and $\pi^{opt} = E\left[\pi\left(P_i^{opt}; s_1, \quad s_2\right)\right]$

Following the same argument as appendix 1, we know that $P_i^{app} = P_i^{opt}\left(1 + o\left(\sigma^2\right)\right)$ and $\pi^{opt} = \pi^{app}$ to the second order approximation. So we substitute the solution of P_i^{app} to the above approximation, we can obtain

$$E\left[\pi^{PCP}\right] \approx CH\left[\begin{array}{l}\frac{\gamma}{\eta(\gamma-1)} - 1 + \frac{1}{2}\left(\frac{\gamma^2(\gamma-\varepsilon)}{\eta(\gamma-1)} - \frac{\gamma^2\delta - \gamma(\gamma-\varepsilon) + \gamma(1-\omega)}{\eta}\right)(VAR(s_1) + VAR(s_2)) \\ - \frac{\delta\gamma^2 + \gamma(1-\omega)}{\eta} COV(s_1, s_2)\end{array}\right]$$

If we follow the similar steps for LCP, we will obtain that

$$E\left[\pi^{LCP}\right] \approx CH\left[\frac{\gamma}{\eta(\gamma-1)} - 1 + \frac{1}{2}\frac{\gamma}{\eta(\gamma-1)}(VAR(s_1) + VAR(s_2))\right]$$

Compare these results, we can find the necessary and sufficient condition for LCP to yield higher expected profit is

$$\begin{array}{l}(\gamma - 1 - \varepsilon - \delta\gamma(\gamma-1) - (1-\omega)(\gamma-1))(VAR(s_1) + VAR(s_2)) \\ < (\gamma-1)(\gamma\delta + (1-\omega))COV(s_1, s_2)\end{array}$$

This is how we obtain the condition (14).

Reference:

Baron, D. P., 1976. Fluctuating Exchange Rates and the Pricing of Exports. Economic Inquiry 14, 425-438.

Bascom, W. O., 1994. The Economics of Financial Reform in Developing Countries. St. Martin's Press, New York.

Baxter, M., Stockman, A. C., 1989. Business Cycles and the Exchange-Rate Regime: Some International Evidence. Journal of Monetary Economics 23, 377-400.

Betts, C., Devereux, M. B., 1996. The Exchange Rate in a Model of Pricing to Market. European Economic Review 40, 1007-1021.

Clark, P. B., 1973. Uncertainty, Exchange Risk, and the Level of International Trade. Western Economic Journal 11, 302-313.

Devereux, M. B., Engel, C., 1998. Fixed Versus Floating Exchange Rates: How Price Setting Affects the Optimal Choice of Exchange Rate Regime. NBER Working Paper No. 6867.

Devereux, M. B., Engel, C., 1999. The Optimal Choice of Exchange Rate Regime: Price-setting Rules and Internationalized Production. NBER Working Paper No. 6992.

Devereux, M. B., Engel, C., Storgaard, P. E., 2003. Endogenous Exchange Rate Pass-through When Nominal Prices are Set in Advance. Journal of International Economics, forthcoming.

Donnenfeld, S., Zilcha, I., 1991. Pricing of Exports and Exchange Rate Uncertainty. International Economic Review 32, 1009—1022.

ECU Institute, 1995. International Currency Competition and the Future Role of the Single European Currency, Kluwer Law International, London.

Ethier, W., 1973. International Trade and the Forward Exchange Market. American Economic Review 63, 494-503.

Eiteman, D. K., Stonehill, A. I., Moffett, M. H., 1998. Multinational Business Finance. Reading, Mass.: Addison-Wedsley.

Engel, C., 2003. On the Relationship between Pass-Through and Sticky Nominal Prices. Working paper, University of Wisconsin and NBER.

Feenstra, R., Kendall, J., 1997. Pass-through of Exchange Rates and Purchasing Power Parity. Journal of International Economics 43, 237-61.

Flood, R., Rose, A. K., 1995. Fixing Exchange Rates: A Virtual Quest for Fundamentals. Journal of Monetary Economics 36, 3-37.

Friberg, R., 1998. In which currency should exporters set eheir prices? Journal of International Economics 45, 59-76.

Friberg, R., 1999. Exchange Rates and the Firm-Strategies to Manage Exposure and the Impact of EMU. St. Martin's Press, Inc., New York.

Giovannini, A., 1988. Exchange Rates and Traded Goods Prices. Journal of International Economics 24, 45-68.

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

Kawai, M., Zilcha, I., 1986. International Trade with Forward-Future Market under Exchange Rate and Price Uncertainty. Journal of International Economics February, 83-98.

Kumar, P., 1988. Shareholder-Manager Conflict and the Information Content of

Dividends. Review of Financial Studies 1, 111-126.

Mussa, M., 1986. Nominal Exchange Rate Regimes and the Behavior of Real Exchange Rates: Evidence and Implications. Carnegie-Rochester Conference Series on Public Policy 25, 117-214.

Obstfeld, M., Rogoff, K., 1995. Exchange Rate Dynamics Redux. Journal of Political Economy 103, 624-60.

Obstfeld, M., 1998. Open-Economy Macroeconomics: Developments in Theory and Policy. Scandinavian Journal of Economics 100, 247-75.

Rawls, W. S., Smithson, C. W., 1990. Strategic Risk Management. Journal of Applied Corporate Finance 2, winter, 6-18