

# The Choice of Invoice Currency in International Trade: Implications for the Internationalization of the Yen

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*In this paper, we present an overview of theoretical research on the choice of an invoice currency for exports from the perspective of expected profit maximization. We then use this theory as a basis to offer a current assessment and future outlook regarding the use of the yen in trade transactions, which is one aspect of the internationalization of the yen. Our analysis demonstrates that the current use of the yen to price exports is largely consistent with levels that can be explained by theory. This suggests that the current measures for improving Japanese financial markets are, by themselves, likely to have only a limited impact on expanding the use of the yen as a denomination for trade transactions, given the current international competitiveness and market share of Japan's manufacturing industry and the current exchange rate regimes. Moreover, the currency-basket regime that has been proposed for East Asia from the perspective of the internationalization of the yen is not necessarily theoretically desirable for the region, nor is expanded use of the yen in trade transactions necessarily a free lunch for Japan, in that it may very well bring with it new problems for implementing economic policies.*

Keywords: Invoice currency; Local currency pricing (LCP); Producer's currency pricing (PCP); Internationalization of the yen; New open-economy macroeconomics; Currency-basket regime

JEL Classification: F41, F42, L11

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We would like to thank Professor Shin'ichi Fukuda, Faculty of Economics, University of Tokyo, and staff at the International Department and the Institute for Monetary and Economic Studies (IMES) of the Bank of Japan for their valuable comments. Furthermore, we would like to express our appreciation to Ryoji Koike in Research Division I of IMES for his help with data on trade between Japan and East Asia. The opinions and inevitable errors contained in this paper are purely those of the authors, and do not represent the official views of either the Bank of Japan or IMES.

## I. Introduction

In response to recent developments in international macroeconomics, there has been strong interest among academics and central bankers regarding the firm's choice of a currency to price its exports. Since Obstfeld and Rogoff (1995) published their work on new open-economy macroeconomics, a dynamic general equilibrium open-economy model with micro foundations, many researchers have incorporated the firm's invoicing decision into this model. This line of research shows that the transmission of monetary policy, optimal monetary policy rules, and the optimal exchange rate regime all depend on the firm's choice of an invoice currency for exporting its goods, that is, whether it chooses producer's currency pricing (PCP) or local currency pricing (LCP).<sup>1</sup>

One problem with this area of research, however, is that the exporting firm's invoicing decision is given exogenously (Fujiki and Otani [2002] and Gerlach [2002]). Consequently, in recent years focus has begun to shift toward theoretical research using models in which the currency choice is endogenous.

Until now, research on the choice of an invoice currency has largely focused on why the U.S. dollar has become the world's vehicle currency for international transactions. This research on vehicle currency can be divided into several categories according to the essential function of money.<sup>2</sup> The first category is analysis focused on money as a medium of exchange, and the research is based on the transaction cost of currency conversion. Swoboda (1968) is a pioneer in this area. Regarding why only a small number of currencies, led by the U.S. dollar, were used as vehicle currencies in international trade, Swoboda pointed out that (1) a higher transaction cost in converting between the home and foreign currencies resulted in a larger amount of foreign currency held, and (2) the total amount of overall foreign currency holdings could be reduced by holding a single vehicle currency for all trade settlement rather than holding the currencies of each trading partner, leading to a reduction in overall transaction cost. Regarding which country's currency became the vehicle currency, Swoboda found that the vehicle currency chosen was the currency of a country with (1) a large value of international trade and a large volume of transactions in its currency in the forex markets,<sup>3</sup> and (2) well-developed financial markets.<sup>4</sup> Krugman (1980) also focused on the transaction cost between the home and foreign currencies, and found that when the average transaction cost was decreasing in trading volume, the currency with the lowest translation cost, i.e., the currency with the largest transaction volume, would become the vehicle currency. He also found that a currency's status as a vehicle currency was aided by inertia.<sup>5</sup>

1. See Lane (2001) regarding recent progress in theoretical research incorporating the firm's price-setting behavior into new open-economy macroeconomics.

2. For more on this, see Magee and Rao (1980).

3. This is because the greater the trading volume, the lower the transaction costs of exchanging currencies.

4. Chrystal (1977) used the U.S. dollar, British sterling, French franc, and German mark to provide empirical support to the criteria for selecting a vehicle currency identified by Swoboda (1968).

5. To support this, Krugman (1980) provides the example of Great Britain, which although it declined in economic importance following World War I, was able to maintain the pound sterling's status as the vehicle currency together with the U.S. dollar until World War II.

Rey (2001) built a more rigorous model to analyze the research done by Swoboda and Krugman. Rey (2001) introduced transaction costs of currency exchange to a three-country general equilibrium model and theoretically showed how multiple equilibria as to the choice of a vehicle currency arose from the strength of trade ties and the size of transaction costs. She found that the currency of the country with the greatest degree of openness and the currency with the lowest transaction costs of exchange with other currencies become the vehicle currency.<sup>6</sup>

The second category of research on vehicle currency focuses on money as a unit of account. McKinnon (1979) stated that international transactions of highly homogeneous primary goods were concentrated in specialized exchange markets in the United States and the United Kingdom, and concluded that a single vehicle currency would be used for trading in homogeneous goods because expressing prices in the same currency made more efficient transactions possible when trading in such goods.<sup>7,8</sup>

Nevertheless, the fraction of primary goods invoiced in U.S. dollars continues to decline, whereas the fraction of machinery and other highly heterogeneous products traded in dollars in international trade increases. McKinnon (1979) argued that the home currency is selected for pricing highly heterogeneous goods.<sup>9</sup> Consequently, the above-noted research on vehicle currency does not adequately explain the actual invoicing decision made, and this in turn makes it necessary to examine the choice of non-vehicle currency, i.e., the decision on which country's currency is chosen as the invoice currency in bilateral trade. Regarding this point, Giovannini (1988) analyzed the currency choice made by a monopolistic exporting firm from the perspective of maximizing expected profits under uncertainty in exchange rate movements. He concluded that the choice of an invoice currency depended on the shape of the profit function.<sup>10</sup> Since his research, there has been a large body of theoretical research on choosing the invoice currency from the perspective of maximizing expected profits.

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6. As noted above, research focused on money as a medium of exchange was largely dependent on the transaction costs between currencies. There is one theoretical work, however, that ignores the transaction cost between currencies to discover the mechanism that creates a vehicle currency: Matsuyama, Kiyotaki, and Matsui (1993). Using a random matching model, Matsuyama, Kiyotaki, and Matsui (1993) analyzed the type of equilibrium that would arise as to the regional use of money, in a world where only two types of money, the home currency and the foreign currency, existed. They found that three types of equilibrium would arise: (1) the regional currency case, in which absolutely no international transactions took place, and the home currency was only used in the home country and the foreign currency only used in the foreign country; (2) the single vehicle currency case, whereby one currency became a regional currency, and the other currency was used not only in its country of issue but also in the foreign country; and (3) the dual vehicle currency case, whereby both currencies were used in both the home country and the foreign country. Furthermore, they showed that the currency of a country with a large economy is more likely to become the vehicle currency, and the higher the degree of economic integration, the greater the likelihood that two vehicle currencies would coexist.
  7. The same argument can be made for financial transactions. That is, it is possible to lower the cost of collecting information and trade more efficiently by using a single vehicle currency for financial transactions and holding financial assets denominated in that vehicle currency, rather than by using multiple currencies and holding financial assets denominated in each of the currencies. For related literature, see Brunner and Meltzer (1971).
  8. There is also research on vehicle currency that focuses on money as a store of value, arguing that when currency is used for settlement at a future date, the currency with a stable value is chosen as the invoice currency and becomes the vehicle currency.
  9. Grassman (1973) studied the invoice currency used in the trade of Sweden and Denmark and found that both countries tended to use the producer's currency as the invoice currency in their trade. This tendency for the producer's currency to be used as the invoice currency in international trade is now known as Grassman's Law, following Grassman (1973).
  10. The advantage of this approach is that it enables simultaneously solving the problems of choosing an invoice currency and setting the export price, and that it is possible to describe the relationship between the choice of

Such theoretical research can be an extremely useful guideline for assessing the current state, and projecting the future, of the use of the yen as the invoice currency in trade transactions, one aspect of the internationalization of the yen.<sup>11</sup> Given that a large proportion of Japan's exports are differentiated, heterogeneous goods such as machinery, we believe that Giovannini (1988) and later research on choosing an invoice currency based on maximization of expected profits is extremely germane. Up until now, however, the analysis and policy proposals on the use of the yen as an invoice currency have been based on research focusing on money as a medium of exchange and as a unit of account. As far as we know, none of these studies or policy proposals have taken advantage of the partial or general equilibrium analysis based on expected profit maximization from Giovannini (1988) and later research.<sup>12</sup>

Recently, some economists, particularly in Japan, have been advocating the introduction of a currency-basket regime in East Asia.<sup>13</sup> Many of the countries in East Asia are now using a *de facto* U.S. dollar peg.<sup>14</sup> If high volatility in the yen-dollar rate, which implies high volatility in the exchange rates between the yen and East Asian currencies, is standing in the way of expanded use of the yen as an invoice currency, it is likely that the introduction of a currency-basket regime in East Asia would stabilize the exchange rate between the yen and East Asian currencies and thereby promote use of the yen. Thus, there is a need to examine whether a currency-basket regime is desirable in East Asia when considering the use of the yen as an invoice currency in the future. New open-economy macroeconomics is extremely beneficial in this regard, given that it enables examination of the optimal currency regime from an economic welfare perspective. In this paper, we will examine the optimality of a currency-basket regime in East Asia, taking advantage of recent developments in new open-economy macroeconomics.

Our paper is organized as follows. In Section II, we provide an overview of endogenous currency choice theory. We first survey research using the partial equilibrium models that have dominated the analysis to date, and then introduce recent research based on a general equilibrium model. In actual trade, a large percentage of trade transactions is invoiced in U.S. dollars, even in trade not involving the United

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invoice currency and the exchange rate pass-through. For example, Friberg (1998) showed that the condition for choosing the local currency as the invoice currency is the same as the condition requiring the exchange rate pass-through of the export prices to be less than one.

On the other hand, there are also problems with this approach. That is, this literature assumes that the price is set beforehand and that the export volume can be flexibly determined. In actual trade transactions, however, not only the price but also the export volume is decided when making the export contract. Therefore, the model's assumptions are inconsistent with actual trade. Furthermore, even a single firm can choose from among the home currency, the foreign currency, and a vehicle currency for the invoice currency. Under the profit maximization approach, however, the firm can only choose between two options—PCP or LCP—and thus this model is also limited in its ability to explain actual invoice currency decisions.

11. The internationalization of the yen signifies the expanded use of the yen not only in conducting trade but also in capital transactions and as a denomination of foreign reserves. For example, the Ministry of Finance (1999) defined yen internationalization as "increasing the percentage of Japan's cross-border transactions and transactions conducted overseas denominated in yen as well as raising the fraction of nonresidents' asset portfolios denominated in yen, pointing specifically to raising the yen's profile in the international currency regime and increasing the weight of business transactions, capital transactions, and foreign currency reserves held in yen."

12. See Section III for further discussion regarding this point.

13. Literature on this topic includes Ogawa and Ito (2000).

14. See Kawai (2002) and McKinnon and Schnabl (2002).

States (where the dollar is a third country's currency). Then, we examine the possibility for the third country's currency to be chosen as an invoice currency using the expected profit maximization framework that allows for use of a third country's currency in addition to PCP or LCP, rather than traditional research on vehicle currency. In Section III, we start by looking at the use of the yen as an invoice currency. We then assess this current use and forecast future use by examining the extent to which the actual invoicing decision in Japan and other industrialized countries can be explained by the conditions found in the theoretical research discussed in Section II. In Section IV, we take advantage of new open-economy macroeconomics to examine the desirability of a currency-basket regime in East Asia from the perspective of the use of the yen as an invoice currency. In Section V, we consider the effect of an increase in the use of the yen as an invoice currency on economic policy, and then close by presenting our conclusions.

In Appendices 1 and 2, we explain our methodology for deriving the equations for choosing between PCP and LCP examined in Section II, and also provide a more detailed explanation of the conditions governing the invoicing decision when a third-country currency is available. In Appendix 3, we explain the methodology for estimating the price elasticity for each product category of Japan's exports to East Asia (excluding China) and the estimated result, which was used in the empirical analysis of Section III. In Appendix 4, we introduce prior research analyzing the impact on the international transmission of monetary policy in the hypothetical case of growth in the yen's use as an invoice currency.

Our paper introduces a theory on the choice of an invoice currency for exports and uses that theory to examine the use of the yen as an invoice currency for export transactions. The yen is used as an invoice currency considerably less for imports than for exports, and the use of the yen for pricing Japan's imports is outside the scope of this paper.

## **II. Theory on the Endogenous Choice of Invoice Currency**

Theoretically, a firm chooses an invoice currency based on which currency maximizes expected profits (or the expected utility of profits) in the presence of uncertainty. Theoretical research in this area can be broadly divided into two types. The first type, a partial equilibrium approach in which the only uncertainty is exchange rate fluctuations,<sup>15</sup> has been the predominant analytical framework in research to date. The second type is a general equilibrium approach that has drawn increasing attention due to recent advances in new open-economy macroeconomics. In this approach, which takes into account that the exchange rate varies due to various shocks such as

15. Japan made a large amount of foreign direct investment, primarily in East Asia, in response to the rapid appreciation of the yen following the Plaza Accord. As a result, some firms have globalized their production organizations. The globalization of these firms has led to the increased use of yen as an invoice currency (Otani, Shiratsuka, and Shirota [2003]). As indicated, a dramatic change in the exchange rate forces changes in firms' production systems and influences their choice of an invoice currency. Nevertheless, our paper surveys the existing theoretical research from the perspective of uncertainty over the exchange rate fluctuations, rather than of huge changes in the exchange rate level.

monetary shocks and production shocks and that such shocks also affect other macroeconomic variables, the invoicing decision is made in light of all of the effects from these shocks.

By surveying developments in the literature on endogenous currency choice theory, we aim to shed light on both the criteria used and the decision made regarding which currency to use as the invoice currency.

### A. Partial Equilibrium Approach

The partial equilibrium approach assumes uncertainty regarding exchange rate fluctuations, but no uncertainty regarding demand or production costs, and examines the choice of an invoice currency by a monopolistic firm facing a downward-sloping demand curve. This partial equilibrium approach can be subdivided into two different models: the simplest monopoly model where only one monopolistic firm exists, and an oligopoly model in which multiple monopolistic firms compete in the export market.<sup>16</sup>

#### 1. Monopoly model

##### a. Choosing between the home currency and local currency

Research to date has shown that the invoicing decision in a monopoly model is largely determined by the shapes of the demand function, the cost function, and the resulting profit function.

Suppose that, with uncertainty in the variation of the home-currency denominated nominal exchange rate  $e$ , the exporting firm sets the price prior to knowing the exchange rate for that period. Additionally, the firm has two choices: (1) setting the export price at the foreign currency equivalent of the domestic sales price (PCP); or (2) setting the export price in local currency terms (LCP).

Let the demand curve for the goods produced by the firm be  $D(p)$  and the firm's cost function be  $C(q)$  (where  $p$  is the price faced by the consumer of the exports, and  $q$  is the production volume). With  $p^p$  representing the home currency-denominated price, the export price denominated in the foreign currency under PCP is  $p^p/e$ . The export price under LCP is given by  $p^l$ . Based on these assumptions, profit under PCP,  $\Pi^p$ , and profit under LCP,  $\Pi^l$ , are defined as follows:

$$\Pi^p = p^p D(p^p/e) - C(D(p^p/e)), \quad (1)$$

$$\Pi^l = ep^l D(p^l) - C(D(p^l)). \quad (2)$$

Given that the exchange rate  $e$  is uncertain, the firm's decision on whether to choose PCP or LCP is made based on which price-setting behavior gives the highest expected

16. We introduce a static model for the choice of the invoice currency by a monopolistic or oligopolistic firm, based on a partial equilibrium approach. In the real world, however, firms are thought to make decisions from a long-run perspective, and thus a dynamic model for the invoicing decision would also seem beneficial. As far as we know, however, no research has been conducted on the choice of an invoice currency using a dynamic partial equilibrium model.

In trade theory, however, there is a large body of research based on a dynamic partial equilibrium model that explores oligopolistic firms' decision-making on export prices, and the volume of production, and exports. For example, Krugman (1987) analyzes the dynamic changes in exchange rate pass-through of exporting firms, taking account of the time required for the establishment of a sales network and for changes in prices to affect the level of consumer demand.

utility of profits.<sup>17</sup> In other words, if the expected utility of profits under PCP is greater than under LCP ( $EU(\Pi^p) > EU(\Pi^l)$ ), the home currency will be selected as the invoice currency, and if LCP provides the greater expected utility ( $EU(\Pi^l) > EU(\Pi^p)$ ), the currency of its trading partner will be chosen as the invoice currency.

Below, we examine the conditions under which the relative size of  $EU(\Pi^p)$  and  $EU(\Pi^l)$  are determined, following Bacchetta and van Wincoop (2002a).

Bacchetta and van Wincoop (2002a), under the assumption that the firm chooses the optimal price in both the PCP and LCP cases,<sup>18</sup> showed the relationship of the difference in expected utilities under PCP and under LCP ( $EU(\Pi^p) - EU(\Pi^l)$ ) and the source of uncertainty, given by the exchange rate fluctuation (variance  $\sigma^2$  in the exchange rate), with the following equation:<sup>19</sup>

$$EU(\Pi^p) - EU(\Pi^l) = 0.5U' \frac{\partial^2(\Pi^p - \Pi^l)}{\partial e^2} \sigma^2. \quad (3)$$

As is clear from equation (2), the second derivative of  $\Pi^l$  with respect to the exchange rate is zero. Thus, equation (3) suggests that the home currency will be selected as the invoice currency when  $\Pi^p$  is convex with respect to the exchange rate ( $\partial^2\Pi^p/\partial e^2 > 0$ ) and the local currency will be selected when  $\Pi^p$  is concave ( $\partial^2\Pi^p/\partial e^2 < 0$ ). This result that the invoicing decision depends on the shape of the profit function is the same as in Giovannini (1988), the pioneering theoretical work analyzing the invoice currency choice through the maximization of expected profits. The intuition behind this result is as follows. Suppose the exchange rate fluctuates around an expected level. Under the LCP case, since the profit function is linear with respect to the exchange rate, the expected profit is the same as the profit with the actual exchange rate being equal to its expected level. Under the PCP case, in contrast, when the profit function is concave, expected profit is lower than profit with the actual exchange rate being equal to its expected level. Thus, LCP is selected to stabilize the local currency price against exchange rate fluctuations (the opposite is true when the profit function is convex).

Whether the profit function is convex or concave depends on the shapes of the demand function and the cost function. Bacchetta and van Wincoop (2002a) used the following demand and cost functions to show that the degree of differentiation in the firm's products affects its choice of invoice currencies:

$$D(p) = p^{-\mu}, \quad (4)$$

$$C(q) = wq^n, \quad (5)$$

17. Although we follow Bacchetta and van Wincoop (2002a) and Friberg (1998) in using a framework whereby the choice of the invoice currency depends on the expected utility of profits, interpreting the utility function  $U$  as a value function of profits does not change our results.

If the firm is risk neutral, it is indifferent in its choice of invoice currencies, even if the exchange rate fluctuation is uncertain. For this reason, the firm is assumed to be risk averse.

18. Without uncertainty, when a firm sets the optimal price based on a given exchange rate, the price is the same whether under PCP or LCP, provided it is measured in the same currency.

19. For the derivation of equation (3), see Appendix 1. This condition does not apply under various exchange rate levels, but rather is a local condition that applies only in the neighborhood around the equilibrium exchange rate.

where  $\mu$  is the price elasticity of demand<sup>20</sup> and  $w$  is the wage rate.<sup>21</sup> By substituting equations (4) and (5) into equation (3), equation (3) can be shown in the following form:

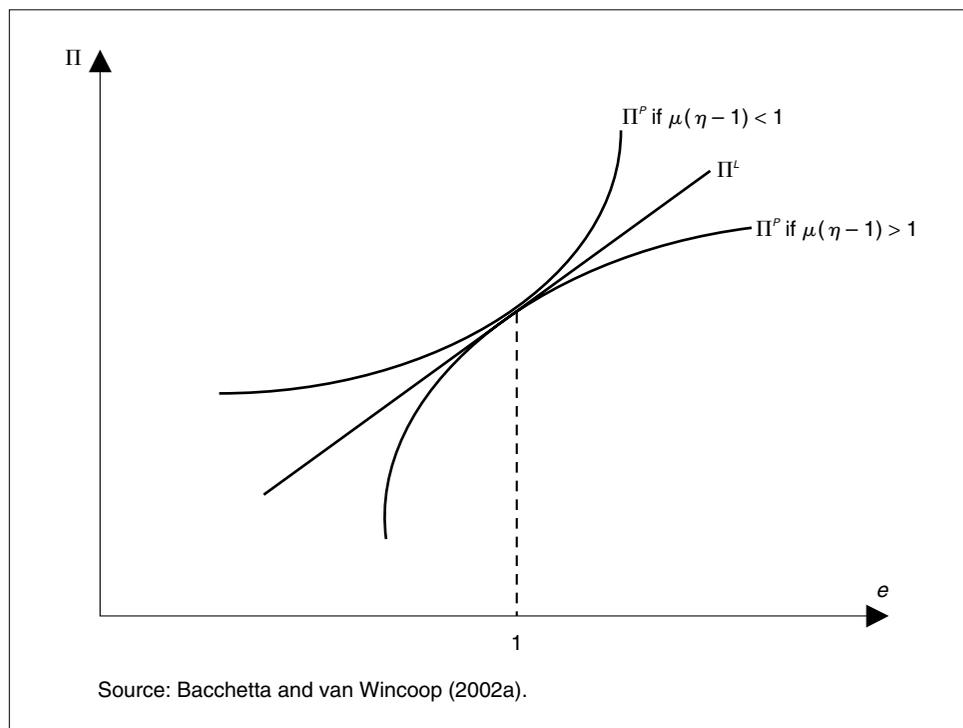
$$EU(\Pi^p) - EU(\Pi^l) = 0.5U'(\mu - 1)\bar{p}^{1-\mu}[1 - \mu(\eta - 1)]\sigma^2. \quad (6)$$

$\bar{p}$  is the firm's optimal price under the assumption that  $E(e) = 1$ , and  $\bar{p}^p = \bar{p}^l = \bar{p}$  holds. Therefore, when  $\mu(\eta - 1) < 1$  (the profit function being convex under PCP), PCP is chosen, and when  $\mu(\eta - 1) > 1$  (the profit function being concave under PCP), LCP is selected (Figure 1). As noted earlier,  $\mu$  is the price elasticity of demand, and the lower  $\mu$  is, the more differentiated and the more competitive the product. Accordingly, given  $\eta$ , the firm chooses PCP when the degree of differentiation is high and chooses LCP when differentiation is low.

**b. Choosing an invoice currency when a third country's currency is an option**

Friberg (1996, 1998) showed that the U.S. dollar had more than a 50 percent share of world trade in terms of the invoice currency used, despite the United States having only a 14 percent share of the worldwide trade in goods. Then, Friberg pointed out the need to consider the possibility of using a third country's currency, rather than the

**Figure 1 Relationship between Profits and the Exchange Rate under PCP and LCP**



20.  $\mu > 1$  is assumed to ensure that the production of the monopoly firm is positive.

21. Assuming that  $L$  is the labor input and the production function is given by  $q = L^{1/\eta}$ ,  $\eta$  is the reciprocal of labor's share. This can be easily verified by using the property that the marginal productivity of labor is equal to the real wage.

home currency or the trading partner's currency, as the invoice currency and examined the criteria for such use from a theoretical perspective.<sup>22</sup> Friberg demonstrated that the choice of an invoice currency depended not only upon the shape of the profit function, but also on the degree of uncertainty (size of the variance) for two distinct exchange rates: the home currency with the trading partner's currency and the third country's currency with the trading partner's currency. Below, we examine the criteria for choosing a third country's currency by using the above-noted framework from Bacchetta and van Wincoop (2002a).<sup>23</sup>

Let the exchange rate for the trading partner's currency per unit of third-country currency be given as  $e^o$ , and the export price denominated in the third country's currency as  $p^o$ . When the firm uses the third country's currency as its invoice currency, its profit  $\Pi^o$  is given by the following equation:

$$\Pi^o = \frac{e}{e^o} p^o D\left(\frac{p^o}{e^o}\right) - C\left(D\left(\frac{p^o}{e^o}\right)\right). \quad (7)$$

Assuming that  $e$  and  $e^o$  are independent of each other,<sup>24</sup> and using the same methodology shown in Appendix 1, the conditions for selecting between the third country's currency and LCP, and between the third country's currency and PCP are given as follows:

$$EU(\Pi^o) - EU(\Pi^l) = 0.5U' \frac{\partial^2 \Pi^o}{\partial (e^o)^2} (\sigma^o)^2, \quad (8)$$

$$EU(\Pi^o) - EU(\Pi^p) = -0.5U' \frac{\partial^2 \Pi^p}{\partial e^2} \sigma^2 + 0.5U' \frac{\partial^2 \Pi^o}{\partial (e^o)^2} (\sigma^o)^2. \quad (9)$$

Assume that the firm sets its optimal price at a given exchange rate and that  $E(e) = E(e^o) = 1$ . We can then derive, from equations (3), (8), and (9), the following conditions for the invoicing decision when a third country's currency is an option.

- (1) When the profit functions  $\Pi^p$  and  $\Pi^o$  are concave with respect to the exchange rates  $e$  and  $e^o$  ( $\partial^2 \Pi^p / \partial e^2 < 0$ ,  $\partial^2 \Pi^o / \partial (e^o)^2 < 0$ ), LCP offers the highest expected profits. If the fluctuation in the exchange rate between the third country's currency and the trading partner's currency is smaller than that in the rate between the home currency and the trading partner's currency ( $(\sigma^o)^2 < \sigma^2$ ), the next highest expected utility after LCP<sup>25</sup> is obtained by choosing the third country's currency as the invoice currency.<sup>26</sup>

22. Friberg (1998) incorporated forward currency transactions, a factor we do not consider explicitly, into his model for analyzing theoretically the choice between LCP, PCP, and a third country's currency. The result is the same, however, whether or not forward currency transactions are modeled. Virtually no research has been done on the invoicing decision in the presence of a futures market, and this line of research would be promising.

23. For the derivation of the conditions when a third country's currency is an option, see Appendix 2.

24. It has been widely pointed out that movements in both directions tend to be contagious between the yen-U.S. dollar rate and the Eurodollar rate, so this assumption may be fairly strong.

25. Given that Japanese exports to East Asia are almost never invoiced in the local currency, it would be beneficial to study a second-best solution in which the choice of LCP is ruled out and the choice is between PCP and a third country's currency. One likely reason that LCP is rarely used for exports by Japanese firms to East Asia is the lack of a forex market offering direct exchange between the yen and local currencies in East Asia.

26. This result is identical to that of Friberg (1998).

- (2) When the profit functions  $\Pi^p$  and  $\Pi^o$  are convex with respect to the exchange rates  $e$  and  $e^o$  ( $\partial^2 \Pi^p / \partial e^2 > 0$ ,  $\partial^2 \Pi^o / \partial (e^o)^2 > 0$ ), whichever of the home currency and the third country's currency has the greatest fluctuation in exchange rate is selected as the invoice currency. LCP offers the lowest expected profits.

## 2. Oligopoly model

In the case of one monopolistic firm, the invoicing decision is made solely by that firm and is not influenced by other firms. In the case of multiple monopolistically competitive firms, however, a firm's decision is affected by the decisions made by other firms, and likewise its behavior also affects the behavior of other firms. This points to the need to examine the invoicing decision under a game theoretical framework. Below, we extend the above-mentioned monopoly model to an oligopoly model.

Bacchetta and van Wincoop (2002a) examined an extension of the above-noted monopoly model in which the home country has multiple firms producing homogenous final goods and those firms compete with each other in the foreign country.

Let  $N$  be the number of firms producing the homogenous product in the home country and  $N^*$  be the number of such firms in the foreign country, with the home country's market share shown by  $n$  ( $n = N/(N + N^*)$ ). The demand function for the good produced by firm  $j$  is defined as follows:<sup>27,28</sup>

$$D_j(p_j, P^*) = \frac{1}{N + N^*} \left( \frac{p_j}{P^*} \right)^{-\mu} d^*, \quad (10)$$

where  $p_j$  is the price of firm  $j$ 's product denominated in the foreign currency,  $P^*$  is the general price index in the foreign country, and  $d^*$  is the real consumption expenditure in the foreign country.

The general price index in the foreign country  $P^*$  is given by the following equation:

$$P^* = [(1 - n)(p^*)^{1-\mu} + nf(p^p/e)^{1-\mu} + n(1 - f)(p^L)^{1-\mu}]^{1/(1-\mu)}, \quad (11)$$

where  $f$  represents the fraction of firms in the home country that set export prices based on PCP. Equation (11) illustrates that the general price index in the foreign country is affected by the invoicing decision of the home country's firms. Thus, equation (10) demonstrates that the demand for a firm's exports is affected not only by that firm's export prices but also by the invoicing decision made by competing firms in the home country.

To simplify the calculations, we assume that  $d^*/(N + N^*) = 1$ , and using equations (10) and (11), we recalculate equation (3) to arrive at the following condition for selecting the invoice currency:

27. The demand function for firm  $j$ 's product is defined as in equation (10) because overall real demand in the foreign country is implicitly assumed to be a CES function. Furthermore, the general price index in the foreign country is given by equation (11), which is the dual of real demand determined by a CES function.

28. To ensure that demand does not fall to zero for any of the goods (that a corner solution is excluded), it is assumed that the price elasticity of demand  $\mu$  for the goods is greater than one. Given the assumption that real overall demand is determined by a CES function, the price elasticity of demand  $\mu$  shows the elasticity of substitution between competing goods.

$$EU(\Pi^p) - EU(\Pi^l) = 0.5U'(\mu - 1)\bar{p} [1 - \mu(\eta - 1)(1 - 2fn)]\sigma^2, \quad (12)$$

where  $\bar{p}$  is the firm's optimal price assuming  $E(e) = 1$ , and  $\bar{p}^p = \bar{p}^l = \bar{p}$ .

A comparison of equation (12), the oligopoly case, with equation (6), the monopoly case, reveals that the size of the home country's share  $n$  affects the firm's invoicing decision. This reflects the fact that demand for that firm's product is affected by the currency choice made by competing firms in the home country through the general price index in the foreign country.

Equation (12) shows that when  $\mu(\eta - 1) < 1$  (when the profit function is convex under PCP), the firm chooses PCP, just as in the monopoly model.<sup>29</sup>

When  $\mu(\eta - 1) > 1$  (the profit function is concave under PCP), however, the result differs from the monopoly model, and the firm does not necessarily select LCP. That is, as long as the home country's share of the trading partner's market  $n$  is below a certain value  $\bar{n} (= 0.5 - 0.5/\mu(\eta - 1))$ , LCP is chosen. If this share exceeds  $\bar{n}$ , in contrast, there are three possible equilibria: (1) all firms choose LCP; (2) all firms choose PCP; and (3) a fraction chooses LCP, while the rest select PCI.<sup>30</sup>

Note that when  $n$  exceeds  $\bar{n}$  and competing firms coordinate, they prefer to choose PCP.<sup>31</sup> To understand this, consider the case where  $n = 1$ . In this case, the general price index in the foreign country is determined by the price setting of the home-country firms. When firms other than the firm in question choose PCP, the firm faces the risk that demand for its product changes with fluctuations in the exchange rate. When this firm chooses PCP, however, the changes in both  $P$  and  $p_j$  brought by exchange rate fluctuations are the same, and thus the ratio  $P/p_j$  is constant, which eliminates the demand uncertainty of this firm's product stemming from exchange rate fluctuations. Accordingly, when home-country firms have a high share, expected utility can be maximized by all the firms coordinating and choosing PCP.<sup>32</sup>

29. This can be verified as follows. Assume that  $\mu(\eta - 1) < 1$ . Given that both  $f$  and  $n$  are between zero and one,  $-1 \leq 1 - 2fn \leq 1$  and thus  $\mu(\eta - 1)(1 - 2fn) < 1$  holds. This means that  $1 - \mu(\eta - 1)(1 - 2fn) > 0$  and therefore  $EU(\Pi^p) > EU(\Pi^l)$ . In other words, the firm chooses PCP. It follows that, when  $\mu(\eta - 1) < 1$ , PCP is chosen.

30. Let  $\mu(\eta - 1) > 1$ . If  $f = 0$  (all firms choose LCP) in this case,  $1 - \mu(\eta - 1)(1 - 2fn) = 1 - \mu(\eta - 1) > 0$  and thus the inequality  $EU(\Pi^p) < EU(\Pi^l)$  holds. Regardless of the value of  $n$ , no firm has any incentive to choose PCP.

Next, we assume that  $\bar{n} = 0.5 - 0.5/\mu(\eta - 1)$ ,  $\mu(\eta - 1) > 1$  and  $n > \bar{n}$ . Under these assumptions, if  $f = 1$  (all firms choose PCP), then  $1 - \mu(\eta - 1)(1 - 2fn) > 1 - \mu(\eta - 1)(1 - 2\bar{n}) = 0$ , and thus  $EU(\Pi^p) > EU(\Pi^l)$ . No firm would choose LCP in this situation.

Finally, in the case where  $f = \bar{n}/n$  ( $0 < f < 1$ ; i.e., a fraction chooses LCP, while the rest choose PCP), then  $1 - \mu(\eta - 1)(1 - 2fn) = 0$  and thus  $EU(\Pi^p) = EU(\Pi^l)$ . In this case, firms are indifferent to the choice of an invoice currency.

There are thus three possible equilibria when  $\mu(\eta - 1) > 1$ : (1) all firms choose LCP; (2) all firms choose PCP; and (3) a fraction chooses LCP, while the rest choose PCP.

31. This can be verified by comparing the expected utility when all firms choose PCP with the expected utility of other cases.

32. Bacchetta and van Wincoop (2002b) built a model in which there were multiple firms in the foreign country producing intermediate goods, and multiple firms in the home country producing final goods assembled from the intermediate goods produced in the foreign country, to analyze the choice of invoice currencies by these firms. They showed that, when the firms producing the final goods choose PCP, the exporters of the intermediate goods would choose the home currency as the invoice currency if competitive pressures on these firms were low (the price elasticity of demand for its product were low), as in the monopoly model. In this case, the exchange rate pass-through to import prices is 100 percent and the pass-through to the consumer price index is zero percent.

## B. General Equilibrium Approach

The partial equilibrium approach takes exchange rate fluctuations as the only exogenous uncertainty. Rather than just treating the exchange rate as a direct, exogenous shock, however, a more rigorous approach would be to first generate external shocks via changes in the money supply and productivity, and have the overall economy adjust to these shocks through endogenous changes in the exchange rate. Such shocks would be expected to change not only the exchange rate, but also real consumption and other macroeconomic variables at the same time.

There has recently been research from this perspective, analyzing the invoicing decision from a general rather than partial equilibrium approach. Below we introduce two models using this general equilibrium approach, Bacchetta and van Wincoop (2002a) and Devereux and Engel (2001).<sup>33</sup>

### 1. Bacchetta and van Wincoop (2002a)

To analyze the conditions for choosing an invoice currency, Bacchetta and van Wincoop (2002a) assumed the changes in the money supply in the home and foreign countries as the source of uncertainty, then extended the above-noted partial equilibrium model to a two-country, general equilibrium model by adding the following assumptions: (1) variances of the money supply in both countries are identical; (2) money is held under a cash-in-advance (CIA) constraint<sup>34</sup> and real consumption in both countries also changes with the money supply; and (3) demand for each product is affected both by changes in the exchange rate and changes in real consumption, while the labor supply changes in response to changes in the demand for each good. In this model, the equilibrium exchange rate is determined by the ratio of the home country's money supply to the foreign country's money supply.

Using the above framework, Bacchetta and van Wincoop (2002a) compared the expected utility from profits under the PCP and LCP cases, under both nominal wage rigidity and real wage rigidity, to study the choice between the home country's currency and the trading partner's currency.

Examining first the case of nominal wage rigidity, the results are nearly the same as the conditions found in equation (12) above.<sup>35</sup> Specifically, when  $(\mu - 1)(\eta - 1) < 1$ , the firm chooses PCP. When  $(\mu - 1)(\eta - 1) > 1$ , however, all firms choose LCP

33. This general equilibrium analysis assumes a floating exchange rate regime.

34. The CIA constraint implies that goods consumed in a given period are purchased with cash held during that period.

35. As a result of the extension to a general equilibrium model by Bacchetta and van Wincoop (2002a), the conditions for choosing PCP are modified from  $\mu(\eta - 1) < 1$  in equation (12) to  $(\mu - 1)(\eta - 1) < 1$ , thereby expanding the range for parameters  $\mu$  and  $\eta$  under which all firms choose PCP. That is, supposing the home currency depreciates, when the home country firm has chosen PCP, its product will become more competitive and demand will increase. On the other hand, given that a change in the money supply, such as a decrease in the foreign country money supply, causes the depreciation of the home currency, under the CIA constraint, aggregate demand in the foreign country will decrease. Consequently, the negative effect on demand for this firm's product will be lessened because these two effects are offsetting. When the firm has selected LCP, however, the competitiveness of its product does not change even with depreciation of the home currency, and thus there is nothing to offset the impact from declining demand in the foreign country. Consequently, it is likely that the negative impact from exchange rate fluctuations will be lower under PCP than under LCP, thus expanding the parameter region under which PCP is preferable.

In contrast, consider the case where the home country currency depreciates due to growth in the home country money supply. Under LCP, there is no change in the product's competitiveness in the foreign country while sales in the home country increase, whereas under PCP sales increase in both the home and foreign countries, because the product becomes more competitive and demand in the home country grows. Thus, PCP is preferable to LCP.

if the home country's share of exports to that trading partner is small, whereas there are two possible equilibria if the home country's share is sufficiently large: (1) all firms choose PCP or (2) all firms choose LCP. Even in case of two equilibria, if the firms coordinate, PCP will be chosen. Thus, regardless of the value of  $(\mu - 1)(\eta - 1)$ , the larger the home country's share, the more likely that the home country's currency will be chosen.

Next, in the case of real wage rigidity, where the nominal wage moves in proportion to the price index, it is concluded that the country's size has a huge impact on the choice of invoice currency. That is, the invoicing decision made by firms in a large country is the same as in the case of nominal wage rigidity explained above, whereas it becomes more likely that a small country's firm selects LCP when a large country's firm selects PCP.

The reason for this result is that, since the home-country firm prices its domestic sales in the home currency, as long as the home country is large, the home country's price index is almost completely unaffected by the foreign country export price; as a consequence, fluctuations in the exchange rate have very little effect on the home country's price index. Therefore, assuming that the price of the good is sticky, the large country's price index will also be sticky, as will nominal wages. As a result, for a large country, the conditions for choosing an invoice currency are nearly the same under real wage rigidity as under nominal wage rigidity. For a small country, on the other hand, when the large country selects PCP, depreciation of the small country's currency causes an increase in the small country's price index, and nominal wages increase accordingly. Thus, nominal production costs in the small country increase. If the small country has selected PCP in this case, demand for the small country's product in the large country will increase in response to depreciation of its currency. Nevertheless, since it will not change the nominal receipts per unit of export measured in its currency, the rise in nominal costs will pull down profits. When the small-country firm selects LCP, however, the nominal receipt per unit of export goes up, and thus profits are not squeezed as much as under PCP. Therefore, as long as the large country selects PCP, the small country will select LCP.

## **2. Devereux and Engel (2001)**

In contrast with Bacchetta and van Wincoop (2002a), which analyzes the case where both the home-country and foreign-country money supplies have the same variance, Devereux and Engel (2001) built a dynamic general equilibrium model that incorporated different uncertainties between the home and the foreign money supply, to analyze differences in firms' price-setting behavior between developed and developing countries.<sup>36</sup>

36. The main difference between the general equilibrium models of Bacchetta and van Wincoop (2002a) and Devereux and Engel (2001) is the way in which money is introduced into the model. The former uses the CIA constraint, while the latter uses the money in the utility function (MIU). Consequently, in the former the exchange rate is expressed as the ratio of the home country money supply to the foreign country money supply, while in the latter the exchange rate is affected not only by the money supply in the home and foreign countries but also by the degree of relative risk aversion and by the price level in the home and foreign countries. Accordingly, the money supply's impact on the economy is more complex in the latter relative to the former.

The analysis by Devereux and Engel (2001) does not directly compare the expected profits under PCP and LCP as previously shown. Their analysis is focused on the conditions for a firm to make the same choice as a competing firm, in the case where all of the other firms make the same choice, be it PCP or LCP. They then show the conditions for choosing an invoice currency that achieves the equilibrium wherein all firms select the same invoice currency.

They found that both domestic and foreign firms would choose the currency of the country with the smallest money-supply variance. In other words, when the variance of the money supply in the home country is small, the home-country firm chooses PCP and the foreign-country firm chooses LCP, whereas when the variance of the home country's money supply is large, the home-country firm chooses LCP and the foreign-country firm chooses PCP.<sup>37</sup>

### C. Summary of Conditions for the Invoicing Decision

We began this section with an introduction to the partial equilibrium approach to the choice of an invoice currency, and followed that with an overview of recent theoretical research using a general equilibrium approach.

The partial equilibrium approach abstracts from the mechanism by which the basic shocks—monetary shock and productivity shock—are transmitted to the exchange rate and other macroeconomic variables. As a consequence, the assumption is that an exogenous shock directly causes exchange rate fluctuations, and that the other variables are unaffected other than via the exchange rate. Although setting up the model in this way makes it easier to handle, it also makes it less rigorous. With the general equilibrium approach, on the other hand, although the direction of theoretical extension is correct, the only shock allowed for is a money supply shock, and thus, as noted in Gourinchas (2002), at this stage it is too early to judge how robust the conclusions are.

To provide criteria by which to evaluate the current use of the yen as an invoice currency in the next section, we summarize below the conditions for an endogenous invoicing decision as obtained from theoretical research on both sides, partial equilibrium and general equilibrium.

- (1) If there is an option to use a third country's currency for invoicing and LCP is not selected,<sup>38</sup> whichever of the home currency and the third country's currency that has the smaller exchange rate variance with the trading partner's currency will be selected as the invoice currency.<sup>39</sup>

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37. Devereux and Engel (2001) pointed out that their result has important implications for the implementation of monetary policy. That is, the currency of a country with a highly credible monetary policy is going to be selected as the invoice currency by exporting firms in a foreign country, and thus the exchange rate pass-through to that country's imports is low and prices in the home country become more stable. On the other hand, for countries with little credibility in monetary policy, exporting firms in the foreign country will choose PCP, creating a high exchange rate pass-through to imports of the home country and thus threatening the stability of prices. For more on this, see Otani, Shiratsuka, and Shirota (2003).

38. As explained in Footnote 25, Japanese firms almost never opt for LCP on their exports to East Asia.

39. The assumption here is that the profit function is concave with respect to the exchange rate. In this case, the condition is the same as condition (1) found in Section IIA.1.b, which examines the possibility of selecting a third country's currency.

- (2) The greater the degree of product differentiation, the more likely the firm is to select PCP.
- (3) The higher the home country's share in the trading partner's market, the more likely the firm is to select PCP.
- (4) The larger the size of the economy, the more likely that PCP will be chosen.
- (5) When variance in the home-country money supply is smaller (larger) than in the foreign country, the home-country firm chooses PCP (LCP).

Conditions (1) through (5) are summarized in Table 1. Condition (5) is for analyzing the difference in firms' price-setting behavior between developed and developing countries, and thus requires careful attention for application to a generalized invoicing decision. Additionally, this condition has very little empirical support compared with other conditions, considering that monetary models perform poorly in determining exchange rates, and that, even though variance of the money supply (M2+CDs) in Japan has decreased relative to other countries in recent years, the use of the yen as an invoice currency has not increased in recent years, as explained later. Accordingly, in the next section we will use conditions (1) through (4) to assess the current use of the yen as an invoice currency.

**Table 1 Conditions for Choosing an Invoicing Currency for Exports**

	High/large	Low/small
(1) Ratio of $var(e)$ to $var(e^e)$	Third country's currency	PCP
(2) Product differentiation	PCP	LCP
(3) Home country's share of the trading partner's market	PCP	LCP
(4) Size of the home country	PCP	LCP
(5) Ratio of the variance in the home country's money supply to the variance in the foreign country's money supply	LCP	PCP

Note: Condition (1) is for the case when a third country's currency is available and LCP is not chosen, even though the profit function is concave with respect to the exchange rate and LCP should be chosen.

### III. Assessing the Use of the Yen as an Invoice Currency

In Section II, we gave an overview of the development to date in theoretical research on the endogenous choice of an invoice currency. In this section, we use the results of these theoretical works to assess the current use and forecast the future use of the yen as an invoice currency for Japan's exports.<sup>40</sup>

We begin this section by considering the current use of the yen for pricing exports using data and then introduce prior research in this regard. Next, we examine the extent to which the conditions governing the choice of an invoice currency noted in

40. The analysis in this section is extremely simple in that it is limited to comparisons by country and by product category, and does not comprise a detailed empirical analysis of data across categories as done by Fukuda and Ji (1994), a paper we will introduce below. Nevertheless, this provides the advantage of being able to get a bird's-eye view of the relationship between invoicing decision theory via expected profit maximizing and the actual invoicing decisions made.

the previous section are able to explain the actual invoicing decision made in industrialized countries including Japan, as well as the actual share by product category of Japan's exports to Asia denominated in yen. Then, we assess the current use, and forecast the future use, of the yen as an invoice currency.

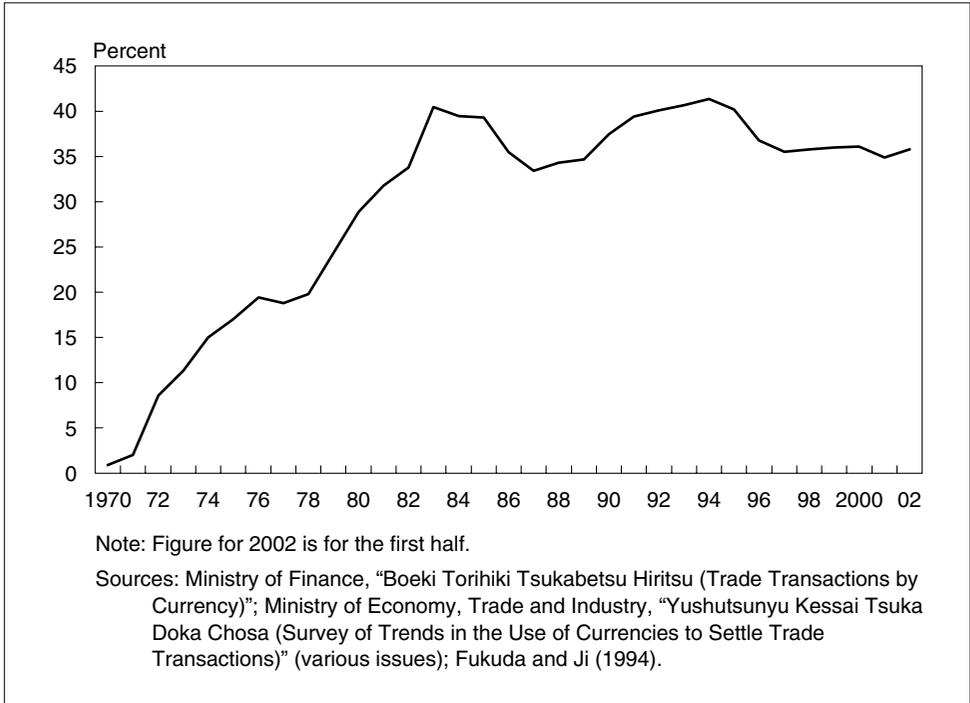
**A. Current Use of the Yen as an Invoice Currency and Prior Research**

**1. Trends in the yen's use as an invoice currency**

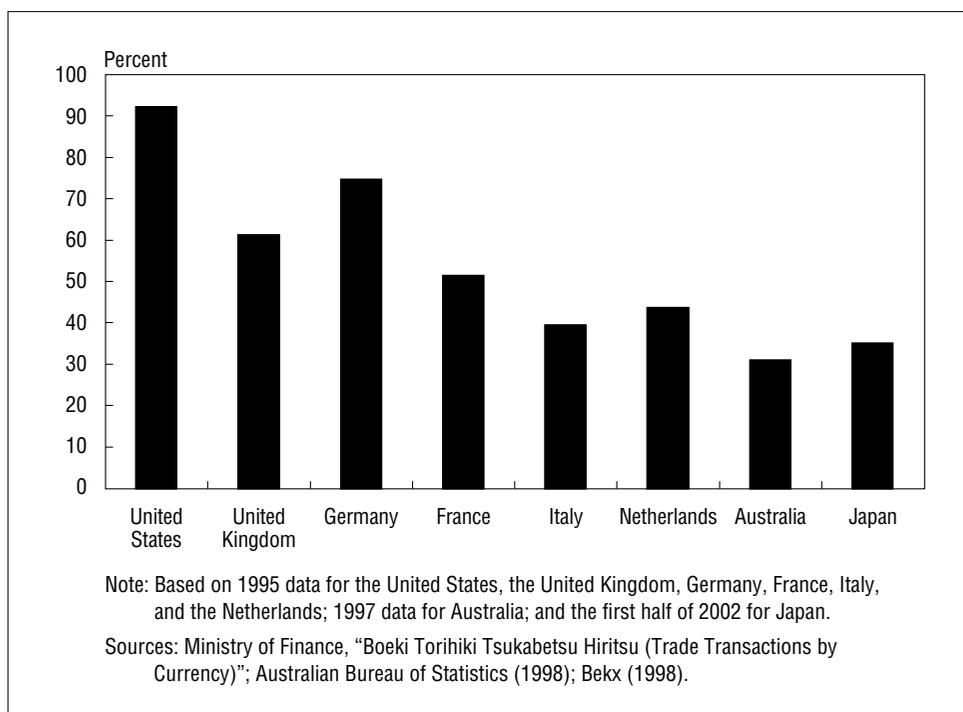
The percentage of Japan's exports denominated in yen was on a rising trend from the 1970s until the early 1980s, but has been roughly flat around the 35 percent level since then (Figure 2). The percentage of exports denominated in the home currency is much lower for Japan than it is for the United States (over 90 percent), Germany (over 70 percent), and even the United Kingdom and France (both over 50 percent) (Figure 3).

Looking next at the percentage of Japan's yen-denominated exports by region, in 1998 less than 20 percent of exports to the United States were denominated in yen, whereas approximately 50 percent of exports to East Asia, where economic integration with Japan is high, were priced in yen. Breaking down Japan's exports to East Asia by product category, those products with a high percentage of exports denominated in yen include food products and machinery products, including general machinery, transportation equipment, and precision equipment (Table 2).

**Figure 2 Percentage of Japan's Exports Denominated in Yen**



**Figure 3 Percentage of Exports Denominated in the Home Currency among Leading Developed Countries**



**Table 2 Percentage of Japan's Exports to East Asia by Product Category**

Percent

Fiscal year ended	Mar. 1994	Mar. 1995	Mar. 1996	Mar. 1997	Mar. 1998
All categories	52.0	47.2	44.1	45.5	48.4
Food products	52.5	63.8	67.7	65.8	59.2
Textiles and textile products	29.5	26.3	28.4	31.0	28.2
Chemical products	23.6	19.2	20.7	22.0	29.8
Nonmetallic mineral products	37.6	28.9	24.9	34.8	53.1
Metals and metallic products	20.1	17.9	17.5	21.5	23.2
General machinery	69.0	66.8	59.9	59.7	59.7
Electric machinery	41.8	37.0	39.7	37.9	42.7
Transportation equipment	78.4	71.5	58.5	72.3	81.3
Precision equipment	79.0	71.6	59.3	49.5	61.5
Other	34.1	32.8	32.6	37.2	40.3

Note: East Asia here is defined as the newly industrializing economies (NIES), specifically Taiwan, Hong Kong, South Korea, and Singapore) and the members of ASEAN. China is not included.

Source: Ministry of Economy, Trade and Industry, "Yushutsunyu Kessai Tsuka Doka Chosa (Survey of Trends in the Use of Currencies to Settle Trade Transactions)" (various issues).

## 2. Prior research

As noted above, Japan has a very low percentage of its trade transactions denominated in its own currency compared with other developed countries. Kawai (1992), Frankel and Wei (1993), Taguchi (1993), and the Ministry of Finance (2001) analyzed the reason behind this, and identified the following factors: (1) inertia in use of the U.S. dollar; (2) the lack of a market for direct transactions between the yen and East Asian currencies; (3) relatively small financial markets in Japan (compared with the United States); (4) the *de facto* dollar peg adopted in East Asia; (5) the high degree of trade dependence with the United States;<sup>41</sup> and (6) the presence in Japan of general trading companies.<sup>42</sup> Many of these factors are based on the classic analyses related to vehicle currency introduced in Section I.

As far as we know, the only prior research from the perspective of maximization of expected profits consists of Fukuda and Ji (1994) and Sato (1999). Fukuda and Ji (1994) used the partial equilibrium model introduced in Section II, wherein PCP is chosen when the firm's profit function is convex, and LCP when it is concave. In other words, when the profit function is concave, the firm stabilizes its export price denominated in the local currency irrespective of exchange rate fluctuations. Thus, the correlation between export prices denominated in the home currency and the exchange rate is high, and shocks to the firm's production costs do not impact export prices denominated in the home currency. In contrast, when the profit function is convex, export prices denominated in the home currency have a low correlation with exchange rate fluctuations but are affected by shocks to production costs.

Fukuda and Ji (1994) examined the validity of this theory by focusing on the products for which U.S. dollars are used as the invoice currency when they are exported to the United States and for which the yen is used when they are exported to Asia, such as TVs, videocassette recorders, and automobiles. If this theory is consistent with reality, the profit function for these goods when exported to the United States is concave, and exports to the United States priced in yen are highly correlated with the exchange rate while being unaffected by shocks to production costs. In contrast, if the profit function for exports to Asia is convex, exports to Asia priced in yen would be unaffected by the exchange rate but affected by shocks to production costs.<sup>43</sup>

Fukuda and Ji (1994) analyzed empirically the relationship between yen-denominated export prices of these products to the United States and Asia on one side and changes in the exchange rate and production costs on the other. They found the relationship consistent with the theoretical model and thereby validated the invoicing decision model based on profit maximization. Additionally, Sato (1999) used the analytical methods of Fukuda and Ji (1994) to analyze semiconductor components exported to Asia and to the United States. His empirical results were consistent

41. Because the percentage of U.S. imports denominated in dollars is extremely high, a high percentage of trade with the United States effectively means a low use of the home country's currency.

42. The general trading companies hold a large quantity of credit claims and obligations denominated in foreign currency and are able to hedge against exchange rate fluctuations in-house. Thus, they have little incentive to denominate transactions in the home country's currency as a way to avoid exchange rate risk.

43. The reason why the shape of the profit function for the same product differs by export region could be that the shape of the demand function is different. For example, if the number of competing firms in the United States is large and thus the product's price elasticity is high, LCP will be chosen for exports to the United States. For the exports to East Asia, if the Japanese firms have strong monopolistic power and thus price elasticity is low, PCP will be selected.

with the hypothesis that the U.S. dollar would be used as the invoice currency to stabilize the dollar-denominated export price, based on the pricing-to-market (PTM) behavior in that industry. Sato attributed the decline in Japan's percentage of yen-denominated exports since the late 1990s to the rising export share of integrated circuit (IC) components.

## **B. The Use of the Yen Viewed from Endogenous Invoicing Decision Theory**

As noted above, Fukuda and Ji (1994) and Sato (1999) are virtually the only papers that analyze the use of the yen as an invoice currency from the perspective of the recent theoretical research on expected profit maximization. Next, we assess the current use of the yen as an invoice currency using analysis based on expected profit maximization, an approach we have already explained in detail.

Specifically, we examine the extent to which the conditions for choosing an invoice currency introduced in Section II.C are able to explain invoicing decisions in Japan and other leading economies (the United States, Germany, France, the United Kingdom, Italy, the Netherlands, and Australia),<sup>44</sup> as well as Japan's choice of invoice currency across product categories.

As noted earlier, of the conditions for choosing an invoice currency, the condition on money supply volatility has little power to explain the actual invoicing decision made.<sup>45</sup> We will therefore analyze current use of the yen as an invoice currency based on the other conditions (exchange rate volatility, degree of differentiation in the exported goods, market share, and size of the economy).

### **1. Exchange rate volatility and the invoicing decision**

As explained in the previous section, if the exchange rate volatility between the trading partner's currency and the home currency is higher than the volatility between the trading partner's currency and the third country's currency, the home firm will price its exports in the third country's currency rather than in the home currency. We examine the relationship between exchange rate volatility and the invoicing decision, assuming the third country's currency to be the U.S. dollar—the most widely used third-country currency.

Figure 4 shows the relationship between the invoicing decision and the ratio of the standard deviations in the nominal effective exchange rate denominated in the home currency and that denominated in the U.S. dollar for industrialized countries other than the United States.<sup>46</sup> If the condition derived from theory is correct, then

44. For the invoicing decisions in the United States, Germany, France, the United Kingdom, Italy, and the Netherlands, we use 1995 data in Bekx (1998), and for Australia we use 1997 data published by the Australian Bureau of Statistics (1998).

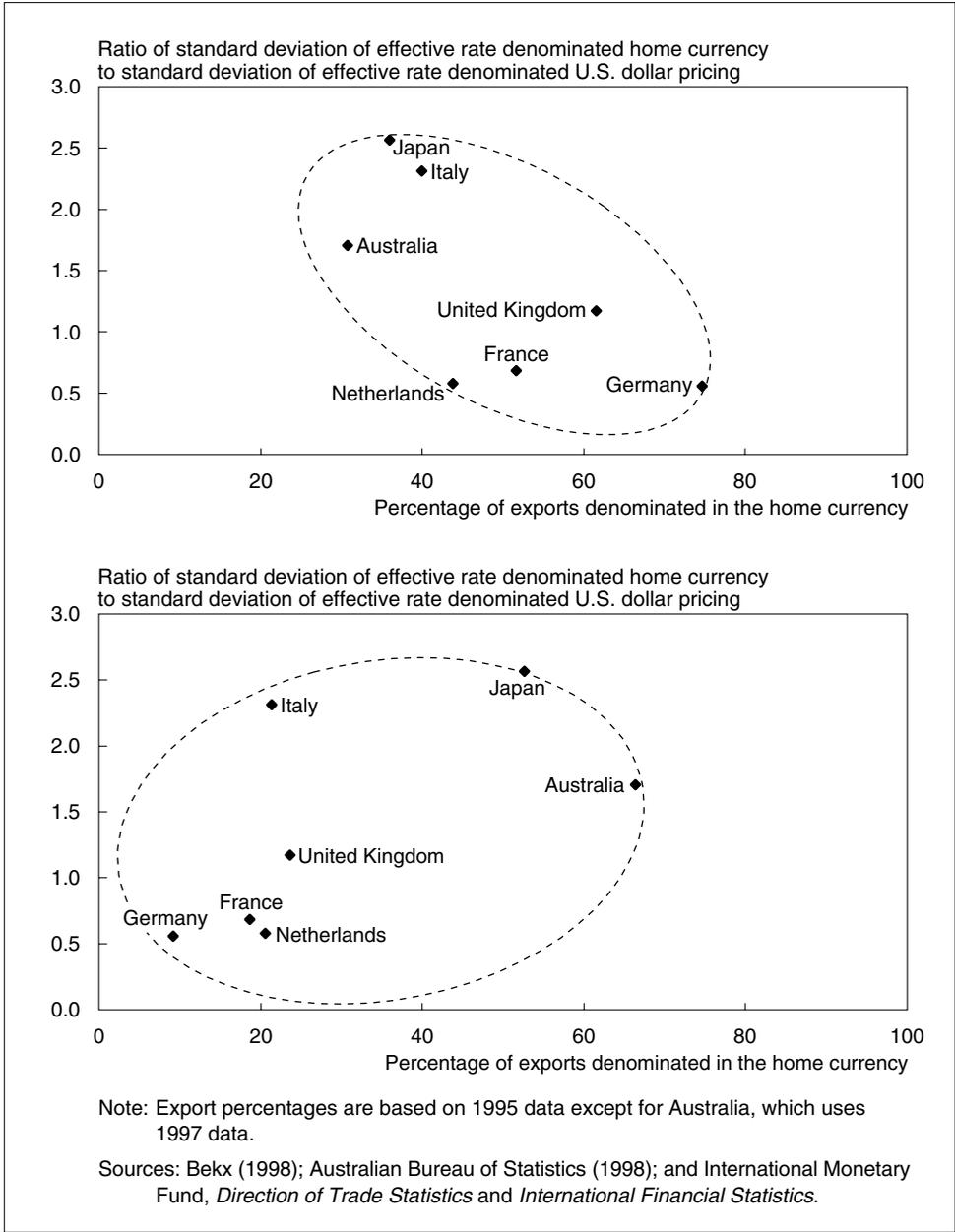
45. For Japan, the United States, Germany, France, the United Kingdom, Italy, the Netherlands, and Australia, we regressed the PCP ratios against the weighted average of the standard deviations in money supply for each country's top 10 trading partners and the relative standard deviations in money supply of these countries. The result was, however, insignificant.

46. To calculate the nominal effective rate for each country, we used the value of exports to the top 10 trading partners (excluding the United States) as of 1995 as weights and calculated the standard deviation using monthly data from 1991 to 1995. In 1995, the top 10 trading partners excluding the United States for each country were, in descending order, as follows:

Japan (South Korea, Taiwan, Hong Kong, Singapore, China, Germany, Thailand, Malaysia, the United Kingdom, and Indonesia).

Germany (France, the United Kingdom, Italy, the Netherlands, Belgium, Switzerland, Australia, Spain, Japan, and Sweden).

**Figure 4 Exchange Rate Volatility and the Choice of Invoice Currency**



France (Germany, Italy, the United Kingdom, Belgium, Spain, the Netherlands, Switzerland, Japan, Portugal, and Hong Kong).

United Kingdom (Germany, France, the Netherlands, Belgium, Italy, Ireland, Spain, Japan, Sweden, and Switzerland).

Italy (Germany, France, the United Kingdom, Spain, Switzerland, the Netherlands, Belgium, Australia, Japan, and Greece).

Netherlands (Germany, Belgium, France, the United Kingdom, Italy, Spain, Sweden, Switzerland, Denmark, and Australia).

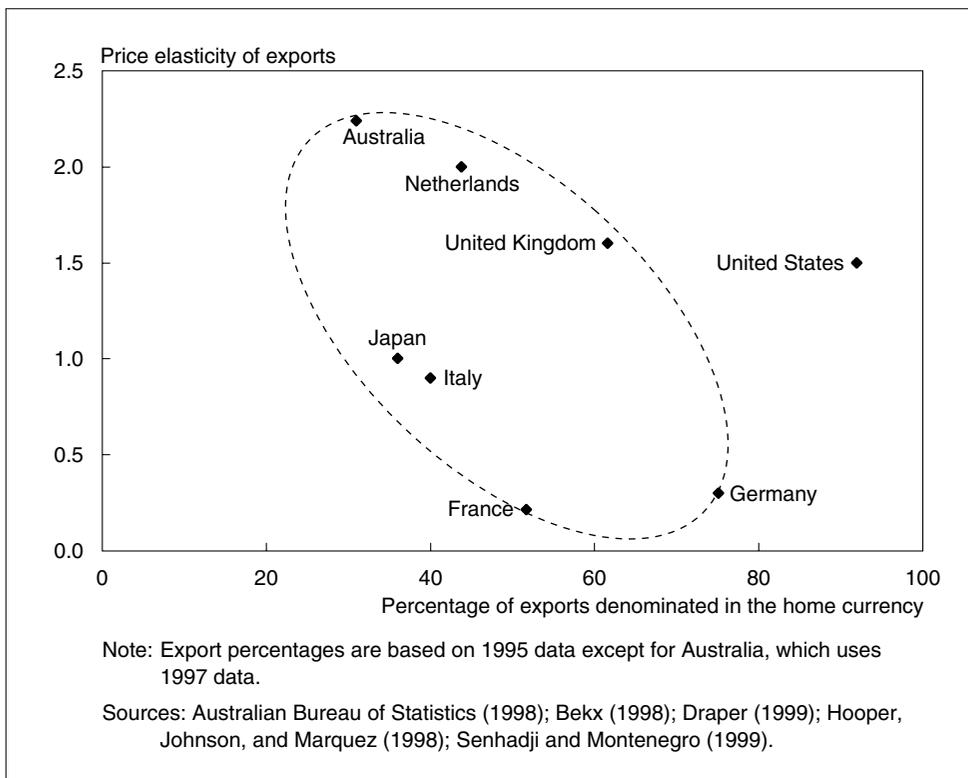
Australia (Japan, South Korea, New Zealand, Singapore, Taiwan, China, Hong Kong, the United Kingdom, Indonesia, and Malaysia).

the higher the volatility of the nominal effective rate denominated in the home currency relative to the standard deviation of the U.S. dollar, the higher the proportion of exports denominated in dollars, and the lower the PCP rate. Figure 4 shows this relationship clearly and demonstrates the impact that exchange rate volatility has on the invoicing decision.<sup>47</sup>

## 2. Differentiation of the exported product and the invoicing decision

The greater the differentiation of the exported product, the lower its price elasticity. Based on this theoretical condition, we first examine the macroeconomic relationship between the invoicing decision made in the leading industrialized economies and the price elasticity of exports (Figure 5). It is clear that, for countries other than the United States, the lower the price elasticity of exports (the greater the degree of differentiation), the more likely that the home currency will be chosen for pricing exports.<sup>48</sup> Despite the high degree of price elasticity in U.S. exports, an overwhelming percentage of U.S. exports is denominated in home currency; this reflects the special status of the U.S. dollar as the world's vehicle currency.

**Figure 5 Price Elasticity of Exports and the Percentage of Exports Using PCP**

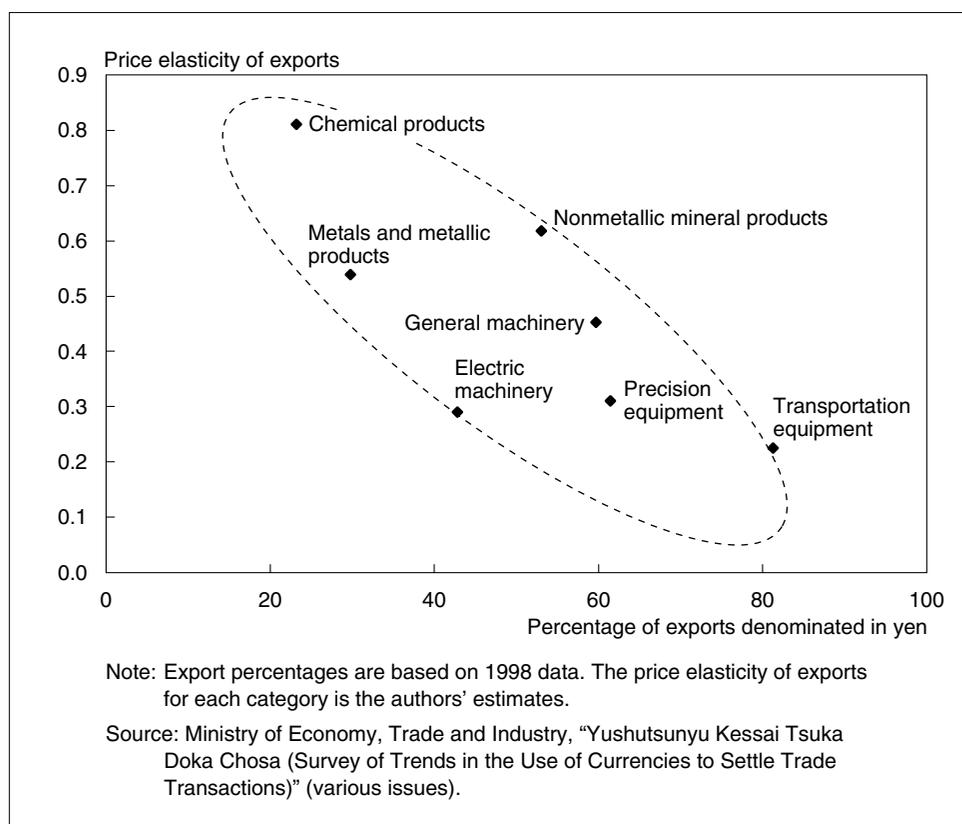


47. The dominant currency used by East Asian economies for settling export transactions is the U.S. dollar. This suggests that even for East Asia's interregional trade, a third-country currency (the dollar) is used for pricing exports. The *de facto* dollar peg used by many East Asian economies and the resulting low volatility in exchange rates between East Asian currencies may also explain why the yen is not used as a third-country currency for settling trade transactions within East Asia.

48. We used data on the price elasticity of exports (long term) for Japan, the United States, Germany, France, the United Kingdom, and Italy from Hooper, Johnson, and Marquez (1998), for Australia from Senhadji and

Next, we examine the relationship between the invoicing decision and price elasticity for Japan's exports to East Asia by product category. It is clear that, just as with the international comparison noted above, there is a negative correlation between export price elasticity and the percentage of exports denominated in yen (Figure 6).<sup>49</sup> Specifically, for homogenous goods such as chemical products and metals and metallic products with high price elasticity, the percentage of exports denominated in yen is low, whereas for highly differentiated goods with low price elasticity such as general machinery, precision equipment, and transportation equipment, the percentage of exports denominated in yen is high.<sup>50</sup>

**Figure 6 Price Elasticity of Exports to East Asia and the Percentage of Exports Denominated in Yen**



Montenegro (1999), and for the Netherlands from Draper (1999). Note that the results from empirical analysis on the price elasticity of exports for each country vary widely for each paper. Much of this empirical analysis, however, suggests that the exports of Germany and France have very low price elasticity, while Japan's exports have relatively high elasticity.

49. See Appendix 3 regarding the estimation of price elasticity of Japan's exports to East Asia by product category.

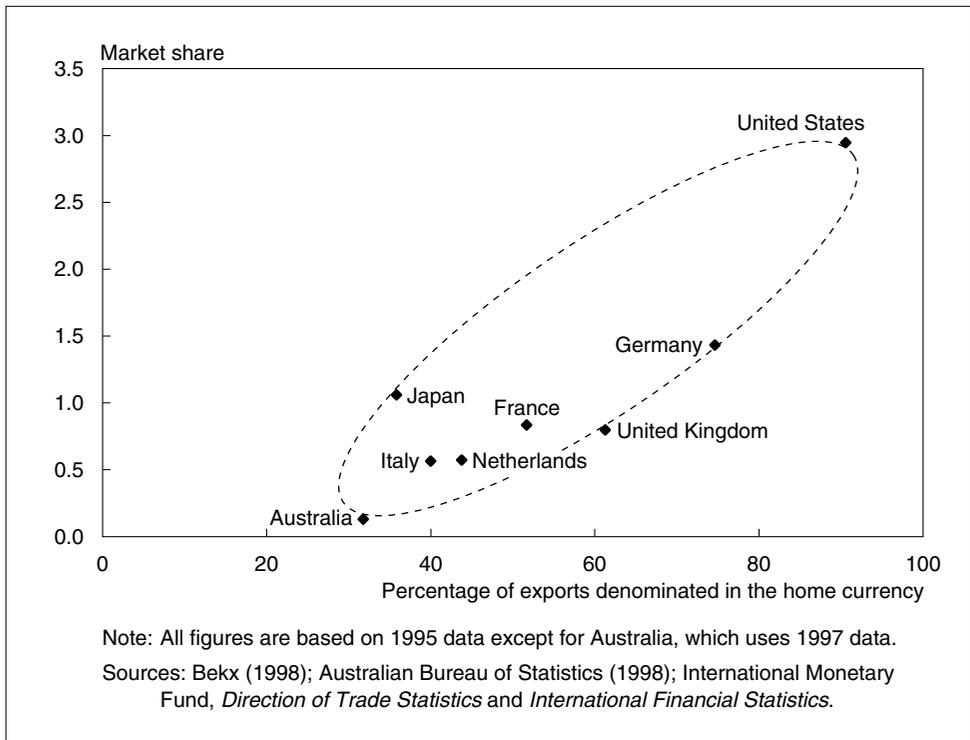
50. Although these results are consistent with the theoretical models, there are of course other factors that may also come into play. For example, Japan's machinery industry has made a considerable amount of foreign direct investment, mostly in East Asia. If the percentage of intra-company trade priced in the home currency is higher than for trade between companies, then one result of this foreign direct investment would be an increased percentage of exports being denominated in yen, particularly between Japan and East Asia. Accordingly, the high percentage of machinery products denominated in yen could be influenced by this globalization of manufacturing operations.

The results of this comparison of macro data among developed countries, as well as the comparison across product categories of Japan's exports to East Asia, are consistent with the conclusion of the theoretical model that the degree of product differentiation affects the invoicing decision.

### 3. Market share and the invoicing decision

There is clearly a proportional relationship between each country's world market share and the choice of an invoice currency, in which countries with a higher market share are more likely to price their exports in the home currency (Figure 7).<sup>51</sup> The relationship across product categories between the shares of Japan's industrial product exports to East Asia and the percentage of exports denominated in yen also indicates that the higher the share, the higher the use of the yen (Figure 8).<sup>52</sup> Thus, whether by country or by product category, there exists a clear positive correlation between market share and the percentage of exports denominated in the home currency.

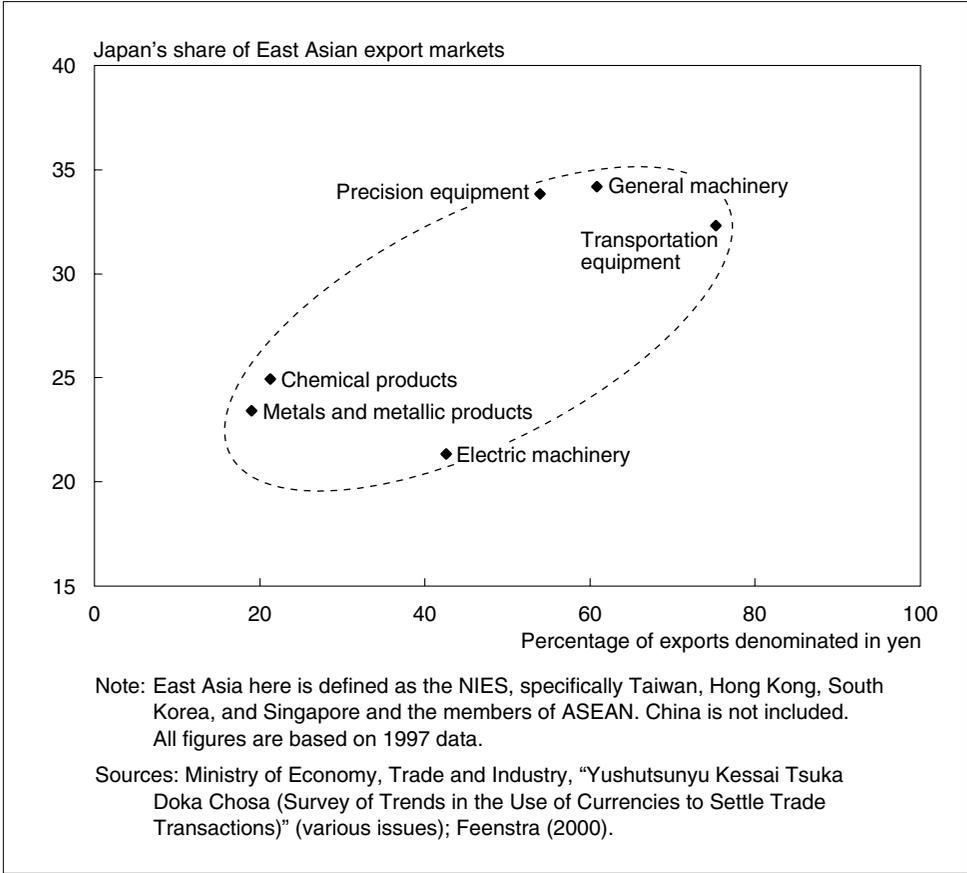
**Figure 7 Market Share and the Percentage of Exports Using PCP for Each Country**



51. We calculated the world market share for each country by dividing the country's exports by (the world's nominal GDP minus total exports worldwide plus total imports worldwide minus the country's nominal GDP plus its exports minus its imports), using data as of 1995 in all cases. Since Japan has a low degree of trade dependence on foreign countries, its world market share calculated according to the above formula is not very large.

52. Due to the limited availability of data on nominal production by product category in East Asia, we calculated Japan's market share by product category by dividing the amount of East Asia's imports from Japan by East Asia's total imports.

**Figure 8 Japan’s Share of East Asian Export Markets and the Percentage of Exports Denominated in Yen**



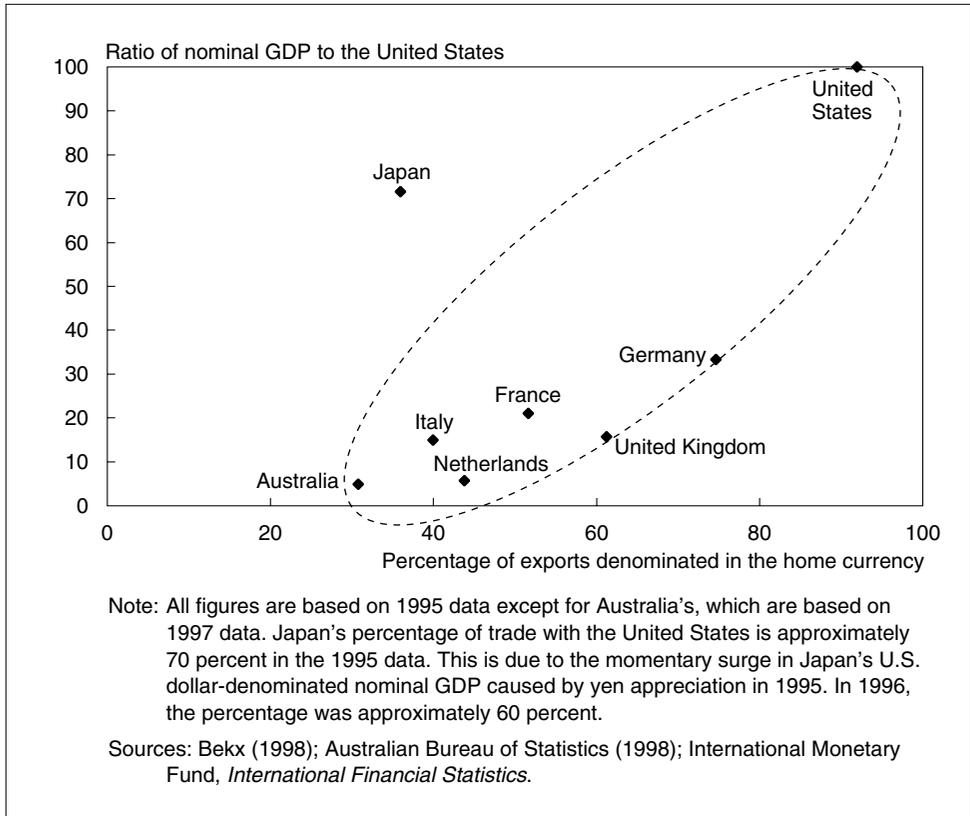
**4. Size of the economy and the invoicing decision**

Finally, examining the relationship between the economic size and PCP rates of each country, there is clearly a tendency among developed countries other than Japan for the home currency to be used more for pricing exports, the larger the size of that country’s economy (Figure 9). Nevertheless, even though Japan has the world’s second-largest economy, an extremely low percentage of its exports is denominated in yen.

**C. Assessing the Current Use, and Forecasting the Future Use, of the Yen as an Invoice Currency**

The above findings show that three of the four factors affecting the invoicing decision—exchange rate volatility, degree of product differentiation, and market share (leaving out economic size)—explain the actual currency choice made. Thus, it indicates the invoicing decisions made in developed countries including Japan and the percentage of Japan’s exports to East Asia denominated in yen are largely consistent with invoicing decision theory based on expected profit maximization as introduced in this paper. Accordingly, given the current competitiveness and market power of Japan’s manufacturing industries in export markets, and given also the exchange rate regime

**Figure 9 Size of Economy and the Percentage of Exports Using PCP**



now in place in Japan and East Asian economies, it appears reasonable to conclude that the current level of the use of the yen as an invoice currency is appropriate.

Of course, with respect to economic size, the percentage of Japan's exports denominated in the home currency is considerably less than in other developed countries. This could be interpreted as evidence of considerable room for an increase in use of the yen as an invoice currency.

In Japan, policymakers have recently implemented measures to promote the internationalization of the yen (changes in Japan's financial markets, including the lifting of restrictions on yen-denominated bond transactions in offshore markets). To what extent can these measures be expected to increase use of the yen as an invoice currency—one critical element of the internationalization of the yen?

As explained in Section I, the internationalization of the yen means the increased use of the yen in trade transactions and capital transactions. When a firm is conducting both trade transactions and capital transactions, it can have an incentive to denominate both types of transactions in the same currency to reduce exchange rate risk. Many East Asian economies can only raise funds denominated in U.S. dollars in international financial markets, due to their "original sin."<sup>53</sup> If the currency of settlement for trade

53. For details on "original sin," see Eichengreen and Hausmann (1999).

transactions is related to that for capital transactions, then it seems reasonable that such countries would be motivated to use dollars rather than yen for their trade transactions. For this reason, it is possible that the improvement of Japan's financial markets, including the elimination of restrictions on yen-denominated corporate bond transactions, will relax the constraint imposed by this "original sin" and promote use of the yen in international trade.

Nevertheless, as our analysis shows, it is important to realize that use of the yen as an invoice currency is not likely to increase until Japanese firms further improve their competitiveness in, and increase their share of, export markets. Accordingly, if there are no changes in the current level of Japanese firms' export competitiveness or in the existing currency regimes, reform of financial markets alone is unlikely to prompt a major increase in the percentage of Japan's exports denominated in yen, which currently stands at approximately 35 percent.<sup>54</sup>

#### **IV. Increase in the Use of the Yen as an Invoice Currency and the Currency-Basket Regime**

We pointed out above that as long as there is no change in either the current competitiveness of Japan's exporting firms or the existing currency regime, use of the yen as an invoice currency is not likely to increase. Nevertheless, the Ministry of Finance and some economists advocate the introduction of a currency-basket regime in East Asia to replace the current *de facto* U.S. dollar peg arrangements. They note that attempting to stabilize economic fluctuations in East Asia by stabilizing the exchange rates between East Asian currencies and the yen provides one reason to promote introduction of a currency-basket regime, given the deepening economic ties between Japan and East Asian economies. Another reason cited is the need to internationalize the yen.<sup>55</sup>

Next, we discuss the advantages of a currency-basket regime from the perspective of expanding the use of the yen as an invoice currency.

##### **A. The Impact of a Currency-Basket Regime on the Use of the Yen as an Invoice Currency**

Many East Asian economies currently adopt a *de facto* U.S. dollar peg arrangement.<sup>56</sup> If these countries were to move from this to a currency-basket regime, the volatility of prices on Japan's exports to East Asia would decrease if denominated in yen, but increase if denominated in dollars.

For this reason, as is shown by Figure 6, the introduction of a currency-basket regime in East Asia would likely result in a reduction in the percentage of exports to

54. From the opposite end of the spectrum, if Japan's foreign direct investment into Asia continues to grow and Japanese firms succeed in establishing a greater manufacturing presence globally, and this in turn results in the improved competitiveness and lower price elasticity of Japanese exports, the use of yen as an invoice currency is likely to increase.

55. For example, the Ministry of Finance (2001) wrote, "A closer linkage of Asian currencies to the yen under currency-basket systems will serve to improve the relative stability between Asian currencies and the yen and can contribute to enhancing the role of the yen."

56. See Footnote 14 regarding empirical research on this subject.

East Asia denominated in U.S. dollars and an increase in those denominated in yen, thereby leading to expanded use of the yen as an invoice currency.

### **B. The Desirability of a Currency-Basket Regime If the Use of the Yen as an Invoice Currency Has Expanded: An Application of New Open-Economy Macroeconomics**

Is it possible to say, however, that a currency-basket regime is desirable once the use of the yen as an invoice currency has expanded? Below, we will use a new open-economy macroeconomics framework to examine the desirability of a currency-basket regime in East Asia from an economic welfare perspective. Specifically, we introduce theoretical research by Engel (2001), which examines the optimal exchange rate regime when the home country and foreign country make different invoice currency decisions, to consider the implications for a currency-basket regime in East Asia.<sup>57</sup> Note that expanded use of the yen as an invoice currency in our two-region setting comprised of Japan and East Asia means that Japanese firms choose PCP and Asian firms choose LCP.

Engel (2001) assumes that the money supply is the only source of external shock. Realistically, however, changes in the exchange rate are caused both by real factors and monetary factors. Furthermore, representing monetary shocks with the money supply is another strong assumption aimed at simplification. Generally, the optimal exchange rate regime depends on the relative sizes of the real shocks and the monetary shocks (including in the money supply) that cause exchange rate volatility. It is therefore important to note that arguments based on Engel (2001) focus on an extremely limited source of shocks.

First, we examine the benchmark case, in which all firms in both the home and foreign country choose LCP (in the argument below, we let Japan be the home country and East Asia the foreign country).<sup>58</sup> In this case, changes in the exchange rate do not cause changes in the foreign country's import price, and the foreign country is completely insulated against the home monetary shock. For this reason, the variance of the foreign country's macroeconomic variables is determined only by the foreign monetary shocks. If the variance of the foreign country's money supply is greater than the variance of the money supply in the home country, it becomes optimal for the foreign country to introduce a fixed currency regime and import the highly credible monetary policy of the home country.

57. The prior research introduced in this section is based on the assumption that the invoice currency decision is determined exogenously. In truth, however, it is difficult to imagine an invoice currency being chosen independent of changes in the currency regime. In fact, reflecting recent advances in research on the endogenous invoicing decision, new strides have been made in research introducing new open-economy macroeconomics to the endogenous currency choice. Nevertheless, this research (i.e., Corsetti and Pesenti [2002]) assumes the behavior of all economic agents in the home country and foreign country are symmetric, and thus the invoice decisions made by home firms and foreign firms are also symmetric. In other words, if the home firm chooses PCP (LCP), the foreign firm also chooses PCP (LCP), and this is not very helpful for considering the implementation of economic policy when the use of the yen as an invoice currency has expanded. For this reason, although reliance on an exogenous invoicing decision is a problem, we will use the results from research in which asymmetric pricing behavior is explicitly introduced in this section.

58. There has been considerable research on the optimal exchange rate regime when assuming the invoicing decisions of the home firm and the foreign firm are symmetric, including Devereux and Engel (1998) and Obstfeld and Rogoff (2000). For a survey of these works, see Fujiki and Otani (2002).

Let us suppose that the domestic firm changes its pricing behavior from LCP to PCP (the asymmetric case in which the domestic firm chooses PCP and the foreign firm chooses LCP). In this case, changes in the exchange rate influence the foreign country's import price, as well as the foreign country's general price level. Consequently, the desirable exchange rate regime for the foreign country will differ depending on the relative sizes of money supply volatility in both the home and foreign countries and that of their economies.

To be precise, Engel showed that under floating exchange rates, the variance of consumption is given by  $var(c^*) = n^2\sigma_m^2 + (1-n)^2\sigma_{m^*}^2$ , where  $\sigma_m^2$  is the variance in the home country's money supply,  $\sigma_{m^*}^2$  is the variance in the foreign country's money supply, and  $n$  is the size of the home country relative to the foreign country ( $0 < n < 1$ ). Under a fixed exchange rate regime, however,  $var(c^*) = \sigma_m^2$ . Therefore, even if  $\sigma_m^2$  is larger than  $\sigma_{m^*}^2$ , the variance in consumption can be smaller under floating exchange rates than under fixed exchange rates, depending on the size of  $\sigma_m^2$ ,  $\sigma_{m^*}^2$ , and  $n$ .<sup>59</sup>

Accordingly, in the case where the domestic firm selects PCP and the foreign firm selects LCP, the desirability of a fixed exchange rate regime for the foreign country will depend both on the relative size of the economies and the volatility of monetary shocks between the home country and foreign country.

Based on Engel's research as explained above, when the use of the yen as an invoice currency has expanded, if the monetary shocks in East Asia are considerably larger than those in Japan, then a currency-basket regime (an exchange rate regime that is close to being fixed against the yen) is preferable to a U.S. dollar peg regime (floating exchange rates against the yen). Nevertheless, many East Asian economies currently are using a *de facto* dollar peg regime and track the credible monetary policies of the United States, such that it is unlikely that shocks in East Asian economies will be considerably larger than shocks in Japan. Accordingly, as long as we follow the assumptions of the Engel model, it is very possible that the introduction of a currency-basket regime among East Asian economies together with the expanded use of the yen as an invoice currency is not the best combination.

## V. Conclusion

We have provided an overview of recent developments in research with micro foundations on the choice of an invoice currency from the perspective of expected profit maximization, instead of focusing on the classical analyses, as conducted since the 1960s, of a vehicle currency. We have drawn on this pool of theoretical knowledge and assessed the current use, and forecast the future use, of the yen as an invoice currency.

We conducted our analysis primarily from the perspective of whether the use of the yen in international trade will expand. There is not necessarily an obvious answer,

59. Specifically, when the ratio of money supply variances in the foreign country and home country ( $\sigma_{m^*}^2/\sigma_m^2$ ) is larger than  $(1+n)/(1-n)$ , a fixed exchange rate regime is optimal, and if it is smaller than  $(1+n)/(1-n)$ , a floating exchange rate regime is optimal.

however, to the question of whether it is necessary to promote the use of the yen as an invoice currency.

One approach to this question is to ask whether, if in fact certain constraints are preventing use of the yen, it is necessary to eliminate those constraints and promote use of the yen, even when granting that use of the yen as an invoice currency is desirable for Japan's exporting firms. In this context, if the paucity of financial transactions denominated in yen is serving as a barrier to the use of the yen in trade transactions, although it is outside the scope of our paper, then it is probably necessary to take further measures to improve Japanese financial markets and facilitate the use of the yen in financial transactions.

Another approach is to ask whether expanded use of the yen might present new problems and issues, and if such problems and issues do arise, whether there is a risk that the disadvantages they bring would outweigh the advantages as enumerated above.

Many economists argue the necessity of expanding the use of the yen, but virtually no analysis has been done of the problems and issues that may arise as a result. In this regard, we conclude our paper by pointing out the possibility that the policymakers may confront new problems in implementing policy as a result of the expanded use of the yen as an invoice currency, an analysis taken up by one particular paper based on new open-economy macroeconomics.

Otani (2002) extended Betts and Devereux (2000) to analyze how the international transmission of monetary policy would be affected by asymmetric (different) invoice currency decisions between domestic and foreign firms. He found that, considering Japan as the home country and East Asia as the foreign country, in the case corresponding to expanded use of the yen—a sufficiently high percentage of Japanese firms setting prices based on PCP and a sufficiently high percentage of East Asian firms setting prices under LCP—monetary easing in Japan would provide positive effects to East Asian economies (as measured by economic welfare), whereas monetary easing in East Asia would have either almost no effect on Japan or a slightly negative effect.<sup>60</sup> As these results make clear, since the external effects of Japan's monetary policy would only become larger if the use of the yen as an invoice currency were expanded, Japan may be asked, even more frequently than before, to take into account the ramifications for East Asian economies when implementing its monetary policy.

Thus, it is important to keep in mind that the increased use of the yen in international trade would not represent a “free lunch” for policymakers, and in fact could create new problems in implementing policy.

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60. See Appendix 4 regarding this point.

## APPENDIX 1: DERIVATION OF THE CONDITIONS FOR CHOOSING PCP AND LCP

In this appendix, we explain the methodology for deriving equation (3) introduced in Section II, which is the condition for choosing between PCP and LCP.

First, let  $f(e)$  represent the difference between the utility obtained from profits under PCP and the utility from profits obtained under LCP, that is,  $f(e) = U(\Pi^p) - U(\Pi^l)$ . In this case, the first-order and second-order derivatives of  $f(e)$  with respect to  $e$  are as follows:

$$f_e = U'(\Pi^p) \frac{\partial \Pi^p}{\partial e} - U'(\Pi^l) \frac{\partial \Pi^l}{\partial e},$$

$$f_{ee} = U'' \left[ \left( \frac{\partial \Pi^p}{\partial e} \right)^2 - \left( \frac{\partial \Pi^l}{\partial e} \right)^2 \right] + U' \left[ \frac{\partial^2 \Pi^p}{\partial e^2} - \frac{\partial^2 \Pi^l}{\partial e^2} \right].$$

Letting  $\bar{e}$  be the expected value of the exchange rate, a Taylor expansion of  $f(e)$  in the neighborhood of  $\bar{e}$  can be approximated with the following equation:<sup>61</sup>

$$f(e) = f(\bar{e}) + f_e(\bar{e})(e - \bar{e}) + \frac{1}{2} f_{ee}(\bar{e})(e - \bar{e})^2.$$

Making use of the identity  $Ee = \bar{e}$ , the expected value of the above equation is as follows:

$$Ef(e) = Ef(\bar{e}) + \frac{1}{2} f_{ee}(\bar{e})(e - \bar{e})^2.$$

Because it is assumed that the firm sets the optimal price based on a given exchange rate, the profit is going to be the same whether under PCP or LCP ( $Ef(\bar{e}) = 0$ ), given the same expected exchange rate. Thus, the following relationship holds:

$$Ef(e) = \frac{1}{2} f_{ee}(\bar{e})(e - \bar{e})^2.$$

Substituting into this equation the second-order derivative of  $f(e)$  with respect to  $e$  as shown above, and using the fact that, when the firm sets its optimal price, the partial derivative of profit with respect to the exchange rate will be the same for both PCP and LCP ( $\partial \Pi^p / \partial e = \partial \Pi^l / \partial e$ ), we can arrive at equation (3).

61. The process of deriving the conditions for selection makes use of an approximation through a second-order Taylor expansion. This is an appropriate analytical technique when the exchange rate fluctuation is small. Nevertheless, the exchange rate can jump sharply in response to changes in the socioeconomic situation, and a second-order Taylor expansion is no longer appropriate in this situation. Therefore, the above-noted condition for selecting an invoice currency is valid only under certain conditions.

## APPENDIX 2: CONDITIONS FOR CHOOSING AN INVOICE CURRENCY WHEN A THIRD COUNTRY'S CURRENCY IS AVAILABLE

In this appendix, we explain the method for deriving equations (8) and (9), which describe the condition for selecting an invoice currency when a third country's currency is available, and discuss the implications.

### A. Derivation of the Equations

We begin by deriving equation (8), which is the condition for selecting between a third country's currency and LCP. Let  $g(e, e^o)$  represent the difference between the utility from profits when the third country's currency is selected and the utility from profits under LCP ( $g(e, e^o) = U(\Pi^o) - U(\Pi^L)$ ). In this case, the first-order and second-order derivatives of  $g(e, e^o)$  with respect to  $e$  and  $e^o$  are given as follows:

$$\begin{aligned} g_e &= U'(\Pi^o) \frac{\partial \Pi^o}{\partial e} - U'(\Pi^L) \frac{\partial \Pi^L}{\partial e}, \\ g_{e^o} &= U'(\Pi^o) \frac{\partial \Pi^o}{\partial e^o} - U'(\Pi^L) \frac{\partial \Pi^L}{\partial e^o}, \\ g_{ee} &= U'' \left[ \left( \frac{\partial \Pi^o}{\partial e} \right)^2 - \left( \frac{\partial \Pi^L}{\partial e} \right)^2 \right] + U' \left[ \frac{\partial^2 \Pi^o}{\partial e^2} - \frac{\partial^2 \Pi^L}{\partial e^2} \right], \\ g_{e^o e^o} &= U'' \left[ \left( \frac{\partial \Pi^o}{\partial e^o} \right)^2 - \left( \frac{\partial \Pi^L}{\partial e^o} \right)^2 \right] + U' \left[ \frac{\partial^2 \Pi^o}{\partial (e^o)^2} - \frac{\partial^2 \Pi^L}{\partial (e^o)^2} \right], \\ g_{ee^o} &= U'' \left[ \frac{\partial \Pi^o}{\partial e} \frac{\partial \Pi^o}{\partial e^o} - \frac{\partial \Pi^L}{\partial e} \frac{\partial \Pi^L}{\partial e^o} \right] + U' \left[ \frac{\partial^2 \Pi^o}{\partial e \partial e^o} - \frac{\partial^2 \Pi^L}{\partial e \partial e^o} \right]. \end{aligned}$$

Letting  $\bar{e}$  and  $\bar{e}^o$  be the expected values of the exchange rate, a Taylor expansion of  $g(e, e^o)$  in the neighborhood of  $\bar{e}$  and  $\bar{e}^o$  can be approximated with the following equation:

$$\begin{aligned} g(e, e^o) &= g(\bar{e}, \bar{e}^o) + g_e(e - \bar{e}) + g_{e^o}(e^o - \bar{e}^o) + \frac{1}{2} g_{ee}(e - \bar{e})^2 \\ &\quad + \frac{1}{2} g_{e^o e^o}(e^o - \bar{e}^o)^2 + g_{ee^o}(e - \bar{e})(e^o - \bar{e}^o). \end{aligned}$$

Using  $Ee = \bar{e}$ ,  $Ee^o = \bar{e}^o$ , and the assumptions that  $\bar{e}$  and  $\bar{e}^o$  are mutually independent (i.e., the covariance between the two is zero), the expected value of the above equation can be expressed as follows:

$$Eg(e, e^o) = Eg(\bar{e}, \bar{e}^o) + \frac{1}{2} g_{ee} \sigma^2 + \frac{1}{2} g_{e^o e^o} (\sigma^o)^2.$$

Further, assuming that the firm sets the optimal price under a given exchange rate, the expected level of profit under that exchange rate is going to be the same whether under LCP or using a third country's currency ( $Eg(\bar{e}, \bar{e}^o) = 0$ ), and the following relationship holds:

$$Eg(e, e^o) = \frac{1}{2}g_{ee}\sigma^2 + \frac{1}{2}g_{e^oe^o}(\sigma^o)^2.$$

Substituting into this equation the above formulas for the second-order derivatives of  $g(e, e^o)$  with respect to  $e$  and  $e^o$ , and using the fact that, under optimal pricing, the partial derivative of profits with respect to the exchange rate is the same under both LCP and when using a third country's currency ( $\partial\Pi^o/\partial e = \partial\Pi^L/\partial e$ ,  $\partial\Pi^o/\partial e^o = \partial\Pi^L/\partial e^o$ ), as well the fact that  $\partial^2\Pi^L/\partial e^2 = \partial^2\Pi^L/\partial(e^o)^2 = \partial^2\Pi^o/\partial e^2 = 0$  holds from equations (2) and (7), the condition for selecting between LCP and a third country's currency is as shown in equation (8).

The same steps can be followed to derive the condition for selecting between PCP and a third country's currency in equation (9).

## B. Invoicing Decision When a Third Country's Currency Is Available

Next, we use equations (8) and (9), obtained using the above method, to examine under which conditions PCP, LCP, and a third country's currency are chosen. To do this, we first examine the conditions for selecting between a third country's currency and LCP, and then derive the conditions for choosing between a third country's currency and PCP. Combining these conditions with the condition for selecting between LCP and PCP shown in equation (6), we can clarify the conditions governing the invoicing decision when a third country's currency is available.

### 1. Choice between a third country's currency and LCP

Equation (8) shows the choice that will be made between a third country's currency and LCP. If  $\Pi^o$  is convex with respect to  $e^o$  ( $\partial^2\Pi^o/\partial(e^o)^2 > 0$ ), the third country's currency will be chosen, and if it is concave, LCP will be chosen.

### 2. Choice between a third country's currency and PCP

Equation (9) describes the conditions for selecting between a third country's currency and LCP. To get a closer look at what this equation means, we first derive the second derivative of  $\Pi^p$  with respect to  $e$ , and the second derivative of  $\Pi^o$  with respect to  $e^o$ . Assuming that the firm sets the optimal price for a given exchange rate, and that  $E(e) = E(e^o) = 1$  to simplify the calculations, the second-order conditions are as follows, where  $\bar{p}$  represents the optimal price:

$$\frac{\partial^2\Pi^p}{\partial e^2} = \bar{p}[\bar{p}^2D'' - 2D - \bar{p}C''(D')^2 - \bar{p}C'D''],$$

$$\frac{\partial^2\Pi^o}{\partial(e^o)^2} = \bar{p}[\bar{p}^2D'' + 2\bar{p}D' - \bar{p}C''(D')^2 - \bar{p}C'D''].$$

Using the assumption that the price elasticity of demand ( $\mu = -pD'/D$ ) is greater than one to ensure that the monopolistic firm produces a positive quantity, we obtain the inequality  $\partial^2\Pi^p/\partial e^2 > \partial^2\Pi^o/\partial(e^o)^2$ . Using this relationship, equation (9) can be expressed using the following inequalities:

$$EU(\Pi^o) - EU(\Pi^p) > 0.5U' \frac{\partial^2\Pi^p}{\partial e^2} [-\sigma^2 + (\sigma^o)^2], \quad (\text{A.1})$$

$$EU(\Pi^o) - EU(\Pi^p) < 0.5U' \frac{\partial^2 \Pi^o}{\partial (e^o)^2} [-\sigma^2 + (\sigma^o)^2]. \quad (\text{A.2})$$

Inequality (A.1) shows that the third country's currency is selected when either  $\partial^2 \Pi^p / \partial e^2 < 0$  and  $\sigma^2 > (\sigma^o)^2$ , or  $\partial^2 \Pi^p / \partial e^2 > 0$  and  $(\sigma^o)^2 > \sigma^2$ . Inequality (A.2) shows that PCP is selected when either  $\partial^2 \Pi^o / \partial (e^o)^2 < 0$  and  $(\sigma^o)^2 > \sigma^2$ , or  $\partial^2 \Pi^o / \partial (e^o)^2 > 0$  and  $\sigma^2 > (\sigma^o)^2$ .

### 3. Conditions for selecting a third country's currency

Based on the above examination and equation (3), the conditions for selecting among the third country's currency, LCP, and PCP can be summarized as below.

- (1) When  $\partial^2 \Pi^p / \partial e^2 < 0$  and  $\partial^2 \Pi^o / \partial (e^o)^2 < 0$ , LCP maximizes expected profits. The next highest expected profits are obtained from the third country's currency when  $\sigma^2 > (\sigma^o)^2$ , and from PCP when  $(\sigma^o)^2 > \sigma^2$ .
- (2) When  $\partial^2 \Pi^p / \partial e^2 > 0$  and  $\partial^2 \Pi^o / \partial (e^o)^2 > 0$ , expected profits are maximized by PCP if  $\sigma^2 > (\sigma^o)^2$  and by the third country's currency if  $(\sigma^o)^2 > \sigma^2$ . LCP brings the lowest expected profits in both cases.
- (3) When  $\partial^2 \Pi^p / \partial e^2 > 0$  and  $\partial^2 \Pi^o / \partial (e^o)^2 < 0$ , PCP offers the highest expected profits, followed by LCP and lastly the third country's currency.

## APPENDIX 3: PRICE ELASTICITY OF JAPAN'S EXPORTS TO EAST ASIA BY PRODUCT CATEGORY

The price elasticity of Japanese exports to East Asia by product category shown in Section III was found by estimating an export function for each product category. Details of this estimation process are as follows.

For the estimation equation, we used the following formulation, which includes a partial-adjustment term:

$$\begin{aligned} LX_i &= C^i - \alpha^i LP_i + \beta^i LX_{i-1} + \delta LY_i, \\ \gamma^i &= \alpha^i / (1 - \beta^i) \end{aligned}$$

where  $LX$ ,  $LP$ , and  $LY$  represent the logs of export volume, relative price, and income in East Asia, respectively, and the superscript  $i$  indexes each product category. The values used in Figure 6 are the long-term price elasticities represented by  $\gamma$  (for estimation results, see Appendix Table 1).

We estimated the above formula for seven product categories: chemical products, nonmetallic mineral products, metals and metallic products, general machinery, electric machinery, transportation equipment, and precision equipment.

**Appendix Table 1 Long-Run Price Elasticity of Japan's Exports to East Asia**

	Chemical products	Nonmetallic mineral products	Metals and metallic products	General machinery	Electric machinery	Transportation equipment	Precision equipment
$\gamma$	0.54 (0.15)	0.62 (0.11)	0.81 (0.23)	0.45 (0.16)	0.28 (0.14)	0.22 (0.31)	0.31 (0.18)

Note: Numbers in parentheses are standard errors.

electric machinery, transportation equipment, and precision equipment, by seemingly unrelated regression (SUR) using the correlation of estimated errors for each product category.<sup>62</sup> Our estimates used quarterly data covering the first quarter of 1983 until the fourth quarter of 2002 of the eight East Asian economies for which we were able to obtain data: Hong Kong, Indonesia, Malaysia, the Philippines, Singapore, South Korea, Taiwan, and Thailand.

As for the details of the data, we converted the nominal amount of exports to East Asia by product category reported in the trade statistics into real terms by dividing by each category's export price index and totaled these for the eight economies. For the relative price, we used the ratio between the export price index for each category  $P^i$  and the domestic price index for East Asia  $P^*$ .  $P^*$  is a trade-weighted geometric average of the wholesale price index in each economy, although due to the limited availability of data we used the producer price index in Thailand and the consumer price index in Singapore and Malaysia. Finally, we calculated East Asian income by totaling the amount of real imports, which was available for all of the economies.<sup>63,64</sup>

#### **APPENDIX 4: INTERNATIONAL TRANSMISSION OF MONETARY POLICY UNDER ASYMMETRIC PRICE SETTING**

In this appendix, we introduce Otani (2002), which analyzes the international transmission of monetary policy when the invoice currency decisions made by domestic firms and foreign firms are asymmetric.

Otani (2002) built a model using new open-economy macroeconomics in which a fraction  $s$  of domestic firms and a fraction  $s^*$  of foreign firms select LCP, and the remaining firms select PCP ( $0 < s, s^* < 1$ ). He then analyzed how the transmission of monetary policy in the home country and foreign country would be affected by changes in  $s$  and  $s^*$  from an economic welfare perspective.

He found that the external transmission of monetary policy for the home country and foreign country could be asymmetric, depending on the sizes of  $s$  and  $s^*$ , as shown in Appendix Figure 1.

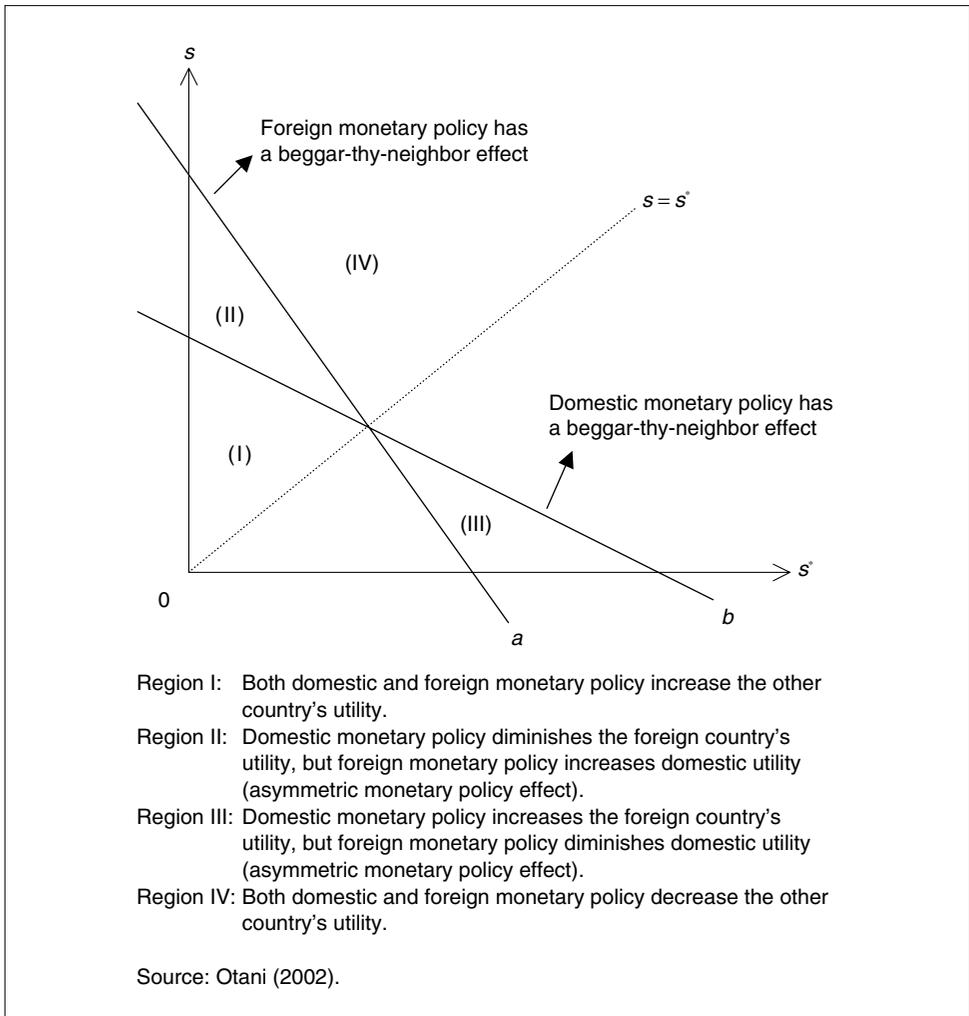
In this figure, the region in which  $s$  is small and  $s^*$  is large (region III) corresponds to the region in which the use of the yen as an invoice currency is expanded, and closer to line  $a$  within region III the effects of the foreign country's monetary policy on the home country are negligible, whereas the home country's monetary policy has an impact on the foreign country.

62. Prior to running the SUR estimates, we performed an OLS regression for each category, and for those categories where we found, based on the Durbin- $h$  statistic, autocorrelation of the error term (electric machinery and precision equipment), we ran estimates using a polynomial lag model (0.5, 1.0, and 1.5 years) without the lagged dependent variable. The results were not significantly different, however.

63. Since the data for Indonesian imports are not available from the second to fourth quarter of 2000, we supplemented the data by assuming the ratio of imports to GDP for this period was the same as that from the second quarter of 1999 until the first quarter of 2000.

64. During this period, we obtained data on the Asian region from the International Monetary Fund's *International Financial Statistics*, but for Taiwan and Hong Kong we used the figures published by CEIC Data Company.

**Appendix Figure 1 International Transmission of Monetary Policy in the Home and Foreign Countries**



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