

# The Decline in the Exchange Rate Pass-Through: Evidence from Japanese Import Prices

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*In this paper, we empirically examine the movement of the exchange rate pass-through to the aggregate import prices in Japan from the 1980s through 2001. We demonstrate that the exchange rate pass-through to Japan's import prices fell in the 1990s, and such a decline occurred mainly during the period from the late 1980s to the mid-1990s. In addition, we show that the decline came mainly from declines in the exchange rate pass-through in each product, rather than a shift of import share from raw materials to manufactured goods with a lower exchange rate pass-through. Moreover, the period of the decline in the exchange rate pass-through coincides with the period of the sharp appreciation of the yen and resultant structural changes in the economy and international trade. Although the advance in the globalization of Japanese firms is likely to reduce the exchange rate pass-through to import prices, it should be noted that the decline in the exchange rate pass-through does not necessarily imply that exchange rate fluctuations have become less important in connection with macroeconomic fluctuations.*

Keywords: Exchange rate pass-through; Pricing-to-market; Import structure; Expenditure-switching effect; Firms' sourcing decision

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## I. Introduction

In this paper, we empirically examine the development of the exchange rate pass-through to the aggregate import prices in Japan over time to show when and by how much it has declined since the 1980s. We also throw some light on the factors behind such a decline in the exchange rate pass-through to import prices.

Recently theoretical as well as empirical research on the exchange rate pass-through to aggregate import prices has attracted renewed attention. In this line of research, the focus has shifted to the exchange rate pass-through to “import” prices measured by “aggregate” price indicators, from export price setting by individual exporters in previous studies. In addition, recent studies attempt to derive some policy implications of the exchange rate pass-through on future price developments in the economy as a whole.

Behind the renewed interest in the exchange rate pass-through to import prices lies the following recent developments in theoretical studies on low inflation worldwide and on the relationship between exchange rate fluctuations and their influence on adjustment of the macroeconomy.

First is Taylor’s (2000) conjecture on the recent worldwide decline in the exchange rate pass-through. His conjecture is that firms find it increasingly difficult to fully pass exchange rate movements on their export prices in the context of the recent economic environment, characterized by intensified worldwide competitive pressure and low and stable inflation. In response, the policy implications of a diminished exchange rate pass-through to domestic prices have been widely discussed.

Taylor’s conjecture provides an important implication for future price developments. As long as low and stable inflation is maintained, the exchange rate pass-through remains low, and inflation, in turn, continues to stay at a very low and stable level. This implies that a virtuous circle exists between price development and corporate pricing behavior. If this is the case, a commitment to low and stable price development by a central bank is reinforced by its historical record. To explore the implication of the exchange rate pass-through to future inflation from a macroeconomic perspective, recent research has focused not on corporate export price setting, which was vigorously analyzed until the early 1990s, but on countries’ import prices to estimate the exchange rate pass-through to countries’ import prices.

Second is the recent theoretical development in “new open-economy macroeconomics,” starting from Obstfeld and Rogoff (1995).<sup>1</sup> Since this line of research has micro-foundations, exporters can decide to set their export prices in their currency (producers’ currency pricing [PCP]) or in consumers’ currency (local currency pricing [LCP]) in the models. In the PCP model, on the one hand, the exchange rate pass-through to import prices is always perfect, and thus, exchange rate fluctuations work to adjust the current account imbalance and business cycle.<sup>2</sup>

1. See Lane (2001) for a survey of recent developments in “new open-economy macroeconomics.”

2. Many of these models assume that exporting firms directly sell their products to consumers in the importing country, and import prices are equal to consumer prices. This is equivalent to assuming that home inputs are not used for the sales activity of imported goods. In reality, however, domestic inputs are necessary for sales activity of imported goods. Thus, both import prices of goods and domestic input prices of sales activity influence the retail

On the other hand, in the case of LCP, the exchange rate pass-through is limited, thus producing only a small expenditure switching effect between domestic and foreign goods.<sup>3</sup> Therefore, these studies show that the effect of monetary policy depends on firms' price-setting behavior, since PCP and LCP exert different effects on the exchange rate pass-through.

In this regard, recent studies on the exchange rate pass-through to import prices try to reformulate the argument of "exchange rate pessimism" (Obstfeld [2002]) in the late 1980s to the early 1990s. In fact, despite the drastic depreciation of the U.S. dollar following the Plaza Agreement in 1985, U.S. import prices denominated in dollars did not rise much and the subsequent adjustment of current account imbalances in the industrial countries did not progress. This experience reveals that the adjustment mechanisms of exchange rate fluctuations on the current account imbalance do not work smoothly, contrary to views prevalent at that time.<sup>4</sup>

In this paper, we estimate the exchange rate pass-through to Japan's import prices and examine the movement over time to show when and by how much it has declined since the 1980s. We also investigate the factors behind changes in the exchange rate pass-through over time. It should be noted that the exchange rate pass-through to import prices is larger than that to consumer prices, since the consumer price index (CPI) contains service prices. Nevertheless, it is important to examine the exchange rate pass-through to import prices, considering the increasing globalization of the Japanese economy.

Our major findings in this paper are as follows. First, the decline in the exchange rate pass-through occurred mainly during the period from the late 1980s to the early 1990s. Second, such decline came mainly from the decline in the exchange rate pass-through in each product, rather than the shift of import share from raw materials to manufactured goods with a lower exchange rate pass-through. The latter finding contrasts with that of Campa and Goldberg (2002), who emphasized the effects of changes in trade share.

In drawing the above conclusions, we pay due consideration to the robustness of the data series as well as econometric procedures. First, we use the import price series in the corporate goods price index (CGPI) to estimate the exchange rate pass-through to Japanese import prices of eight disaggregated product categories.<sup>5</sup> The CGPI is compiled carefully to control the changes in product quality over time. This enables us to exclude "spurious" changes in the exchange rate pass-through, possibly caused by the shift in average product quality in response to exchange rate fluctuations. Second, we apply a specification that is simple but flexible enough to capture the

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prices consumers face. As a result, the exchange rate pass-through on import prices is generally higher than that on domestic retail prices.

3. Research includes Betts and Devereux (2000) and Otani (2002).

4. Krugman (1987) proposed exporters' price-setting behavior as embodied in pricing-to-market (PTM) to provide a theoretical foundation to explain the limited power of exchange rate changes to adjust the current account imbalance. A key implication of the PTM behavior of exporters was that they did not change their export prices in local currency terms commensurate with changes in production costs and exchange rates. This was deemed highly consistent with the weak response of their local currency-denominated export prices to exchange rate fluctuations.

5. The CGPI replaced the wholesale price index (WPI) at the time of base-year revision from 1995 to 2000 in December 2002. This is mainly because the percentage of prices surveyed at the production stage has been increased from that under the previous index due to the changes in the selection criteria for price survey stage.

exact long-term impacts of exchange rate fluctuations on import prices. In addition, this specification enables us to employ rolling regression analysis to explore in detail when and by how much the long-term exchange rate pass-through has declined since the 1980s.

This paper is structured as follows. Section II briefly reviews the theoretical and empirical research on the exchange rate pass-through to export prices from microeconomic and macroeconomic viewpoints. Section III introduces empirical studies using aggregate import prices, and then presents estimation results of the exchange rate pass-through to Japanese import prices, making comparisons with previous studies. Section IV investigates the factors behind changes in the exchange rate pass-through to Japanese import prices. Finally, Section V summarizes the findings of this paper and examines the implication of recent changes in the exchange rate pass-through for monetary policy. In addition, Appendix 1 explains a profit maximization model for determining the exchange rate pass-through and the sunk-cost model, both of which are mentioned in Section III. Appendix 2 examines the relationship between the decline in the exchange rate pass-through and the choice of invoice currency.

## II. Exchange Rate Pass-Through from Macroeconomic Perspectives

Considerable theoretical models on the exchange rate pass-through to firms' export prices were proposed in the late 1980s. They focused on microeconomic aspects such as the shape of the demand curve and cost function, or the existence of irreversible investment (sunk cost). Following these developments in theoretical studies, since the end of the 1980s through the 1990s, a large amount of empirical research has estimated the exchange rate pass-through using micro data of firms' export prices.<sup>6,7</sup>

Recently Taylor (2000) has stimulated interest in dynamic changes in the exchange rate pass-through from a macroeconomic perspective. He conjectures that the exchange rate pass-through has persistently declined in response to changes in the macroeconomic environment such as intensified competitive pressure and low inflation worldwide. Based on his conjecture, to derive the implication of changes in the exchange rate pass-through to the macroeconomy, some empirical studies attempt to estimate the dynamic movement of the exchange rate pass-through to countries' import prices.

In this section, we first introduce the study by Taylor (2000) to examine the exchange rate pass-through from macroeconomic perspectives. Then, we give an overview of Campa and Goldberg (2002), one of the leading works on the subject, which estimates the exchange rate pass-through to import prices using aggregated data.

6. See Appendix 1 for the details on the theoretical and empirical researches for the exchange rate pass-through on firms' export prices.

7. Recently, some researchers have built structural models of industry behavior based on the industrial organization theory to estimate the exchange rate pass-through on export prices using micro data. For example, Kadiyali (1997) and Hellerstein (2002) estimate the exchange rate pass-through of the photographic film industry and the beer industry, respectively.

### A. Taylor's (2000) Staggered Pricing Model

As mentioned, the conjecture raised by Taylor (2000) has triggered the recent upsurge of interest in the exchange rate pass-through. His argument is based on the following staggered pricing model.

Let a linear demand curve for a firm's goods be defined as equation (1).

$$y_t = \epsilon_t - \beta(x_t - p_t), \quad (1)$$

where  $y_t$  expresses production of the firm's goods,  $x_t$  denotes its price,  $p_t$  is the average price of other goods produced by competitive firms, and  $\epsilon_t$  is a random shift to demand.<sup>8</sup>  $\beta$  is the inverse of the firm's market power, and a higher value of  $\beta$  represents less market power with  $\beta \rightarrow \infty$  representing perfect competition.

Suppose that the firm presets its price for the next four periods and reviews its price every four periods. Let  $c_t$  be the firm's marginal cost of producing goods. Then, the firm's expected profit for the four periods at period  $t$  when it sets its price at  $x_t$  can be expressed as follows.<sup>9</sup>

$$\sum_{i=0}^3 E_t(x_t y_{t+i} - c_{t+i} y_{t+i}), \quad (2)$$

where  $E_t$  indicates the conditional expectations operator based on information at period  $t$ . The firm maximizes its profit, taking the prices of other firms as given. Then, substituting equation (1) to equation (2) and differentiating it with respect to  $x_t$ , we derive the solution for optimal prices given by the following equation (3).

$$x_t = 0.125 \sum_{i=0}^3 (E_t c_{t+i} + E_t p_{t+i} + E_t \epsilon_{t+i} / \beta). \quad (3)$$

If we apply equation (3) to a firm that imports products from foreign countries and sells them in the home country, we can derive the following implications for the exchange rate pass-through. First, the amount of price change depends on how permanent exchange rate changes are. The changes in exchange rate affect marginal cost, thereby inducing the firm to change its sales price. In this case, however, price is determined by the average marginal cost for the next four periods including the current one. If the exchange rate changes are regarded as temporary, the price does not change so much as the exchange rate and the exchange rate pass-through remains low.

Second, when prices set by other firms are expected to decline persistently in the future, the firm also must lower its price. Hence even if the exchange rate depreciates and the import cost rises, the firm will try to avoid a price hike as much as possible. Third, weaker market power makes it difficult for the firm to change its product price in response to demand shocks. Thus, the firm is less likely to pass the increased cost due to depreciation on to its product price.

8. In Taylor's model, it is assumed that the expected value of  $\epsilon_t$ , a random shift to demand, is not necessarily zero.

9. For simplicity, the discount factor is assumed to be one.

## B. Recent Developments

Campa and Goldberg (2002) estimate the exchange rate pass-through to the import prices for 25 member countries of the Organisation for Economic Co-operation and Development (OECD) by using quarterly data from 1975 to 1999. Their estimation is based on the following specification:

$$\Delta imp^j = \alpha + \sum_{i=0}^{-4} a_i^j \Delta ner^{j-i} + \sum_{i=0}^{-4} b_i^j \Delta mc^{j-i} + c^j \Delta gdp^j + \epsilon^j, \quad (4)$$

where  $\Delta$  represents first difference,  $imp^j$  is import prices of country  $j$  denominated in its currency (log-transformed),  $ner^j$  denotes the nominal effective exchange rate for country  $j$  (log-transformed),  $mc^j$  is an indicator for the marginal cost of all of  $j$ 's trading partners (log-transformed),  $gdp^j$  is the aggregate output of country  $j$  (log-transformed), and  $\epsilon^j$  is the error term. Specifically,  $mc^j$  is the log-transformed value of  $MC^j = NER^j \cdot P^j / RER^j$ , where  $RER^j$  is the real effective exchange rate, and  $P^j$  is  $j$ 's general price.

The short-term exchange rate pass-through is given by the estimated coefficient  $a_0$  that corresponds to the contemporaneous effect of a change in the exchange rate on import prices. The long-term pass-through is given by the sum of the coefficients  $\sum_{i=0}^{-4} a_i^j$  that represents the effect of contemporaneous and four-period lagged exchange rate changes on import prices.

Campa and Goldberg (2002) estimate the exchange rate pass-through to overall import prices for the 25 OECD member countries based on the above specification. They report that the average short-term pass-through for 25 countries is 0.61 and the average long-term pass-through is 0.77 for the full sample period from 1975 to 1999. In addition, to examine whether the pass-through has declined in the 1990s, they compare the estimated coefficients for the full sample with those for the subsample for 1975–89. As a result, they find that the short-term and long-term pass-throughs for the 25 countries are respectively lower by  $-0.04$  and  $-0.27$  in the former subsample than the latter one.

As for their estimation results on the Japanese pass-through, they report 0.88 for the short-term pass-through and 1.26 for the long-term pass-through for the full sample. These numbers are considerably greater than those of other major industrial countries: the short-term and long-term pass-throughs are 0.26 and 0.41 for the United States and 0.29 and 0.79 for Germany. Moreover, their results reveal that the Japanese short-term and long-term pass-throughs become dramatically lower in the 1990s: the estimates for the short-term and long-term pass-throughs are respectively lower by  $-0.36$  and  $-0.76$  for the full sample period from 1975 to 1999, compared with the estimates for the subsample period of 1975–89.

Campa and Goldberg (2002) further examine two hypotheses to explain the observed decline in the exchange rate pass-through in the 1990s. The first is changes in the macroeconomic environment such as a decline in worldwide inflation and exchange rate volatility. The second is changes in the world trade structure, such as the decrease in the import share of raw materials as well as the increase in the share of manufactured products. They pool the estimated pass-through across countries to regress them with money supply, average inflation, exchange rate volatility, real

GDP (as the proxy of country size), and an indicator for structural change in imports.<sup>10</sup> They conclude that the decline in the pass-through in the 1990s is mainly attributable to the structural change in imports.

### III. Estimation of the Exchange Rate Pass-Through to Japan's Import Prices

As mentioned, Campa and Goldberg (2002) show that the exchange rate pass-through to import prices declined in the 1990s. Their analysis, however, does not show whether the exchange rate pass-through gradually declined throughout the 1990s or whether it declined rapidly during a specific period in the 1990s. To detect changes in the exchange rate pass-through over time across industries, we employ the rolling regression method to estimate the pass-through with a 72-month subsample by using monthly data from January 1978 to October 2002.

#### A. Specification and Data

We estimate the exchange rate pass-through based on the following equation (5) including a partial adjustment term to import prices to allow for the possibility of gradual adjustment of import prices to exchange rate fluctuations.<sup>11</sup>

$$\begin{aligned} \Delta imp_t^j &= \phi^j + \varphi^j \Delta imp_{t-1}^j + \gamma^j \Delta ner_t^j + \eta^j \Delta z_t^j + v_t^j \\ \lambda^j &= \gamma^j / (1 - \varphi^j) \end{aligned} \quad (5)$$

where  $z$  is other control variables that are specified below and superscript  $j$  denotes product categories.  $\gamma$  and  $\lambda$  represent the short-term and long-term pass-through, respectively.<sup>12</sup> Note that this specification enables us to obtain the total effect of the current exchange rate on the current and future import prices, that is, the exact long-term pass-through of the current exchange rate.

Data used in our estimation are as follows. First, for the dependent variable, import prices, we employ import price indexes for each product category from the CGPI. Besides the aggregate series, disaggregated import prices for eight categories are available from the CGPI import price indexes: foods, materials, fuels, chemicals, textiles, metals, machinery, and others.<sup>13</sup> Considering large fluctuations in primary

10. Country size may affect the exchange rate pass-through because foreign firms are likely to have larger market power in a smaller economy. An indicator for structural change in imports is a weighted average of the pass-through for five disaggregated import prices (food, energy, raw materials, manufactured goods, and non-manufactured goods).

11. We do not use an error correction model (ECM) in this paper, since the existence of cointegration between exchange rate and import prices is rejected by the Engle-Granger test.

12. The long-term pass-through in equation (5) is a nonlinear function of estimated coefficients. Accordingly, the standard error of the long-term pass-through is estimated as follows.

$$\text{s.e.} = (\lambda^2 \text{Var}[\gamma] + \lambda_e^2 \text{Var}[\varphi] + 2\lambda_e \lambda \text{Cov}[\gamma, \varphi])^{1/2},$$

where  $\text{Var}[\cdot]$ ,  $\text{Cov}[\cdot, \cdot]$ ,  $\lambda_e$ , and  $\lambda_e$  are estimated variance, estimated covariance,  $\partial \lambda / \partial \gamma = 1 / (1 - \varphi)$ , and  $\partial \lambda / \partial \varphi = \gamma / (1 - \varphi)^2$ , respectively.

13. Since the categories reported by the CGPI are a little different from those in *The Summary Report on Trade of Japan*, we adjusted them for consistency with each other as follows.

commodity prices, we compile two additional series that exclude the import prices of primary commodities from overall import prices: overall excluding fuels and overall excluding fuels and materials series.

Second, as for the independent variables, we use the International Monetary Fund's (IMF's) effective nominal exchange rates.<sup>14</sup> In addition, we adopt demand shock and marginal cost changes as in Campa and Goldberg (2002). We employ the Index of Industrial Production (IIP) as a proxy for demand shock. We calculate marginal cost according to the following formula as used in Campa and Goldberg (2002):  $MC = (NER^{JPN}/RER^{JPN}) \cdot ULC^{JPN}$ , where superscript *JPN* implies Japan and, thus,  $ULC^{JPN}$  represents unit labor cost in Japan in *Main Economic Indicators* (MEI). Since the IMF's real effective exchange rate is deflated by the unit labor cost of trading partners, the calculated marginal cost obtained by the above formula becomes a weighted average of unit labor cost in trading partner countries.

In estimating the exchange rate pass-through based on equation (5) using the aforementioned data, we adopt a seemingly unrelated regression to improve the efficiency, utilizing the residual correlation among the equations of each product category.<sup>15</sup>

## B. Benchmark Estimation Results

We first examine whether the decline in the pass-through to overall import prices comes from the import structure changes, as is suggested by Campa and Goldberg (2002). Table 1 summarizes the short-term and long-term pass-through coefficients of overall import prices as well as import prices of product categories. The sample periods are divided into the periods before and after 1990.<sup>16</sup>

Looking at the full-sample estimation results in the first column, the pass-through coefficients for overall import prices in the short term and long term are 0.63 and 1.02, respectively, confirming that the pass-through coefficient is larger in the long term by 0.39 than in the short term.<sup>17</sup> The short-term pass-through coefficients are almost the same regardless of including or excluding primary materials: overall, 0.63; overall excluding fuels, 0.65; and overall excluding fuels and materials, 0.61. In contrast, the long-term coefficients become low if primary commodities are excluded: overall, 1.02; overall excluding fuels, 0.81; and overall excluding fuels and materials, 0.74.

The estimates differ across product categories, and such differences are more significant with respect to the long term than the short term. Looking at short-term

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Materials: natural fiber materials + metalliferous ore and metal scrap + logs + lumber + inedible agricultural, forestry, and livestock products + nonmetallic crude minerals + pulp + wastepaper + ceramic, stone and clay products.

Textiles: textiles – natural fiber materials.

Metals: metals and related products – metalliferous ore and metal scrap.

Others: other primary products and manufactured goods + lumber chips + processed wood materials – inedible agricultural, forestry, and livestock products – nonmetallic crude minerals – pulp – ceramic, stone and clay products – wastepaper.

14. They are expressed in yen terms.

15. The estimations are conducted using the logarithmic first difference of variables to control for the possibility of unit roots in variables included in estimation equations. The results of the augmented Dickey-Fuller test for variables included in the estimated equations reject the existence of the unit root in the first difference, but do not reject in terms of the level.

16. Durbin's *h* statistics rejects the existence of autocorrelation in the error term.

17. The estimates are a little smaller than those in Campa and Goldberg (2002), partly due to the longer sample period until October 2002 in our estimation, as against 1999 in Campa and Goldberg (2002).

**Table 1 Exchange Rate Pass-Through: Benchmark Estimation Results**

	Jan. 1978– Mar. 2002	Jan. 1978– Dec. 1989 (a)	Jan. 1990– Oct. 2002 (b)	(b) – (a)
<b>[1] Short-Term Pass-Through</b>				
(OLS estimation)				
Overall	0.63 (0.03)	0.79 (0.05)	0.53 (0.04)	–0.26 [0.00]
Overall excluding fuels	0.65 (0.02)	0.74 (0.04)	0.60 (0.02)	–0.14 [0.00]
Overall excluding fuels and materials	0.61 (0.02)	0.65 (0.04)	0.58 (0.02)	–0.07 [0.05]
(SUR estimation)				
Foods	0.62 (0.04)	0.72 (0.06)	0.57 (0.04)	–0.15 [0.00]
Materials	0.78 (0.04)	0.95 (0.06)	0.66 (0.04)	–0.29 [0.00]
Fuels	0.64 (0.08)	0.94 (0.10)	0.44 (0.12)	–0.50 [0.26]
Chemicals	0.49 (0.04)	0.64 (0.06)	0.40 (0.05)	–0.24 [0.02]
Textiles	0.41 (0.02)	0.31 (0.04)	0.49 (0.03)	0.18 [0.00]
Metals	0.63 (0.06)	0.64 (0.11)	0.66 (0.06)	0.02 [0.50]
Machinery	0.61 (0.02)	0.64 (0.03)	0.60 (0.02)	–0.04 [0.00]
Others	0.62 (0.03)	0.64 (0.05)	0.62 (0.02)	–0.02 [0.00]
<b>[2] Long-Term Pass-Through</b>				
(OLS estimation)				
Overall	1.02 (0.06)	1.42 (0.12)	0.65 (0.05)	–0.76 [0.00]
Overall excluding fuels	0.81 (0.03)	0.97 (0.06)	0.66 (0.03)	–0.31 [0.00]
Overall excluding fuels and materials	0.74 (0.03)	0.86 (0.06)	0.64 (0.03)	–0.22 [0.05]
(SUR estimation)				
Foods	0.79 (0.05)	1.00 (0.09)	0.61 (0.05)	–0.40 [0.00]
Materials	1.11 (0.06)	1.30 (0.09)	0.93 (0.08)	–0.37 [0.00]
Fuels	1.46 (0.21)	2.06 (0.26)	0.94 (0.28)	–1.13 [0.26]
Chemicals	0.78 (0.07)	0.97 (0.10)	0.64 (0.10)	–0.33 [0.02]
Textiles	0.55 (0.04)	0.49 (0.07)	0.59 (0.04)	0.10 [0.00]
Metals	0.92 (0.09)	0.91 (0.15)	0.94 (0.10)	0.03 [0.50]
Machinery	0.76 (0.03)	0.87 (0.05)	0.65 (0.03)	–0.21 [0.00]
Others	0.81 (0.04)	0.91 (0.08)	0.71 (0.03)	–0.20 [0.00]

Note: Figures in parentheses are standard errors. Figures in brackets are *p*-values for the *F*-test on the null hypothesis that estimates in column (a) and (b) are identical.

coefficients, materials is the highest at 0.78 and textiles the lowest at 0.41, chemicals the second lowest at 0.49, but other categories, such as foods, metals, and machinery, show close estimates around 0.61–0.64. As for long-term coefficients, the estimates differ more significantly across product categories. Fuels, materials, and metals show larger estimates of 1.46, 1.11, and 0.92, respectively, while textiles show a smaller estimate at 0.55. Foods, chemicals, machinery, and others exhibit estimates in the middle at 0.79, 0.78, 0.76, and 0.81, respectively.

Comparing the estimates between two subsample periods before and after 1990, the declines in the pass-through coefficients are observed overall as well as with most product categories in both the short and long term. The pass-through coefficient declines much more overall compared with overall excluding fuels and excluding

fuels and materials.<sup>18</sup> Among product categories, fuels exhibit the largest decline in both short-term and long-term estimates. Declines in foods, materials, chemicals, and machinery are smaller, although they are still statistically significant.

The question we must examine next is what causes such a decline in the overall exchange rate pass-through in the 1990s. The above observation of the declines in the pass-through in each category suggests two possibilities: (1) a decreased import share of primary commodities with a high pass-through and (2) a declining pass-through in other products. In this context, as mentioned, Campa and Goldberg (2002) point out that the structural change in imports is the main factor behind the decline in the pass-through.

To confirm the above point, we decomposed changes in the pass-through coefficients of overall import prices into contributions of change in import share and change in the pass-through rate for each product category. To be more specific, since the pass-through coefficient for overall import prices is approximately equal to a weighted average of the pass-through coefficients for product categories,  $\bar{\gamma}_t$ , the changes in the pass-through coefficients between period  $t$  and zero can be written as follows:

$$\begin{aligned}\bar{\gamma}_t - \bar{\gamma}_0 &= \sum_j w_t^j \gamma_t^j - \sum_j w_0^j \gamma_0^j \\ &= \sum_j w_t^j (\gamma_t^j - \gamma_0^j) + \sum_j (w_t^j - w_0^j) (\gamma_0^j - \bar{\gamma}_0),\end{aligned}\tag{6}$$

where  $w_t^j$  is the import share of product category  $j$  at period  $t$ .<sup>19</sup>

Table 2 reports the decomposition results, and clearly demonstrates that the declines in the pass-through to overall import prices are largely attributable to declines in the pass-through to category import prices in both short-term and long-term estimates. In contrast to Campa and Goldberg's (2002) argument, the change in import share is not so significant.

In the following, we test the robustness of the above result in terms of different specification and alternative sets of data used in the estimation.

### C. Robustness Checks

To check the robustness of the above estimation results, we estimate the exchange rate pass-through based on an alternative specification to equation (5). We also estimate the same specification of the benchmark estimation, but by using alternative data series of the effective exchange rate and import prices.<sup>20</sup>

18. The decline in the long-term pass-through after the 1980s is larger than that in the short-term pass-through because partial adjustment parameter  $\beta$  declines, suggesting that import prices have become less sticky recently than in the 1980s. A possible explanation of this decreased stickiness in import prices is increased competitive pressure in import product markets and weakened market power of businesses, suggested by Taylor (2000).

19. The deviation of the weighted averaged pass-through from the estimated pass-through is not so large.

20. In addition to these robustness checks, we also conduct the following two types of robustness check. The first is to use the alternative set of control variables. In addition to the aforementioned IIP as a proxy of demand shock and marginal cost, we test two alternative sets of control variables. One includes primary commodity market price indexes besides the aforementioned two variables. The other does not include any control variables. We attained similar results irrespective of the difference in control variables.

The second is to include a dummy variable for the appreciation of the yen (one during periods when the yen appreciated, and zero otherwise) and the trend or exponential trend as the proxy for an increase in productivity in equation (5) as regressors. Nevertheless, the results are almost same as the reported results in this paper.

**Table 2 Decomposition of Changes in the Pass-Through between the 1980s and the 1990s**

	Changes in the pass-through to overall import prices	Contributions of	
		Changes in import share	Changes in the pass-through to category import prices
(Long-term pass-through)			
Overall	-0.76	-0.17	-0.51
Foods		-0.01	-0.05
Materials		0.02	-0.05
Fuels		-0.02	-0.33
Chemicals		-0.01	-0.02
Textiles		-0.03	0.01
Metals		0.00	0.00
Machinery		-0.11	-0.04
Others		-0.02	-0.02
(Short-term pass-through)			
Overall	-0.26	-0.05	-0.21
Foods		0.00	-0.03
Materials		0.00	-0.03
Fuels		0.01	-0.13
Chemicals		0.00	-0.02
Textiles		-0.01	0.01
Metals		0.00	0.00
Machinery		-0.03	-0.01
Others		-0.01	0.00

Note: Sum of the contributions is not necessarily equal to changes in the estimated pass-through to overall import prices because of approximation error.

### 1. Alternative specification

As an alternative specification to equation (5), we employ a specification similar to equation (4), used in Campa and Goldberg (2002), as follows:<sup>21</sup>

$$\Delta imp^j = \alpha^j + \sum_{i=0}^5 \beta_i^j \Delta ner_{t-i}^j + \delta^j \Delta z_t^j + \epsilon_t^j, \quad (7)$$

where the short-term pass-through of product category  $j$  is given by the estimated coefficient  $\beta_0^j$  and the long-term pass-through is given by the sum of coefficients of exchange rate terms.

Equation (5) assumes that the impact of changes in the nominal effective exchange rate gradually decays in an exponential manner. In contrast, equation (7) allows a more flexible pattern in the impact of contemporaneous and lagged changes in the exchange rate.

21. As shown in equation (4), Campa and Goldberg (2002) add lags of foreign production cost terms to estimation equations. However, we only include a contemporaneous marginal cost term because the coefficients of the lags of marginal cost are not significant.

Table 3 summarizes the short-term and long-term exchange rate pass-through. The results on both specifications, equations (5) and (7), exhibit similar results. This confirms that the above result is robust from the perspective of alternative specification.

## 2. Alternative series of effective exchange rates

We next estimate equation (5), which is the same specification as the benchmark estimation, by using nominal effective exchange rates for each product category with time-varying weight, based on the import value from major trading partners.

In computing the effective exchange rates for each product category with time-varying weight, we use a one-year average of monthly imports of the category from

**Table 3 Robustness Check (1): Alternative Specification**

	Jan. 1978– Mar. 2002	Jan. 1978– Dec. 1989 (a)	Jan. 1990– Oct. 2002 (b)	(b) – (a)
<b>[1] Short-Term Pass-Through</b>				
(OLS estimation)				
Overall	0.70 (0.04)	0.87 (0.07)	0.58 (0.04)	–0.29 [0.00]
Overall excluding fuels	0.67 (0.02)	0.79 (0.04)	0.60 (0.02)	–0.19 [0.00]
Overall excluding fuels and materials	0.63 (0.02)	0.69 (0.04)	0.59 (0.02)	–0.10 [0.00]
(SUR estimation)				
Foods	0.66 (0.04)	0.75 (0.07)	0.59 (0.04)	–0.16 [0.35]
Materials	0.83 (0.04)	1.04 (0.07)	0.69 (0.05)	–0.35 [0.00]
Fuels	0.74 (0.10)	1.01 (0.13)	0.53 (0.15)	–0.48 [0.00]
Chemicals	0.54 (0.05)	0.75 (0.07)	0.40 (0.06)	–0.35 [0.00]
Textiles	0.41 (0.03)	0.32 (0.05)	0.49 (0.03)	0.17 [0.00]
Metals	0.72 (0.07)	0.79 (0.13)	0.71 (0.07)	–0.08 [0.24]
Machinery	0.62 (0.02)	0.65 (0.03)	0.60 (0.02)	–0.06 [0.00]
Others	0.63 (0.03)	0.64 (0.06)	0.62 (0.02)	–0.02 [0.00]
<b>[2] Long-Term Pass-Through</b>				
(OLS estimation)				
Overall	1.00 (0.25)	1.50 (0.43)	0.57 (0.25)	–0.93 [0.00]
Overall excluding fuels	0.74 (0.15)	0.91 (0.29)	0.59 (0.15)	–0.33 [0.00]
Overall excluding fuels and materials	0.69 (0.15)	0.83 (0.29)	0.58 (0.14)	–0.25 [0.00]
(SUR estimation)				
Foods	0.67 (0.24)	0.79 (0.41)	0.54 (0.27)	–0.25 [0.35]
Materials	0.85 (0.27)	1.13 (0.42)	0.63 (0.32)	–0.50 [0.00]
Fuels	1.36 (0.65)	2.30 (0.81)	0.56 (0.91)	–1.74 [0.00]
Chemicals	0.59 (0.29)	0.87 (0.45)	0.31 (0.36)	–0.56 [0.00]
Textiles	0.52 (0.16)	0.45 (0.29)	0.59 (0.17)	0.14 [0.00]
Metals	0.77 (0.42)	0.99 (0.79)	0.64 (0.42)	–0.35 [0.24]
Machinery	0.75 (0.12)	0.90 (0.20)	0.62 (0.13)	–0.28 [0.00]
Others	0.77 (0.18)	0.93 (0.35)	0.63 (0.15)	–0.30 [0.00]

Note: Figures in parentheses are standard errors. Figures in brackets are  $p$ -values for the  $F$ -test on the null hypothesis that estimates in column (a) and (b) are identical.

major trading partner countries as a weight.<sup>22</sup> As Campa and Goldberg (2002) point out, it is important to capture changes in import composition in examining the movement of the exchange rate pass-through over time. The IMF's effective exchange rate, however, is less likely to reflect such changes because it uses a fixed weight, in spite of its advantage of the availability of a long time-series retroactive to January 1978.

It should be noted that, in this robustness check, it is impossible to test the possibility of structural breaks in the exchange pass-through between the 1980s and the 1990s. This is because nominal effective exchange rates with time-varying weight are available only from January 1988 to December 2001 due to the limitation in the availability of the import value of individual goods by major trading partners. In addition, we use the weighted average of trading partners' producer price indexes (PPI)<sup>23</sup> as a proxy for marginal cost, instead of that based on the IMF's effective exchange rate in the benchmark estimation.

Table 4 reports the estimation results of the short-term and long-term pass-through coefficients for nominal effective exchange rates with time-varying weight, for the sample period from January 1990 to December 2001.<sup>24</sup> The results show that both pass-throughs generated from different sets of nominal effective exchange rates exhibit similar estimates.

**Table 4 Robustness Check (2): Alternative Series of Effective Exchange Rates**

	Short-term pass-through	Long-term pass-through
(OLS estimation)		
Overall	0.54 (0.04)	0.68 (0.06)
Overall excluding fuels	0.60 (0.02)	0.68 (0.03)
Overall excluding fuels and materials	0.58 (0.02)	0.66 (0.03)
(SUR estimation)		
Foods	0.52 (0.04)	0.57 (0.05)
Materials	0.66 (0.04)	0.91 (0.07)
Fuels	0.37 (0.11)	0.86 (0.29)
Chemicals	0.38 (0.06)	0.68 (0.12)
Textiles	0.46 (0.02)	0.55 (0.04)
Metals	0.93 (0.09)	1.32 (0.14)
Machinery	0.62 (0.02)	0.67 (0.03)
Others	0.62 (0.03)	0.71 (0.04)

Notes: 1. Figures in parentheses are standard errors.

2. Sample period is January 1990–December 2001.

22. Import value data are taken from *The Summary Report on Trade of Japan* by the Ministry of Finance. Major trading partners are as follows: Australia, Austria, Belgium, Brazil, Canada, Chile, China, Denmark, the European Union (from January 1999), Finland, France, Germany, India, Ireland, Israel, Italy, Kuwait, Malaysia, Mexico, the Netherlands, Norway, Pakistan, the Philippines, Saudi Arabia, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, the United Kingdom, the United States, and Venezuela.

23. We use the WPI when the PPI is not available. If the WPI is also not available, we use the CPI.

24. Estimation results for the benchmark specification remain almost unchanged, if we shorten the second subsample period to up until December 2001.

### 3. Alternative series of import prices

Finally, we estimate equation (5) by using the unit value indexes (UVI) of imports as an alternative import price series.

Some cautions are in order when using the UVI as an import price series. First, the UVI associates the lagged impacts of exchange rate fluctuations. This is because the official exchange rate, used in converting foreign currency-denominated values into yen-denominated values, is the average exchange rate of the last two weeks of the previous month and the first two weeks of the current month. To avoid this problem, we employ quarterly data, instead of monthly data, in estimating the pass-through by using the UVI. Second, the disaggregated categories of the UVI (foods, materials, fuels, and manufactures) do not completely match those of the CGPI.

Table 5 summarizes the estimation result. The estimated long-term pass-throughs using the CGPI and UVI are so similar that it may be well to understand that our estimation results do not depend on the choice of import price series. The short-term pass-through using the UVI tends to be larger than that of the CGPI, since the data frequency of the CGPI is monthly, while that of the UVI is quarterly. These results suggest that shifts in average quality of import products do not significantly respond to exchange rate fluctuations.

### D. Changes in the Pass-Through over Time

The above results for robustness checks suggest that our benchmark estimation results are less influenced by the choices of specifications of lag pattern for exchange rates, nominal effective exchange rate series, and import price series. In the following, we examine changes in the pass-through coefficients over time by implementing a

**Table 5 Robustness Check (3): Alternative Series of Import Prices**

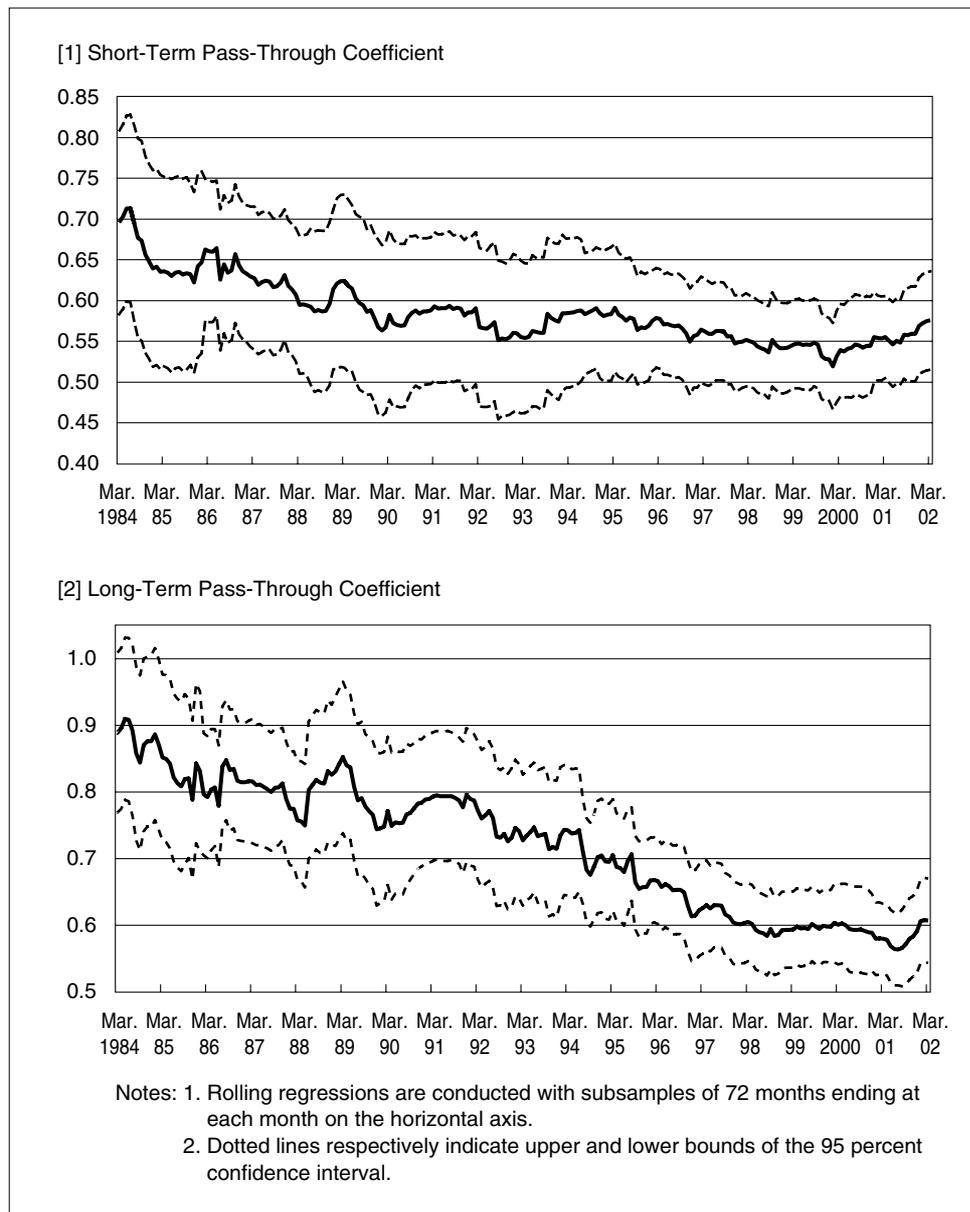
	1978/I–2002/IV	1978/I–1989/IV (a)	1990/I–2002/IV (b)	(b) – (a)
[1] Short-Term Pass-Through				
(OLS estimation)				
Overall	0.84 (0.07)	1.13 (0.10)	0.69 (0.07)	–0.44 [0.00]
(SUR estimation)				
Foods	0.79 (0.06)	0.90 (0.11)	0.69 (0.05)	–0.21 [0.21]
Materials	0.93 (0.07)	1.22 (0.12)	0.72 (0.08)	–0.50 [0.02]
Fuels	0.95 (0.21)	1.79 (0.27)	0.46 (0.26)	–1.33 [0.00]
Manufactures	0.85 (0.06)	0.97 (0.08)	0.75 (0.08)	–0.22 [0.00]
[2] Long-Term Pass-Through				
(OLS estimation)				
Overall	1.12 (0.11)	1.56 (0.12)	0.77 (0.11)	–0.79 [0.00]
(SUR estimation)				
Foods	0.85 (0.07)	0.89 (0.12)	0.76 (0.07)	–0.13 [0.21]
Materials	1.08 (0.10)	1.39 (0.15)	0.79 (0.12)	–0.60 [0.02]
Fuels	1.34 (0.32)	2.83 (0.51)	0.48 (0.12)	–2.35 [0.00]
Manufactures	0.86 (0.07)	1.13 (0.11)	0.66 (0.08)	–0.47 [0.00]

Note: Figures in parentheses are standard errors. Figures in brackets are *p*-values for the *F*-test on the null hypothesis that estimates in column (a) and (b) are identical.

rolling estimation. In this exercise, we focus on the overall pass-through excluding fuels and materials to eliminate the impact of structural changes in imports.

Figure 1 summarizes the estimated coefficients of the exchange rate pass-through over time. The short-term pass-through in the upper panel is largely stable, although it exhibits a slight downward trend in the 1980s. The long-term pass-through in the lower panel declines until the subsample period ending in 1998. A closer look at the

**Figure 1 Exchange Rate Pass-Through over Time (Overall Excluding Fuels and Materials/IMF Nominal Effective Exchange Rate)**



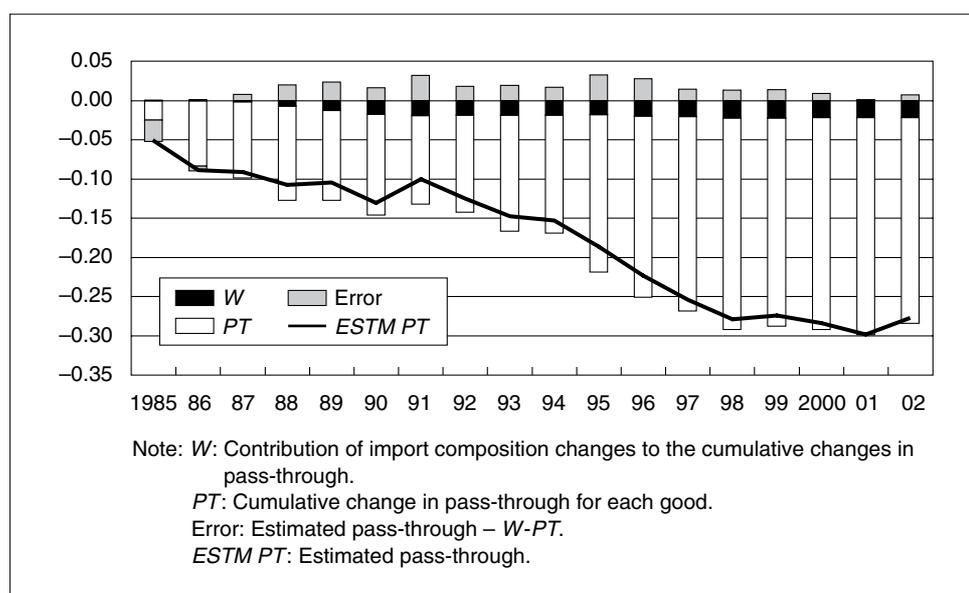
estimation results for the long-term pass-through shows that the downward trend becomes steep during the subsample periods ending in 1992 to 1998.

We also implement a rolling regression to all product categories to decompose the changes in the pass-through coefficients of overall import prices excluding fuels and materials into the contributions of changes in import share and changes in the pass-through rate for each product category.

Figure 2 shows the decomposed result for the cumulative changes in the overall pass-through excluding fuels and materials from 1984, based on equation (6).<sup>25</sup> This figure indicates that the expansion of the cumulative decline in the overall pass-through excluding fuels and materials is mostly attributable to declines in the pass-through to import prices for individual product categories. Therefore, once we exclude the impact of the declining import share of fuels and materials since the mid-1980s, the changes in import shares have a minor impact on the decline in the overall pass-through.

Estimation results shown in this section are summarized as follows. (1) The exchange rate pass-through declined after the 1980s. (2) The decline in the overall pass-through comes mainly from the decrease in the pass-through to individual product categories, when we adjust for the impact of the decreased import share of primary commodities with a high exchange rate pass-through. (3) The overall pass-through declines rapidly during the subsample periods ending from 1992 to 1998, and levels off thereafter. In the next section, we examine the causes of the decrease in the pass-through in detail.

**Figure 2 Factor Decomposition: Cumulative Change in Long-Term Exchange Rate Pass-Through (Overall Excluding Fuels and Materials)**



25. We have translated the estimated pass-through to a calendar-year basis because of data availability.

## IV Factors behind the Decline in the Exchange Rate Pass-Through

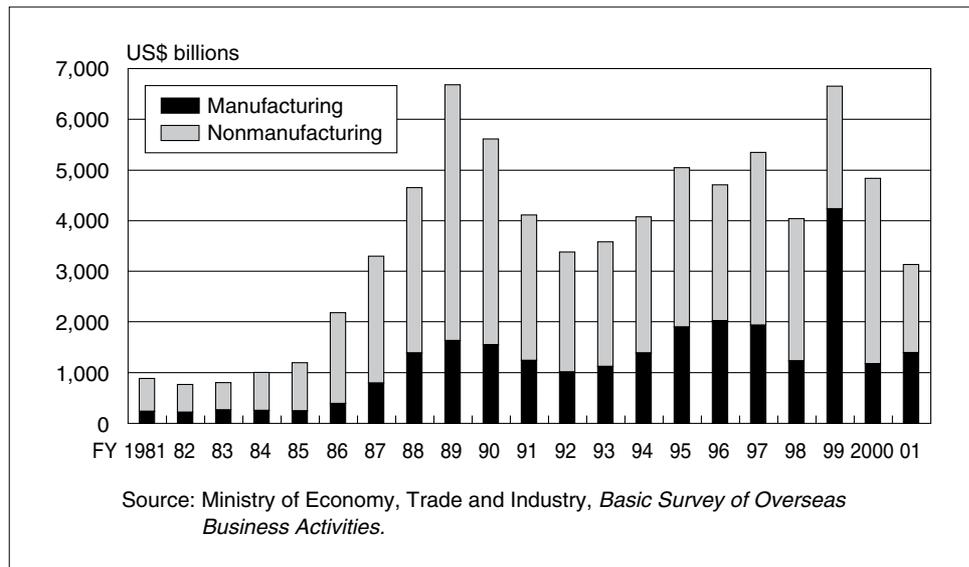
In this section, we discuss the factors behind the decline in the exchange rate pass-through bearing Taylor's (2000) conjecture in mind. Factors we examine here include (1) the yen's sharp appreciation and the change in the Japanese trade structure, and (2) the worldwide low-inflation environment.<sup>26</sup>

### A. The Yen's Sharp Appreciation and the Change in the Japanese Trade Structure

Large and persistent changes in exchange rates influence a firm's decision making with respect to the international allocation of resources, such as foreign direct investment and expansion of procurement and sales networks abroad. As a result, such significant changes in exchange rates are likely to induce structural changes in the economy and international trade, thereby altering the exchange rate pass-through over the medium to long term.

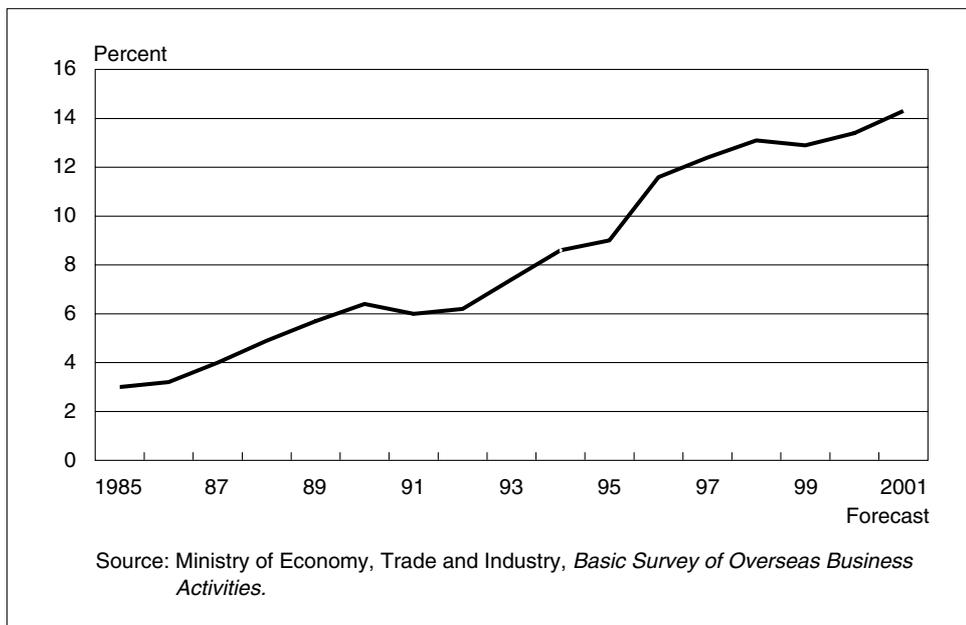
In fact, Japanese firms conducted massive foreign direct investment in response to the yen's sharp appreciation following the Plaza Agreement in 1985 (Figure 3). As a result, the proportion of the overseas production of Japanese firms increased (Figure 4), and Japan's reimports also increased in the 1990s (Figure 5). Such an advance in the globalization of Japanese firms is likely to reduce the exchange rate pass-through to import prices, because firms tend to pass less of a change in exchange rates onto the prices of intrafirm trading across borders than to the prices of interfirm trading. Empirical evidence in the previous section shows that the exchange rate

Figure 3 Value of Japan's Foreign Direct Investment

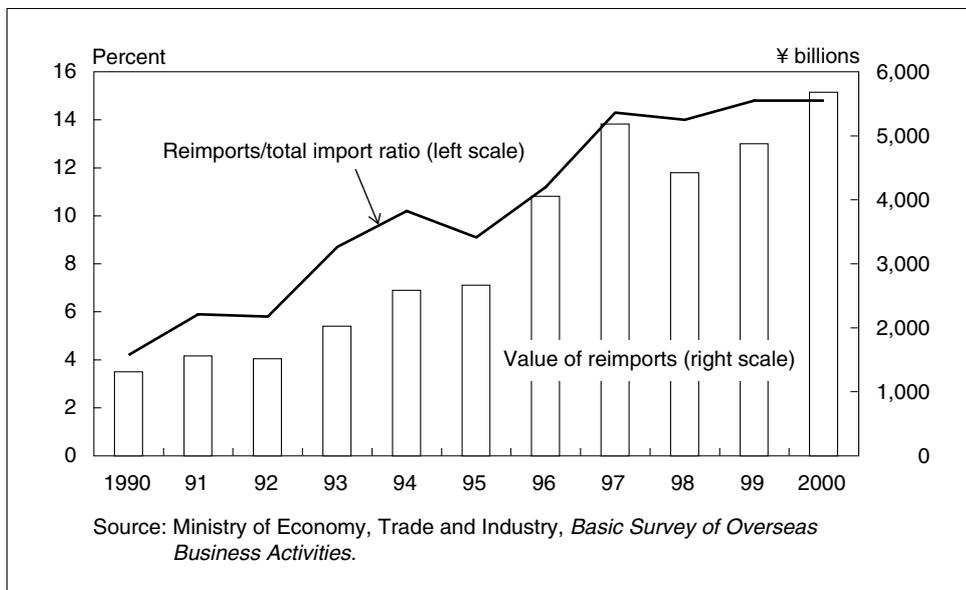


26. As shown in Appendix 2, the decline in the estimated exchange rate pass-through is consistent with the change in the choice of the invoice currency by Japanese firms, suggesting that the choice of invoice currency is closely related with the exchange rate pass-through.

**Figure 4 Overseas Production Ratio of Japanese Manufacturers**



**Figure 5 Japan's Reimports**

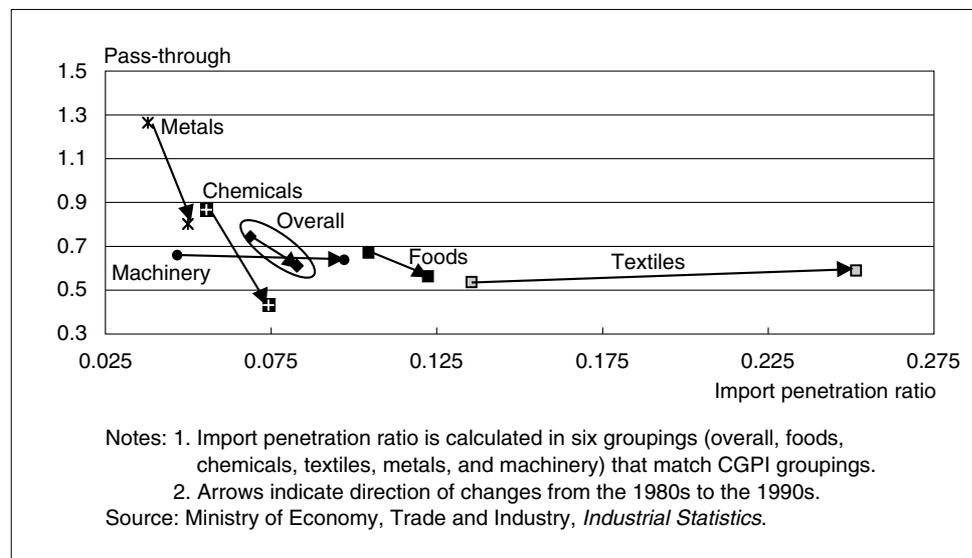


pass-through to Japanese import prices has declined, especially from the late 1980s to the early 1990s. This period of decrease in the exchange rate pass-through coincides with that of the aforementioned advance in the globalization of Japanese firms and rapid changes in Japan's trade structure.

Further, we can point out the possibility that the change in the Japanese trade structure increases competitive pressure in the Japanese market, which is captured by an increase in the import penetration ratio, and results in the decline in the exchange rate pass-through. Based on Taylor's (2000) staggered pricing model, under the assumption that prices are rigid, this upward pressure in worldwide competition leads to the decline in the exchange rate pass-through to import prices. Therefore, such a change in competitive pressure in the world economy is considered to influence the exchange rate pass-through to Japan's import prices.

Figure 6 is a scatter diagram showing the relationship between the exchange rate pass-through and the import penetration ratio since the 1990s, when Japan's overseas production, reimports, and import penetration ratios have dramatically risen. It demonstrates that the exchange rate pass-through fell as the import penetration ratio rose in the 1990s for almost all product categories.<sup>27</sup> It should be noted that the improvement in competitiveness of firms in emerging market economies such as East Asian economies and the increase in the imports from them also contribute to the increase in the import penetration ratio. The increase in foreign direct investment following the Plaza Agreement initiated high economic growth in the East Asian economies and worked to transfer the advanced technology and expertise for efficient production to improve the competitiveness of East Asian firms. As a result, it can be argued that worldwide competitive pressure works to weaken the market power of the existing firms exporting their goods to the Japanese market.<sup>28</sup>

**Figure 6 Import Penetration Ratio and Exchange Rate Pass-Through**



27. Since the estimated pass-through for textiles did not decline but rose as mentioned in the previous section, its relationship between the import penetration ratio and the exchange rate pass-through is upward sloping.

28. It should be noted that it is price elasticity that directly shows a firm's market power. If price elasticity was lower, it can be concluded that the upward pressure in worldwide competition led to a deterioration in a firm's market power. Nevertheless, to the best of our knowledge, there is insufficient empirical industrial organization literature on price elasticity.

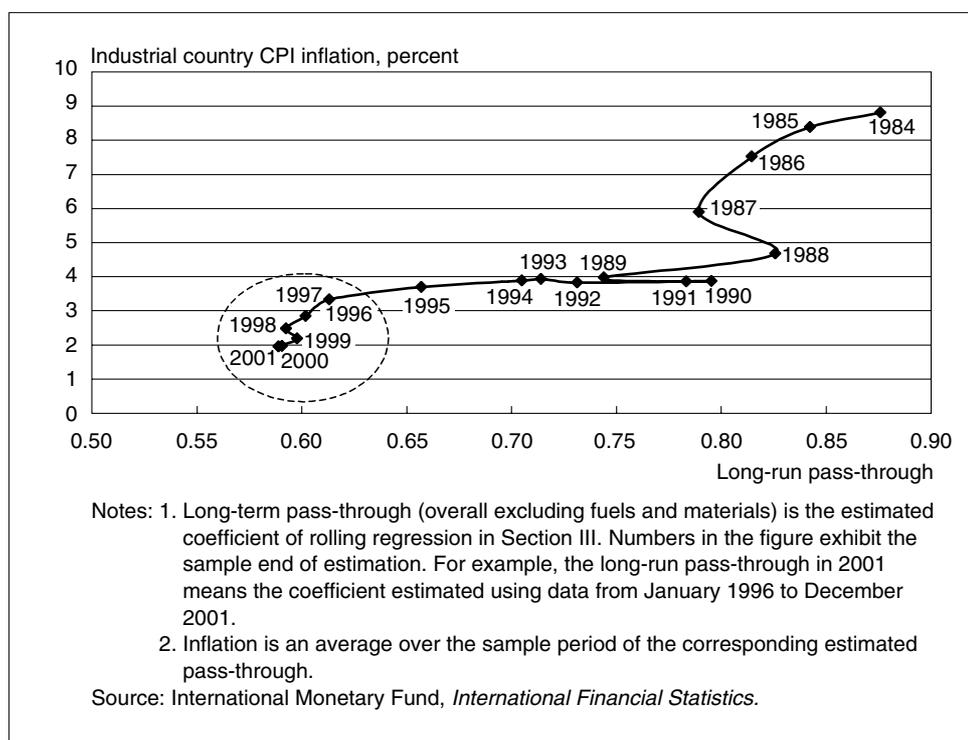
## B. Worldwide Low-Inflation Environment

As mentioned, the yen's sharp appreciation and the resulting globalization of Japanese firms is the likely cause of a large decline in the exchange rate pass-through in the 1990s. In addition, focusing on its development since the 1990s, the current worldwide low inflation is also likely to reduce the exchange rate pass-through.

Taylor's (2000) staggered pricing model shows that product prices are likely to be stable as long as competitors' prices are stable, and that if the exchange rate changes are regarded as temporary, prices do not change so much as the exchange rate. In addition, once the worldwide low-inflation environment is realized, an economy with inflation as low as the average of its trading partners will be less likely to experience persistent nominal exchange rate changes (Taylor [2000]).

Therefore, it can be concluded that in an environment of worldwide low inflation with less persistent exchange rate changes, the exchange rate pass-through to import prices is likely to be low. To investigate the validity of this, we examine the development of worldwide inflation and the exchange rate pass-through to Japan's import prices. Figure 7 shows the relationship between the worldwide inflation rate and the exchange rate pass-through since the 1980s. The figure demonstrates that, from the late 1980s to the early 1990s, while the worldwide inflation rate remained almost unchanged, Japan's exchange rate pass-through dramatically declined. In addition, it shows that the exchange rate pass-through declined to some extent as worldwide inflation fell in the late 1990s. It implies the possibility that in the midst

**Figure 7 World Producer Price Index and Long-Run Pass-Through**



of intensified worldwide disinflation with less persistent exchange rate changes since the late 1990s, the exchange rate pass-through declined modestly.

It should be noted that the decline in the exchange rate pass-through since the late 1990s is by far smaller than that in the early 1990s when worldwide inflation remained almost unchanged. This observation leads us to conclude that while the change in Japan's trade structure mainly reduced the exchange rate pass-through, the effect of the fall in worldwide inflation is considerably smaller than that of the change in the trade structure.

## **V. Concluding Remarks**

In this paper, we have examined the changes in the exchange rate pass-through to import prices in Japan since the 1980s. Our empirical findings show that the exchange rate pass-through to Japan's import prices declined in the 1990s, supporting Campa and Goldberg's (2002) conclusion that the import price pass-through declined in major industrial countries, including Japan, in the 1990s.

In addition, we have shown two further empirical findings. First, the decline in the exchange rate pass-through occurred mainly during the period from the late 1980s to the early 1990s. Second, the decline came mainly from the decline in the exchange rate pass-through in each product, rather than the shift of import share from raw materials to manufactured goods with a lower exchange rate pass-through. This finding contrasts with Campa and Goldberg's (2002) finding that emphasized the effects of changes in trade share.

Our empirical evidence suggests that the decline in the exchange rate pass-through to import prices in Japan is associated with the globalization of Japanese firms' activities, responding to the sharp appreciation of the yen in the mid-1980s. A rise in the import penetration of foreign products increases competitive pressure in Japan's domestic markets. The foreign direct investment of Japanese firms accelerates the globalization of their production bases. Japanese firms also increase their usage of the yen as an invoice currency for their imports. Although all of these movements most likely serve to lower the exchange rate pass-through to Japan's import prices, empirical investigation using firm-level data is required to draw more decisive conclusions on this point.

It should be noted that the decline in the exchange rate pass-through does not necessarily imply that exchange rate fluctuations become less important in macroeconomic fluctuations. As Obstfeld (2002) points out, at least two factors can drastically modify the impact of exchange rate fluctuations on the economy in the conclusions of the abstracted theoretical models. One is that the exchange rate pass-through to domestic prices is much slower than that to import prices, reflecting the complicated chain of transactions linking the two prices. The other is that the magnitude of the expenditure switching effect crucially depends on a firm's sourcing decisions across borders. In fact, it might be the case that the recent increase in intrafirm trading makes it possible to shift business activities across borders smoothly, thereby enhancing the response to exchange rate changes.

## APPENDIX 1: THEORETICAL AND EMPIRICAL RESEARCH ON THE EXCHANGE RATE PASS-THROUGH

In this appendix, we first review the two strands of theoretical models to explain the determinants of the exchange rate pass-through to corporate export prices, developed during the period from the late 1980s to the early 1990s. We then review the empirical researches on the exchange rate pass-through of export firms in response to the development of theoretical analysis.

### A. Theoretical Model

The theoretical models to explain the determinants of the exchange rate pass-through to corporate export prices can be classified into two: the static profit maximization model of monopolistic firms and the sunk-cost model focusing on the hysteresis effect of large changes in exchange rates on export firms' behavior.

#### 1. Static model of profit maximization on the determination of the exchange rate pass-through

We first review the static profit maximization model of monopolistic firms to examine the determinants of the exchange rate pass-through in setting firms' export prices (see Feenstra [1989] and Marston [1990]).

Let us define domestic import demand as  $x(p, q, I)$ , where  $p$  and  $q$  are prices of foreign and domestic goods denominated in the home currency, and  $I$  denotes income. The firm's cost function is given by  $C(x, w^*)$ , where  $w^*$  represents factor prices in a foreign country. Suppose that the cost function is homogeneous of degree one in factor prices, then it can be written as  $C(x, w^*) = \phi(x)w^*$ , where  $\phi'$  is the marginal cost and  $\phi'' > 0$  ( $< 0$ ) indicates increasing (falling) marginal cost.

Letting  $e$  denote the exchange rate (the home-currency price of foreign currency), the profit maximization problem of a foreign firm exporting its goods to the home market can be written as follows.

$$\text{Max}_p [epx(p, q, I) - \phi(x)w^*]. \quad (\text{A.1})$$

The first-order condition of this optimization problem is

$$\phi'(x)(w^*/e) = p[1 - (1/\eta)] \equiv r(p, q, I), \quad (\text{A.2})$$

where  $\eta$  is the price elasticity of demand ( $\eta = -x_p p/x$ ) and  $r(p, q, I)$  represents marginal revenue.

Moreover, letting  $w$  be the home-currency price of foreign factor prices ( $w = w^*/e$ ), total differentiation of equation (A.2) results in the following equation.

$$(dp/dw)(w/p) = 1/[(\phi''x/\phi')\eta + (r_p p/r)]. \quad (\text{A.3})$$

Since  $w^*$  is exogenous and  $w$  is expressed as  $w^*/e$ ,  $(dp/dw)(w/p)$  indicates to what extent a foreign firm's export price responds to exchange rate changes, i.e., the exchange rate pass-through.

The first derivative of equation (A.2) with respect to  $p$  is  $r_p p/r = 1 + (p^2/r\eta^2)\eta_p$ , where  $\eta_p$  and  $r_p$  represent first derivatives of  $\eta$  and  $r$  with respect to  $p$ . This implies that  $r_p p/r > 1$  if  $\eta_p < 0$  and  $r_p p/r < 1$  if  $\eta_p > 0$ . Also, the sign of  $\phi''x/\phi'$ , which is the elasticity of marginal cost with respect to production, is identical with that of  $\phi''$ . Making use of these relations yield the following conditions for the determination of the exchange rate pass-through.

(1)  $(dp/dw)(w/p) < 1$  if  $\eta_p > 0$  and  $\phi'' \geq 0$ .

(2)  $(dp/dw)(w/p) = 1$  if  $\eta_p = \phi'' = 0$ .

(3)  $(dp/dw)(w/p) > 1$  if  $\eta_p \leq 0$  and  $\phi'' < 0$ .

Case (1) shows that if the price elasticity of demand is an increasing function of price  $p$  and the marginal cost is a constant or increasing function of production  $x$ , the exchange rate pass-through is imperfect and less than one. Case (2) means that if the price elasticity and the marginal cost are constant, the exchange rate pass-through is perfect and equal to one. Case (3) indicates that if the price elasticity of demand is a decreasing function of price  $p$  and the marginal cost is also a decreasing function of production  $x$ , then the exchange rate pass-through is larger than one.

## 2. Sunk-cost model of the hysteresis effect

We next briefly explain the sunk-cost model, proposed by Dixit (1989), that focuses on the hysteresis effect stemmed by entry and exit costs, and provides a rationale for exporters' behavior with respect to the imperfect pass-through of exchange rate fluctuations to their export prices. First, we present the intuitive explanation of his theoretical model by assuming all variables are deterministic, and then discuss the model's implication in case of the uncertainty in exchange rate fluctuations.

The setup of the model is as follows. Suppose there exist  $N$  potential exporting firms in the home country and they sell one unit of goods in a foreign country during a period when they decide to enter the foreign market.  $q$  is the volume sold in the foreign market and the goods' price is represented by  $p = P(q)$ , where its first derivative with respect to  $q$  is negative. Let  $e$ ,  $C_n$ ,  $r$  denote the exchange rate (domestic currency price of foreign currency), marginal cost of firm  $n$ , and the discount rate, respectively.

We examine firm  $n$ 's decision about entry and exit under the assumption that all domestic exporting firms other than the  $n$ -th firm export their goods to the foreign market. If firm  $n$  decides to enter the foreign market, its present discounted value of profit denominated in the home currency is given by

$$\pi_n = \sum_{t=1}^{\infty} [1/(1+r)^t] [eP(N) - C_n].$$

Suppose that the entry and exit costs,  $I$  and  $E$ , both of which are not recouped, are incurred to exporters when they enter and exit the foreign market. We also assume  $I > E$ . The former corresponds to the initial cost such as the cost for sales network construction, and the latter corresponds to the closure cost such as the cost for layoff of workers.

Firm  $n$  makes its decision based on a comparison of the present value of profit  $\pi_n$  with sunk cost,  $I$  and  $E$ . It decides to enter the foreign market if its present discounted value of profit exceeds the entry cost ( $\pi_n \geq I$ ), and exit if the exit cost

exceeds its present discounted value of profit ( $\pi_n \leq E$ ). Solving these conditions with respect to  $e$  yields the exchange rates at which firm  $n$  decides to enter and exit the foreign market  $eh_n$  and  $el_n$ :  $eh_n = (rI + C_n)/P(N)$  and  $el_n = (rE + C_n)/P(N)$ . Since we assume  $E < I$ , firm  $n$  makes three decisions as to entry and exit, depending on the level of the exchange rate, as follows.

- (1) Firm  $n$  enters the foreign market if  $e \geq eh_n$ .
- (2) Firm  $n$  exits the foreign firm if  $e \leq el_n$ .
- (3) Firm  $n$  has already entered the foreign market, and stays in the foreign market if  $el_n < e < eh_n$ .

When the exchange rate is in the region of (1) or (2), the number of firms to enter (exit) the foreign market increases as the home currency appreciates (depreciates) and the exchange rate pass-through becomes positive. On the contrary, when the exchange rate is in the region of (3), the number of firms operating in the foreign market remains unchanged regardless of exchange rate changes, and the pass-through is zero. Furthermore, the firm operating in the foreign market at  $e = eh_n$  does not exit even if  $e < eh_n$  and delays exit until  $e$  hits  $el_n$ . This asymmetric response to the exchange rate, called the hysteresis effect, generates inertia with respect to the number of firms in the foreign market and the price of goods.

Next, we examine the effect of the uncertainty in exchange rate fluctuation on firms' entry and exit decision in the foreign market. The introduction of uncertainty in exchange rate fluctuations into the above model broadens the range of the exchange rate, where firms neither enter nor exit the foreign market and they remain in the foreign market. In addition, it should be stressed that the more the exchange rate fluctuates, the larger the firms' incentive to adopt such a waiting strategy. That is, as the uncertainty in the exchange rate fluctuation grows, firms tend to postpone entering the foreign market until the exchange rate reaches a more favorable level. On the other hand, having entered the foreign market, the firm remains operating in the foreign market until the exchange rate reaches a less favorable level.

In this case, we can regard this firm's decision-making problem of entry and exit in the foreign market as an exercise of the option of entry or exit in the foreign market. Once it exercises the option to enter the foreign market, it will bear a loss as the decline in the discounted present value of its profit if the home currency appreciates. However, if it does not exercise the option to enter the foreign market, even if the home currency depreciates, it will lose only part of the increase in the discounted present value of its profit, since it still has the option to enter the foreign market. Therefore, firms tend to adopt the waiting strategy in making a decision about entry or exit under the exchange rate level where the discounted present value of its profit can just cover the entry cost.

## B. Empirical Research

In response to the above theoretical studies, many economists intensively conducted empirical studies using industry-level data on firms' export prices in industrial countries from the end of the 1980s to the early 1990s.

Knetter (1989) is among the first to estimate the exchange rate pass-through using the micro data. He uses the disaggregated seven-digit data of the Standard Industrial

Classification (SIC) of U.S. and German exporting firms, such as refrigerators and switches, and shows that the pass-through is greater for the United States than for Germany. As for the pass-through of Japanese firms, Marston (1990) estimates Japanese firms' exchange rate pass-through for selected products such as automobiles, trucks, and TV sets and shows that it varies across goods, ranging from 33 percent to 69 percent. Ohno (1989) compares the exchange rate pass-through to export prices of U.S. and Japanese firms, and concludes that it is greater for U.S. exporters than for Japanese exporters.<sup>29</sup> Moreover, Knetter (1993) makes a cross-country study to estimate the exchange rate pass-through of selective exporting firms in the United States, Germany, the United Kingdom, and Japan. He also shows the aggregate pass-through of these countries: point estimates are 99 percent, 64 percent, 63 percent, and 52 percent, respectively.

The above empirical studies reveal that the exchange rate pass-through of Japanese firms is quite low, compared with those of other industrial countries, and that the exchange rate pass-through varies across products.

## **APPENDIX 2: THE ESTIMATED EXCHANGE RATE PASS-THROUGH AND CHOICE OF INVOICE CURRENCY**

In Section IV, we discussed (1) the yen's sharp appreciation and the change in Japan's trade structure, and (2) the worldwide low-inflation environment, as the factors behind the decline in the exchange rate pass-through. In this appendix, we examine the relationship between the decline in the exchange rate pass-through and the choice of invoice currency.<sup>30</sup>

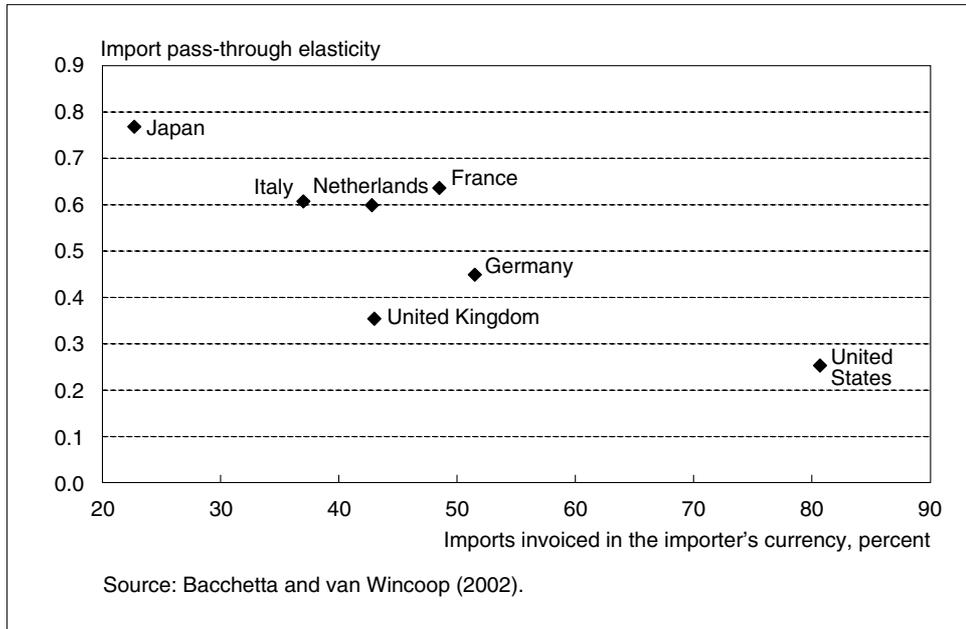
The reason why the choice of invoice currency is related to the exchange rate pass-through is as follows. Suppose that import prices are preset, then the exchange rate pass-through to import prices is zero if the home currency is used as the invoice currency, and it is one if a foreign currency is used. Therefore, the higher the ratio of domestic currency-denominated imports to total imports, the lower the exchange rate pass-through to import prices. In fact, we can see such a relationship from Appendix Figure 1.

This is also the case for Japan over time. As we can see clearly from Appendix Figure 2, our estimates of the long-term pass-through and the ratio of yen-denominated imports to total imports in Japan move in opposite directions. The former fell continuously from 1985 to 1998 and leveled off thereafter, while the latter rose continuously from 1985 to 1995 and then leveled off, with missing observations in 1999 and 2000. This observation implies the possibility that the recent decline in the exchange rate pass-through to import prices is closely related to the "internationalization" of the yen in the choice of invoice currency.

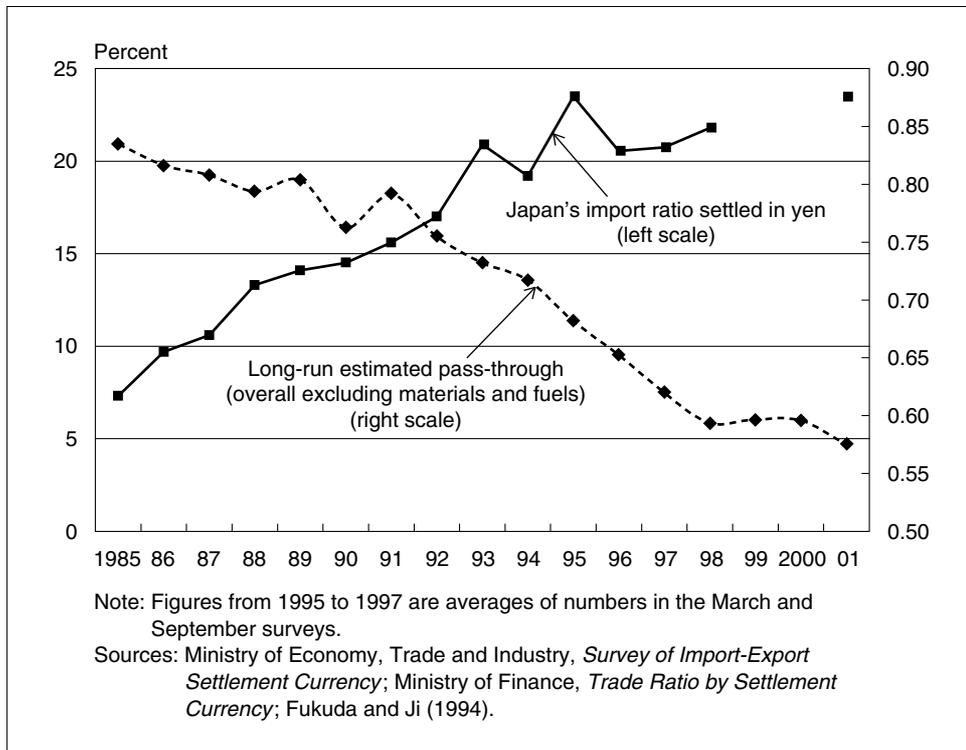
29. Likewise, Gagnon and Knetter (1995) analyze the exchange rate pass-through of Japanese, German, and U.S. automobile industries. They find that the pass-through of Japanese firms is quite small compared with U.S. and German firms.

30. Many theoretical studies exist on the choice of invoice currency for trading (for example, Bacchetta and van Wincoop [2002]). They assume that there exists uncertainty about change in exchange rates. Then, they show the condition regarding the choice of invoice currency by comparing the expected utility from profit when a firm chooses a local currency as invoice currency (local currency pricing) with that when it chooses the domestic currency (producer's currency pricing).

**Appendix Figure 1 Invoice Currency and Exchange Rate Pass-Through**



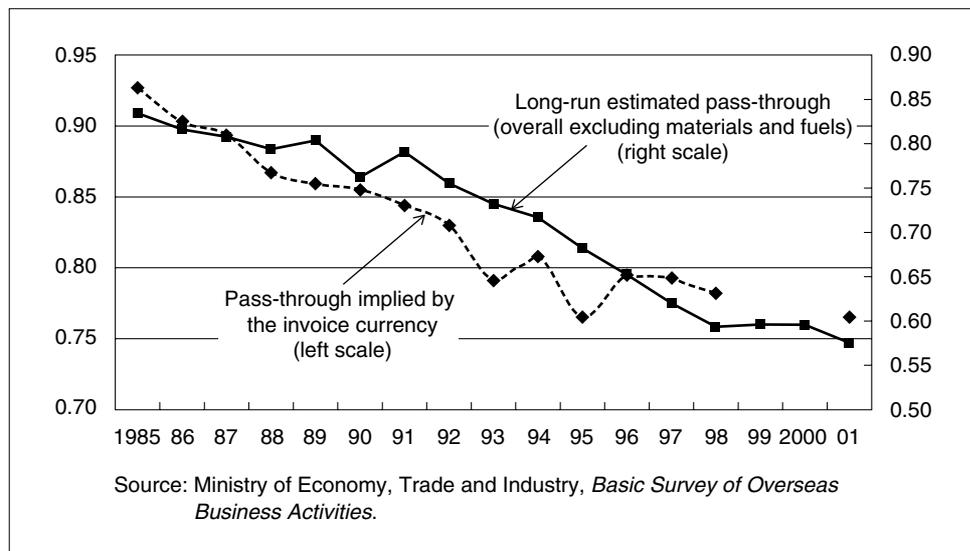
**Appendix Figure 2 Japan's Import Ratio Settled in Yen and Estimated Long-Term Pass-Through**



The above evidence becomes clearer when we compute the implied pass-through from the invoice currency ratio, by simply assuming that import prices are sticky in the short term.<sup>31</sup> Appendix Figure 3 plots the invoice currency-based pass-through, together with the estimated long-term pass-through. We can see from the figure that these two estimates of pass-through move in parallel, in spite of a small discrepancy in their levels due to a difference in their coverage. Note that the invoice currency-based pass-through covers all the categories, while the estimated long-term pass-through excludes fuels and materials.

In this connection, it should be noted that the invoice currency-based pass-through is comparable with the estimates of the long-term pass-through, but not those of the short-term pass-through. On the one hand, considering the time lags in trade transactions from contract to implementation and settlement, import prices are considered to be preset at least several months ahead of the termination of the import transaction.<sup>32</sup> On the other hand, as for the estimated pass-through, the time frame of the short term corresponds to the frequency of data, i.e., one month, and that of the long term is the duration until the impact of current changes in the exchange rate on import prices is exhausted. A simple calculation based on our estimates indicates that the long-term period is three to seven months.<sup>33</sup>

**Appendix Figure 3 Estimated Long-Term Pass-Through and Implied Pass-Through from the Invoice Currency**



31. The procedure to compute the exchange rate pass-through from the invoice currency is as follows. Suppose the invoice currency ratio of yen is 20 percent and that of other currencies is 80 percent. In the short term when prices are sticky, since the pass-through in the case of yen is zero and that of other currencies is one, the implied exchange rate pass-through from the invoice currency is  $0 \times 0.2 + 1 \times 0.8 = 0.8$ .

32. In fact, the time of settlement after importers receive goods is mentioned in the contract and it includes "at sight" and "90 days after sight."

33. This result can be obtained as follows. Suppose the long term is the period in which the total effect of the current exchange rate on current and future import prices is 99.99 percent. Letting  $n$  be this period,  $\alpha + \alpha\gamma + \alpha\gamma^2 + \dots + \alpha\gamma^{n-1} > 0.9999(\alpha + \alpha\gamma + \alpha\gamma^2 + \dots + \alpha\gamma^n)$  holds. Substituting the estimation result of  $\alpha$  and  $\gamma$  leads to the result that  $n$  is three to seven months.

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