Exchange Rate Fluctuations, Financing Constraints, Hedging, and Exports: Evidence from Firm Level Data*

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Abstract

An important puzzle in international macroeconomics is the *exchange rate disconnect puzzle*. Nominal exchange rates seem to be unrelated to other macroeconomic variables, for example, export quantities. This paper uses Japanese firm level data to examine whether exchange rate fluctuations are strongly related to the export quantities of firms. We build a simultaneous nonlinear structural model with external financing costs, and estimate the model on 14 separate Japanese 4 digit level industries. We find that export volumes at the firm level are significantly affected by exchange rate fluctuations. We find higher elasticities of exports with respect to exchange rates than in previous work. Our results cast some doubt on the prevailing wisdom that exchange rates have no effect on trade. Finally, we find in our data that financing constraints play an important role in affecting the sensitivity of exports to exchange rate fluctuations. Firms that are less financially constrained –for example, *keiretsu* firms– tend to have lower exchange rate elasticities, which is consistent with our model.

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1. Introduction

After nearly three decades of exchange rate floating among industrialized countries there is yet to emerge a consensus among academic economists regarding the impact of exchange fluctuations on real economic variables. The traditional view is that fluctuations in exchange rates affect relative domestic and foreign prices, causing expenditures to shift between domestic and foreign goods (Orcutt, 1950; Goldstein and Khan, 1985; Obstfeld, 2002). The new view is that relative prices are not much affected by exchange rate fluctuations in the short-run (see Obstfeld, 2002, and Engel, 2002 for reviews), thus muting expenditure shifts. The new view is buttressed by a recent empirical literature (e.g. Mussa, 1986; Baxter and Stockman; 1989, Flood and Rose, 1995) showing that high exchange rate volatility under floating exchange rates is not related to the high volatility of other macroeconomic variables.

In contrast to this debate among academic economists, business people appear convinced that exchange rate fluctuations have real effects. Executives, especially of exporting firms, agonize over declining exports when their home currency appreciates in nominal terms. They expend much time and resources planning hedging strategies, to lessen the impact of exchange rate fluctuations on their exports. They also expend much time and resources lobbying policymakers, to persuade them to stabilize currencies, either by intervening in foreign exchange markets, or by more extreme measures such as fixing exchange rates.[1]

However, there is little systematic research, examining whether exchange rates affect real quantities at the microeconomic or firm level.[2] This paper fills the void by examining

[1] Frankel (1984) gives a vivid description of Lee Morgan, chairman of Caterpillar Tractor, who came to Washington in 1983 to argue that the cheap yen is making price competition with the Japanese impossible. Morgan and other business executives pressed the U.S. administration to take measures to depreciate the dollar vis-à-vis the yen. One measure was to make buying yen assets easier so as to raise international demand for the currency.

[2] There is a growing literature examining international trade theories at the firm level (Bernard, Eaton, Jensen, and Kortum, 1999; Bernard and Jensen, 2001). However, with the exception of Das, Roberts, and Tybout (2001) this literature has not focused on how exchange rates affect export quantities. Das, Roberts, and Tybout (2001) are interested in the export supply response to an exchange rate change on two margins: entry into and exit from export markets; and export production adjustment among incumbents. Their paper is not concerned with the effects of financing constraints on export quantities, a key concern of this paper. Moreover, while our sample covers over 90 percent of Japanese manufacturing exports, their sample coverage is rather limited (Columbian chemicals industry). Forbes (2002) examined the impact of large devaluations on the export sales of over 13,000 firms in developing countries. She finds that on average export sales improve by 4 percent, one year after the devaluation episodes. Her work is similar to ours in that she is concerned about how financial variables affect export performance. There is also a larger literature

whether exchange rate fluctuations influence the export volumes of firms. We find that export volumes at the firm level are significantly affected by exchange rates. Depending on the industry, a one percent appreciation of the domestic currency results in an average decline in export volumes of 0.02 to 2.9 percent. These elasticities are generally higher than what are found in previous work, using aggregate data. Our results, however, support the findings of other work that also used sectoral or micro-level data.[3]

We build a structural model of the exporting firm, in Cournot competition with the foreign firm in foreign markets. The exporting firm uses its cash flow and borrows from the external financial markets, to produce goods for export; financing costs are increasing with additional amount of external borrowing. The firm's cash flow is exposed to shocks that also cause the exchange rate to fluctuate. Our model is microeconomic or partial equilibrium in nature; we carefully model the response of firms to the aggregate shock, but do not embed our model in general equilibrium.

We estimate our model of the exporting firm using Japanese firm level data from 1982 to 1997, for 105 firms in the 14 largest export industries at the 4-digit level. We find that our model of the exporting firm fits the data remarkably well. We find that shocks to the firm's cash flows or balance sheets have significant real effects. From the estimated parameters of our model, we calculate the elasticity of export volumes to exchange rate changes, and find large elasticities for many industries.

What explains our high estimated export elasticities with respect to exchange rates? One explanation given for the small estimated export elasticities in the previous literature is that prices are sticky in the buyer’s currency (Goldberg and Knetter, 1998; Betts and Devereux, 2000). Since buyer currency prices are sticky, exchange rate changes become powerless in altering the relative prices foreign consumers face, thus limiting changes in trade flows. From our estimates, we also find that export prices in terms of the buyer’s currency are sticky. Thus, the increased responsiveness of exports to exchange rate fluctuations in our model is not induced by changes in international relative prices.

Rather, in our model, the responsiveness of exports to exchange rate fluctuations arises from a loosening of balance sheet constraints. Suppose that a depreciation in the exporter’s currency is positively correlated with a relaxation of financing constraints. With relaxed

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examining the effect of exchange rate changes on corporate profitability, or corporate exposure. See Dekle (2001) and Dominguez and Tesar (2001) for a review of the recent literature on corporate exposure.

[3] Exchange rates were found to affect real quantities, such as labor demand. See Gourinchas (1999) and Goldberg and Tracy (1999).

balance sheet constraints, the exporter with a depreciating currency is then simply able to produce more, for export, regardless of the inflexibility of foreign prices.

In most industries in our sample –10 out of 14 industries– a currency depreciation is correlated with a relaxation of financing constraints. For these industries, a currency depreciation will be related to a strong expansion in exports, through the relaxation of balance sheet constraints. There are 4 industries in which a currency depreciation is correlated with a tightening of financing constraints. However, firms in these industries are able to substantially offset the adverse impact on balance sheets of aggregate shocks through *hedging* activities. Thus, we observe a positive relationship between a currency depreciation and exports, even in these industries.

This paper relates to two literatures. The first is the literature examining the impact of exchange rates on export volumes. This literature is vast, but most of the earlier studies estimated export elasticities using either time series data for one country, or data for a cross-section of countries (see Deardorff, 1984, and Hooper, Johnson, and Marquez, 1998 for reviews). Most studies using data until the mid-1980s have found statistically significant, but small exchange rate elasticities (e.g., Gotur, 1985; Cushman, 1986; Thursby and Thursby, 1987). The most recent empirical studies have tended to find insignificant effects of exchange rate levels, or volatilities on export volumes (Pozo, 1992; Chowdhury, 1993; Parley and Wei, 1993). In fact, much recent international macroeconomic research has focused on explaining this *exchange rate disconnect* puzzle, or why exchange rates have no effect on real variables such as exports, and GDP growth in industrialized countries (Obstfeld, 2002; Engel, 2002).

Our findings of large and significant export elasticities imply that there is no exchange rate *disconnect* at the firm level. Since our sample of Japanese exporters covers over 90 percent of total Japanese manufacturing exports, the discrepancy between the results obtained at the aggregate level and at the firm level is not simply an artifact of incomplete sample coverage. Rather, the discrepancy suggests that it may be important to include financing constraints and potentially other non-linearities, when modeling the relationship between exchange rates and export volumes.[4]

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[4] Using aggregate data, Pozo (1992) and Chowdhury (1993) find that the relationship between exchange rate volatilities and export volumes are significantly negative in a nonlinear specification. However, they do not explicitly model how financing constraints affect the relationship between exchange rates and export volumes.

The second literature related to the current study is that of hedging exchange rate risk under financing constraints. The seminal theoretical paper in this area is Froot, Scharfstein, and Stein (1993), who show that the correlation between the investment opportunities and the availability of cash flows is the main determinant of hedging. When exchange rates and shocks to cash flows are positively correlated, a firm will hedge less than completely or not at all, since when export opportunities are greatest –that is, when the currency is depreciated– cash flows and export production will automatically be high. When exchange rates and cash flow shocks are negatively correlated, a firm will hedge much more or completely, since when the currency is depreciated, cash flows will also tend to be low. In fact, a firm may enter into hedging contracts reversing the negative correlation between a currency depreciation and cash flows. For example, by engaging in foreign currency lending, a firm can build in automatic increases in cash flows, if the domestic currency is depreciating. [5]

The main difficulty in testing theories of foreign exchange hedging behavior at the firm level is the unavailability of comprehensive hedging data. Firms can hedge currency risk in a myriad of ways (Bartov and Bodnar, 1994). For example, a firm can lend internationally, building in a positive correlation between exchange rates and cash flow shocks. Firms can also hedge *operationally*, by engaging in foreign direct investment in export markets, thereby having production costs and revenues in the same currency (Allayannis and Ofek, 2001; Baba and Fukao, 2000). While data on foreign currency forward and option contracts may be available, comprehensive firm level data on foreign currency borrowing/lending and foreign direct investment are difficult to obtain. To get around this problem of incomplete data coverage, we can –using our model– simulate the *hypothetical* export elasticities that would arise if the firm hedged completely. By comparing these *hypothetical* export elasticities with our *estimated* export elasticities, we can infer the degree of hedging by our sample of firms. We find that Japanese exporters indeed hedge currency risk. As our theory predicts, firms hedge less in industries in which an exchange rate depreciation is correlated with loosening financing constraints. In industries in which a currency depreciation is correlated with tightening financing constraints, firms hedge more, to insulate their cash flows from exchange rate shocks.

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[5] Other recent applications of the Froot, Scharfstein, and Stein (1993) model are Allayannis and Mozumdar (1999) and Aguiar (2001). Allayannis and Mozumdar (1999) find that firms use foreign currency derivatives to reduce the volatility of net cash flows. Aguiar (2001), examining the foreign currency debts of Mexican firms before and after the peso crisis of 1994, finds that exporting firms tend to borrow disproportionally in foreign currency before the devaluation.

This paper is organized as follows. In the next Section, we develop our structural model of financing, hedging, and export volumes at the firm level. Section III describes the estimation specification and the data. Section IV presents and discusses the estimation results. We first show that in simple, linear specifications using our firm level data, we can detect a statistically significant relationship between export volumes and exchange rates, provided that appropriate control variables are included. This helps justify our more structural estimation approach, relating aggregate shocks to export volumes. Section V concludes.

2. The Model: Financing Constraints, Hedging and Export Quantities

Our model of the exporting firm emphasizes competition with the foreign firm and financing constraints.[6] We model an exporting firm whose internal cash flow is exposed to shocks that also cause the exchange rate to fluctuate. The firm uses its cash flow, and borrows from external financial markets, to produce goods for export. The firm faces financing costs that increase with the amount of external borrowing. With regards to the competitive structure in the export market, the exporting firm competes with the foreign firm in classic duopoly fashion.

We now develop the model more formally. Assume there are two countries, foreign and domestic, each with one firm. The firm in the domestic country produces the good X only for export to the foreign market, and the foreign firm produces the same good X, but only for its own market.[7]

We assume that each firm uses only domestic inputs for its production. At period t, the domestic exporting firm and the foreign firm produce X_t^E, X_t^F units respectively of the good

[6] Our model's assumptions are standard and are from Froot, Scharfstein, and Stein (1993), which is the seminal paper on hedging with imperfect capital markets.

[7] We do not model the entry of non-exporters into and the exit of exporters from export markets. Rather we focus on export volume adjustment among incumbents. First, in our sample of 105 Japanese exporters from 1982 to 1997, there is not one case of exit from export markets. Since our sample of exporters are companies listed on the stock exchanges, there are no small firms that typically account for the bulk of exiting and entry firms. Second, the export volume response to an exchange rate change is typically driven by the adjustment of existing exporters, rather than by new entry or exit. This is because new entrants are typically much smaller than incumbents. These new entrants are also most likely to exit. For example, Das, Roberts, and Tybout (2001) show in their simulations of the Columbian chemical industry, that in a 10 percent devaluation of the peso, over 90 percent export revenue is drawn by the expansion of existing exporters.

X at price *P* in the *foreign* or *buyer's currency*. We assume that the domestic firm uses its cash given at the beginning of the period to produce goods for export, and that this expected cash flow is affected by shocks that also cause the exchange rate to fluctuate. The firm can finance internally or externally to produce the good *X* in period *t*. We also assume that raising external funds is costly. Specifically, we assume that the marginal cost of external financing increases with the amount of external financing; that is, the external financing constraint is a convex function of the size of external financing.

The total profits of foreign and domestic firms can be written by adding deadweight external financing costs, $f_t(v_t)$, to the normal net profit function, $\Psi_t(X_t)$:

$$\Pi_t^F = \Psi_t\left(X_t^F\right) - f_t^F\left(v_t^F\right)$$
$$= P_t X_t^F - C_t^F X_t^F - f_t^F\left(v_t^F\right) \qquad (1)$$

$$\Pi_t^E = \Psi_t\left(X_t^E\right) - f_t^E\left(v_t^E\right)$$
$$= e_{t+1} P_t X_t^E - C_t^E X_t^E - f_t^E\left(v_t^E\right) \qquad (2)$$

where, $\prod_x > 0$, and $\prod_{xx} < 0$, C_t^F and C_t^E are constant unit costs of production for the foreign and exporting firms, e_{t+1} is the price of the foreign currency in terms of the domestic currency at period t+1. We can rewrite the external financing constraint of the domestic exporting firm, and the foreign firm as:

$$f_t^j(v_t^j) = \left(\delta v_t^j\right)^\beta = \left[\delta(C_t^j X_t^j - w_t^j)\right]^\beta \text{ , where } j = E, F \qquad (3)$$

that is, E and F represent the domestic exporting and foreign firms, w_t^j is cash flow, and δ is the scale factor.

Shocks to the Firm's Cash Flows

The domestic firm's ability to export in period *t* depends on its ability to secure continual access to external funds. If the quantity of credit available to the domestic firm is decreased, the export quantity of the domestic firm would decline.

The firm's internal cash flow is subject to many random shocks, including shocks caused by shifts in domestic and foreign demand (booms and recessions), monetary and fiscal policies, trade policy changes, productivity shocks, labor supply shocks, etc. We assume that firms' cash flows are affected by the aggregate shock, ε_t.

We model the exchange rate as a random walk process, i.e.

$$e_{t+1} = e_t + \varepsilon_t \tag{4}$$

where the aggregate shock, ε_t, is serially uncorrelated and *iid* with a mean of zero and a variance of σ_ε^2.[8]

Thus, the exporting firm's cash flow can be expressed as:

$$w_t^E = w_{t0}^E\left(1+(1-h_t^E)\alpha_t\varepsilon_t\right) \tag{5}$$

where w_{t0} is the firm's initial cash flow at the beginning of the period, h_t is the fraction of the cash flow that is hedged –the hedge ratio– by the firm. α_t measures the correlation between the aggregate shock and the cash flow of the firm during period *t*. The firm uses this correlation to decide on the optimal levels of exports and the hedge ratio. We assume that $\alpha_t \neq 0$.

When the firm completely hedges (h = 1), the firm's cash flow is immune to aggregate shocks. Using (3), the external financing constraint, $f_t^E(v_t^E)$, is:

$$f_t^E(v_t^E) = \left\{\delta\left[C_t^E X_t^E - w_{t0}^E\left(1+(1-h_t^E)\alpha_t\varepsilon_t\right)\right]\right\}^\beta \tag{6}$$

where δ is the scale factor.

A high β implies that external lenders demand a high premium for every additional unit of outside financing. Since the risk of defaulting of a firm increases with its debt, the cost of financing should increase with additional external financing, implying β >1.

[8] Alternatively, we could specify a more general equilibrium model, in which the shocks are identified, say with monetary or fiscal policy. However, the main message of the paper will be the same: with fixed export prices, binding financing constraints are key for nominal exchange rates to be positively correlated with export volumes.

For example, say that the shock is a monetary expansion. This expansion should stimulate the economy, and lead to a depreciation of the nominal exchange rate. If export prices are fixed in the foreign currency, there will be no expenditure switching in the foreign market, and export volumes should not expand. However, with binding financing constraints, the domestic expansion should relax these constraints and lead to an increase in export quantities.

The Firm's Decision on its Exports and Hedging

The time line of the firm's decision to produce, and hedge within period *t* follows Froot, Scharfstein, and Stein (1993) and is summarized below:

Period *t*:

Decision session	Production session	Profit realization session
The firm decides:	The firm produces/exports,	Profit (Π_{it}^{E}) is realized:
X_t^E, h_t^E given e_t, w_{t0}, α_t	the shock (ε_t) is observed	

Period *t* is divided into three successive sessions: 1) decision, 2) production and 3) profit realization. At the beginning of the period *t*, i.e. in the decision session, the firm has to decide how much it has to produce for exporting and how much to hedge. The firm takes α_t and the non-time varying parameters, *a*, *b*, and β as given at the beginning of period *t*, when deciding X_t^E, and h_t^E. In the production session, the firm produces good *X* for exporting. During this session there will be shocks, but the effect of the shocks on the exchange rate and cash flows will be realized at the end of the period, or in the profit realization session.

The domestic exporting firm chooses its export amount and hedge ratio to maximize its expected profit[9]:

$$\underset{X_t^E, h_t^E}{Max}\, E_t\left\{\Pi_t^E\right\} = \underset{X_t^E, h_t^E}{Max}\, E_t\left\{e_{t+1}P_t X_t^E - C_t^E X_t^E - f_t^E(v_t^E)\right\} \qquad (7)$$

$$\text{where } f_t^E(v_t^E) = \left(\delta v_t^E\right)^{\beta} = \left[\delta(C_t^E X_t^E - w_t^E)\right]^{\beta}$$

For simplicity, we assume that the foreign firm's external financing cost is constant, i.e. $f_t^F(v_t^F) = c$. Thus the foreign firm maximizes its expected profit:

[9] The theoretical framework implicitly assumes that the domestic exporting firm is also engaged in Cournot competition with other domestic exporting firms. If domestic exports are approximately equal sized, then the reaction functions (10) and (11), and the expressions for equilibrium production, (13) and (14) remain unchanged (See Bresnahan, 1989).

$$\underset{X_t^F}{Max}\, E_t\left\{\Pi_t^F\right\} = \underset{X_t^F}{Max}\, E_t\left\{P_t X_t^F - C_t^F X_t^F - c\right\} \tag{8}$$

Finally, we assume that the demand for good *X* in the market is given as:

$$P_t = a - bX_t \tag{9}$$
$$\text{where } X_t = (X_t^E + X_t^F)$$

and *a* and *b* are parameters. That is, the price of good X is given to the firm. Firms can only choose their quantities, thus they compete with each other for market share at a given price.

From the first order conditions of the profit maximization problem, we get the following reaction functions for the foreign and domestic firms:

$$X_t^F = \frac{a - C_t^F - bX_t^{E^*}}{2b} \tag{10}$$

$$X_t^E = \frac{1}{2b}\left(a - bX_t^{F*} - \frac{C_t^E}{E_t\left(e_{t+1}\right)} - \beta\delta^\beta \frac{C_t^E}{E_t\left(e_{t+1}\right)} E_t\left[(C_t^E X_t^E - w_t^E)^{\beta-1}\right]\right) \tag{11}$$

In Cournot-Nash equilibrium, the equilibrium price in the foreign market is given by:

$$\begin{aligned} P_t^* &= a - b\left(X_t^{E^*} + \frac{a - C_t^E - bX_t^{E^*}}{2b}\right) \\ &= \frac{1}{2}\left(a - bX_t^{E^*} + C_t^F\right) \end{aligned} \tag{12}$$

The equilibrium productions of good *X* for the foreign and domestic firms are given by:

$$X_t^{F*} = \frac{1}{3b}\left[a - 2C_t^F + \frac{C_t^E}{e_t} + \beta\delta^\beta \frac{C_t^E}{e_t} E_t\left[(C_t^E X_t^{E*} - w_t^E)^{\beta-1}\right]\right] \tag{13}$$

$$X_t^{E*} = \frac{2}{3b}\left[\frac{a}{2} + \frac{C_t^F}{2} - \frac{C_t^E}{e_t} - \beta\delta^\beta \frac{C_t^E}{e_t} E_t\left[(C_t^E X_t^{E*} - w_t^E)^{\beta-1}\right]\right] \tag{14}$$

When the domestic currency depreciates, the relative cost of the domestic firm falls. This situation would be favorable for the domestic firm, but not for the foreign one. Therefore, the domestic firm would prefer to increase its exports when its currency is depreciated. However, the domestic firm cannot expand its export production if the firm's external financing is constrained.

The Aggregate Shock and Export Quantities

Now consider the impact of the aggregate shock on the export quantity of the domestic firm. As a benchmark, if we assume that the external financing constraint, given by $f_t(v_t^E)$, is fixed, then the depreciation of the domestic currency will result in more export sales. Domestic production costs become cheaper compared to costs of the foreign firm, and the domestic firm can grab more market share from the foreign firm, provided that export prices are not fixed.

Thus, from equation (14), the impact of the aggregate shock on the export quantity of the domestic firm is:

$$E_t\left(\frac{dX_t^{E*}}{d\varepsilon_t}\right)=\frac{2}{3b}E_t\left(\frac{C_t^E}{e_t^2}\right)>0 \qquad (15)$$

If $f_t(v_t^E)$ is not exogenously fixed, then the impact of the aggregate shock on the export quantity of the domestic firm depends on how the cash flow affects the external financing constraint:

$$E_t\left(\frac{dX_t^{E*}}{de_t}\right)=\frac{2}{3b}\left[E_t\left(\frac{C_t^E}{e_t^2}\right)-\beta\delta^\beta\frac{C_t^E}{e_t}\left[(\beta-1)\left(C_t^E X_t^{E*}-w_t^E\right)^{\beta-2}\alpha_t w_{t0}^E(1-h_t^{E*})+E_t\left(C_t^E X_t^{E*}-w_t^E\right)^{\beta-1}\right]\right] \qquad (16)$$

The first term in equation (16) gives the export quantity effect through the usual cost channel (15). The rest captures the negative effect of the external financing constraint.

The impact of aggregate shocks on export quantities depends on α_t. Suppose that $\alpha_t > 0$, meaning that increased cash flows are positively correlated with a currency depreciation. For example, this positive correlation can arise when shocks are monetary. A positive monetary expansion should both depreciate the exchange rate and raise cash flows. The increased cash flows will allow the firm to produce and export more, and the firm will be less financially constrained, exactly when the relative costs are low (15). In this case, the negative impact of the financing constraint would be small.[10] Thus, under $\alpha_t > 0$, the effect of the aggregate shock on export volumes (16) will tend to be large.

Suppose instead that $\alpha_t < 0$, which means that when the currency is depreciated, cash flows are lower, and financing constraints are tighter. For example, this negative

[10] A negative monetary expansion, say, should both appreciate the exchange rate and lower cash flows, if $\alpha_t > 0$. In this case, the negative impact of the financing constraint would be large.

correlation between cash flows and exchange rates can arise when aggregate shocks are from the supply side. An unexpected increase in oil prices should both depreciate the exchange rate, and lower cash flows. Although the currency is depreciated, with decreased cash flows, the domestic firm cannot take full advantage of the low relative costs, because of the large and tight financing constraint. Thus, under $\alpha_t < 0$, the impact of the aggregate (exchange rate) shock on export volumes will tend to be small, or could be even negative.

Prediction One of our model is that firms or industries with $\alpha_t > 0$ will tend to have a larger impact of the exchange rate on exports (larger (16)); than firms or industries with $\alpha_t < 0$.

The Optimal Hedge Ratio

By hedging, the firm can offset the impact of fluctuations in the external financing constraint. It can be shown that the optimal hedge ratio is (see Appendix):

$$h_t^{E*} = 1 + \frac{e_t E_t\left[\frac{dX_{it}^E}{dw_{it}^E}\left(P_t^* + \frac{dP_t^*}{dX_{it}^E} X_{it}^E\right)\right] - C_t^E\left(\frac{dX_t^E}{dw_t^E}\right) - E_t\left[\beta\delta^\beta\left(C_t^E X_t^E - w_t^E\right)^{\beta-1}\left(C_t^E \frac{dX_t^E}{dw_t^E} - 1\right)\right]}{\alpha_t w_{t0}^E E_t\left(\Pi_{ww}\right)} \quad (17)$$

Equation (17) shows that the hedge ratio depends on marginal profits, the change in profits resulting from the change in cash flow. If the firm hedges completely $(h_t^E = 1)$, then aggregate shocks will affect export quantities only through relative costs (15). In general, however, the firm will choose optimal h_t^* different from unity. Since $E_t[\Pi_{ww}]$ is negative, whether $h^* < 1$ or $h^* \geq 1$ depends on the sign of α_t.

If α_t is positive, the shock causing the depreciation of the domestic currency will increase cash flows. In this case, from (17), the firm would choose to hedge less than completely. Since cash flows will tend to be high when the exchange rate is depreciated, the firm with low or no hedging can take better advantage of the favorable export opportunities. In fact, depending on the parameters of (21), the firm may choose not to hedge at all ($h_t^{E*} = 0$).

Suppose instead that $\alpha_t < 0$. The shock affects the exchange rate and cash flows in opposite directions. Since its internal cash flows are low when the currency is depreciated and export opportunities are larger, the firm would benefit by obtaining a hedging contract that reduces the impact of the shock on its cash flow. Thus, hedging is likely to be extensive or complete ($h_t^{E*} = 1$).

Prediction Two of our model is that firms or industries with extensive hedging will tend to have a smaller impact of the exchange rate on exports (smaller (16)), than firms or industries with little hedging. This is because firms with extensive hedging will tend to have $\alpha_t < 0$. Although the hedging will tend to raise the export elasticities, the post-hedging elasticities should still be less than the elasticities for firms with $\alpha_{it} > 0$.

3. Estimation Specification and Description of the Data

Intertemporal Considerations

As developed, our model of exports and hedging is static. In the estimation, we fit our model on panel data of Japanese exporting firms. Our model can be extended to an intertemporal framework since we are assuming that the domestic firm *i* chooses export quantities, X_{it}^{E} and the optimal hedging ratio, h_{it}^{E*}, at time *t*, based on α_{it}, and the other fixed parameters of the model. As time evolves, the parameter α_{it} changes, based on new information regarding the correlation between firm cash flows and nominal exchange rates. We assume other parameters in the model as fixed over time.

Specification of Estimation Equations

We jointly estimate equations for export quantity, and foreign demand, using firm level panel data for Japanese multinationals. Rearranging (14), and assuming that the financing constraint is quadratic, i.e. $\beta = 2$, we obtain the estimation equation for the export quantity:

$$X_{it}^{E} = \left(1 + \frac{4}{3b}\frac{C_{it}^{E2}}{e_t}\right)^{-1}\left[\frac{a}{3b} + \frac{C_{it}^{F}}{3b} - \frac{2\beta}{3b}\frac{C_{it}^{E}}{e_t} + \frac{4}{3b}\frac{C_{it}^{E}}{e_t}w_{it}^{E}\right] + \eta_{it} \tag{18}$$

where η_{it} is an error, assumed to be serially uncorrelated and *iid* with a mean of zero and a variance of σ_η^2 and *a* and *b* are parameters to be estimated.[11]

Our second equation is foreign demand for Japanese exports −from equation (12):

$$P_t = \frac{1}{2}\left(a - bX_{it}^{E} + C_{it}^{F}\right) + \mu_{it} \tag{19}$$

[11] Preliminary estimates of β showed that β is statistically indistinguishable from 2.

where μ_{it} is approximation error, assumed to be serially uncorrelated and normally distributed with a mean of zero and a variance of σ_μ^2.

Finally, we impose the financing constraint below − modified from equation (5) − on (18).[12]

$$w_{it}^E = w_{it0}^E \left[1 + \tilde{\alpha}_{it}\varepsilon_t\right] \tag{20}$$

where ε_t is the aggregate shock, which is *iid* with a mean of zero and a variance of σ_ε^2, as defined in (4).

$\tilde{\alpha}_{it}$ is defined as:

$$\begin{aligned}\tilde{\alpha}_{it} &= \frac{\operatorname{cov}\left(\frac{w_{it}-w_{it-1}}{w_{it-1}}, \frac{e_t-e_{t-1}}{e_{t-1}}\right)}{\operatorname{var}\left(\frac{e_t-e_{t-1}}{e_{t-1}}\right)} \\ &= \left(1-h_{it}^{E^*}\right)\alpha_{it}\end{aligned} \tag{21}$$

However, since $\tilde{\alpha}_{it}$ is not known to the firm at the beginning of time *t*, we assume that the firm uses $\tilde{\alpha}_{it-1}$, or the correlation between cash flows and exchange rates up to the period *t*, in predicting the time *t* correlation. $\tilde{\alpha}_{it}$ can be calculated from available data on exchange rates and firm level cash flows.[13] Note, however, that in the absence of comprehensive hedging data, which our and most other datasets lack, it is difficult to disentangle the effect of hedging on cash flow.

Equations (18) and (19) with financing constraints (20) imposed can be jointly estimated consistently by nonlinear least squares (Amemiya, 1985)[14]. In fact all of the parameters of interest can be obtained from just estimating the reduced form (18) with (19) imposed. We estimate the demand function (19) together with (18) to improve the efficiency at the estimations. Finally, we use the estimated parameters, *a* and *b* to calculate the elasticities of interest.

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[12] In our estimation, we substitute (20) into (18), and estimate (18) and (19) jointly.

[13] In our model specification, we could have fixed α_{it} over time, so that $\alpha_{it} = \alpha_i$ and simply estimated α_i, along with the other parameters of the model. This estimation strategy is problematic for two reasons. First, the restriction violates the data since $\tilde{\alpha}_{it}$ varies dramatically over time. Not all of this variation can be attributed to h_{it}^{E*}, so α_{it} must be varying over time. Second, since we do not have comprehensive data on h_{it}^{E*}, α_{it} cannot be separately estimated from h_{it}^{E*}.

[14] We assume that u_{it} and v_{it} have a jointly normal, finite variance-covariance matrix. The efficiency of the estimation could be improved if $\tilde{\alpha}_{it}$ can be estimated in one step with (18) and (19). However, the non-linearity of (18) and (19) made this time-varying joint estimation difficult.

Description of the Data

We estimate equations (18), and (19) with financing constraints (20) simultaneously for Japanese four digit export industries using firm level panel data. Since we are interested only in exporting firms, we include in our sample of industries, only industries with export sales to total sales of over 15 percent. In terms of value, exports from these 14 industries comprise over 90 percent of total Japanese manufacturing exports. We use data for the years *1982-1997*. The firm level panel data are from the *Japan Development Bank* (JDB) Corporate database.

As an exchange rate measure, we use the trade weighted nominal exchange rate, i.e. we compute the trade weighted nominal exchange rates of the top 15 Japanese trading countries by their trade weights. Besides these 15 countries, less than 5 percent of Japan's trade is with other countries. The annual nominal exchange rates are from the *International Financial Statistics* (IFS); trade weights are fixed (1990) and are computed from the Japan Statistical Yearbook.

For industry specific marginal costs (C_E), we use industry specific domestic wholesale price indices –from the Nikkei Economic Electronic Databank System (NEEDS). That is, we assume that domestic wholesale price indices represent a constant markup from domestic marginal costs, $C_{it}^E = k_E P_t^d$.

We lack any direct information on foreign marginal costs. Thus, following Bodnar, Dumas, and Marston (1998), we simply assume that foreign wholesale price indices represent a constant markup from foreign marginal costs. That is, $C_{it}^F = k_F P_t^f$. We construct the aggregate foreign wholesale price index from industrial wholesale price indices of Japan’s top 15 trading partners by using the same trade weights as above. The industrial wholesale price indices are from IFS.

For industry specific Japanese export prices (P_t), we use industry specific export price indices –foreign currency bases– from the *Bank of Japan* (BOJ) Economic and Financial database. We assume that these prices are identical to the industry specific prices that appear in foreign demand.

Export quantities (X_{it}^E) and cash flows (w_{it}^E) are from the *Japan Development Bank* (JDB) *database*. Export quantities are defined as export values divided by the export price deflator for the industry.[15] The firm's internal cash flow is defined as earnings before interest and taxes plus depreciation minus capital expenditures.

The post-hedging correlations between changes in the firm's cash flows and nominal exchange rates, $\tilde{\alpha}_{it-1}$, are calculated for each year and each firm, using our exchange rate measure and firm level cash flows calculated from the *JDB database*. For $\tilde{\alpha}_{i1982}$ in the first year of our working sample, 1982, we take the time series correlation –relative to the exchange rate variance– between changes in exchange rates and cash flows between 1975 and 1981. Thereafter, from 1983-1997, we update $\tilde{\alpha}_{it-1}$ by taking the correlation between changes in exchange rates and cash flows up to the sample year.

4. Estimation Results

Descriptive Statistics

There is large variation in average export quantities across Japanese industries. Between 1982 and 1997, the average firm in the automobile industry had the largest export quantities, followed by the ordinary steel industry and the boiler and turbine industry (Table 1). Internal cash flows were largest for the typical firm in the ordinary steel industry, followed by the automobile industry. The ratios of export sales to total sales averaged about 33 percent in our sample, with the musical instrument industry exporting about 70 percent of its output.

A peculiar institutional feature of Japanese industries is the *keiretsu* system. Table 1 shows that 100 percent of firms in the ordinary steel industry belong to the *keiretsu*, while none of the firms in the agricultural machinery and watch industries belong to the *keiretsu*. *Keiretsu* firms have close relations with banks. Hoshi, Kashyap, and Scharfstein (1991) argue and present empirical evidence showing that these close banking relationships lessen the impact of financing constraints on corporate investment. He and Ng (1998) apply the Hoshi, Kashyap, and Scharfstein insight to corporate profit exposure to exchange rate fluctuations, and find that the profits of *keiretsu* firms are less exposed to exchange rate

[15] It is well known that export price indices are poor measures for firm-level prices, which may introduce measurement error into export quantities. However, since export quantities in our estimation model is an independent variable, measurement error, while raising the standard error of the equation, will not bias the coefficient estimates.

fluctuations, presumably because their banks extend loans to smooth out profit fluctuations.

Our model predicts that *keiretsu* firms should hedge less, since these firms are less concerned with shocks to internal cash flows. The effect of *keiretsu* affiliation on the responsiveness of exports to exchange rate fluctuations is similar to the effect of hedging on exports; the exports of *keiretsu* firms should be less responsive to exchange rate fluctuations.

Finally, Table 1 depicts the ratio of firms that engaged in forward foreign currency sales/purchases in 1997, the indicator of financial hedging available in our *JDB* database. While no firms in the specialty steel, measuring equipment, and watch industries engaged in forward foreign currency sales/purchases, the majority of firms in the boiler and turbine, construction machinery and optical instrument industries traded in these instruments.

We first examine the post-hedging correlation between changes in internal cash flows and changes in exchange rates, that is, $\tilde{\alpha}_{it}$ defined in equation (21). Assume, as it is likely, that $0 < h_{it}^E < 1$. In this case, $\tilde{\alpha}_{it}$ will have the same sign as α_{it}. There is heterogeneity in the sign of average $\tilde{\alpha}_{it}$ across industries (Table 2). In specialty steel, for example, exchange rates and cash flows are negatively correlated, while in ordinary steel, they are positively correlated. Out of 14 industries, 10 industries have exchange rates and cash flows that are on average across firms and over time, positively correlated. Moreover, even within industries, there is substantial heterogeneity in $\tilde{\alpha}_{it}$. Because of the heterogeneity, we present values for the firm with the highest average $\tilde{\alpha}_{it}$ and the lowest average $\tilde{\alpha}_{it}$ over the sample. For example, within the nine firms in the optical instrument industry, $\tilde{\alpha}_{it}$ ranges 33 to -4. Apparently aggregate shocks – trade, productivity, fiscal and monetary policies, commodity price, and other shocks – affect the cash flows of different industries and firms in surprisingly different directions.

Preliminary Results

Table 3 reports the results of the simple regression of the change in macroeconomic or aggregate export volumes on the change in the nominal effective exchange rate, for each of the seven industrialized countries (Canada, France, Germany, Italy, Japan, U.K. and the U.S.) for the period 1975-2001.[16] The estimated coefficients of the change in the exchange rate are not significant except for Italy and the United States. In aggregate or

[16] The data are monthly and are from the IMF's *International Financial Statistics.*

macroeconomic data in five of the G-7 countries, a depreciation of the domestic currency does not appear to increase export volumes. This corroborates the earlier results of Baxter and Stockman (1989), Flood and Rose (1995) and others who find that in macroeconomic data, aggregate quantities, including export quantities, are uncorrelated with the exchange rate.

Next, we regress the changes in export volumes on changes in the trade-weighted nominal exchange rate on our firm-level data aggregated (averaged) across Japanese exporting firms at each period t:

$$\Delta E_t \ln x_{it} = a + b\Delta E_t \ln e_t + \varepsilon_{it}$$

Table 4 depicts these regression results, which are similar to the results that use macroeconomic data (Table 3). The depreciation of the currency has no expansionary effects on export volumes. Table 4 also reports the regression results when the data are aggregated (averaged) across all firms in a given *industry*. Except for the office machinery and communications equipment industries, none of the coefficients on the exchange rate are significant. Thus, the exchange rate disconnect puzzle is observed even in aggregated firm-level data.

Table 5 depicts the results from regressing exports on the exchange rate, and other variables, using our disaggregated panel data of firms. Industry dummy variables are included in all specifications, but are not depicted. In Specifications I and III, we regress exports on only the nominal exchange rate. The coefficients on the exchange rate are always insignificant.

In specifications II and IV, we include some price and productivity variables that were shown to affect export volumes in Dekle, Jeong, and Ryoo (2004). In Dekle, Jeong, and Ryoo (2004), we develop a simple microeconomic model of the exporting firm that is a price taker in international markets. A rise in export prices should increase exports; but a rise in input prices (oil, metal, and wages) should lower exports. (Export prices and wages are at the industry level. Oil and metal prices are aggregate import prices.) In that paper, we also showed that a rise in productivity increases exports by lowering costs. Here we proxy firm level productivity by industry labor productivity. The coefficients on the nominal exchange rate are now statistically significant. An exchange rate appreciation lowers exports. In the fixed-effects specification (IV), the export price has the right sign, but the wage has the wrong sign. A rise in industry productivity significantly increases exports.

On the whole, these results suggest that the exchange rate can have a statistically significant effect on exports at the firm level, provided that appropriate control variables are included. Of course, the exchange rate is an endogenous variable, and the above estimates are only suggestive, since they can be plagued by simultaneity biases. Our structural model below tries to control for this simultaneity bias, by not explicitly including the exchange rate as an explanatory variable, but instead focusing on the impact of exogenous aggregate shocks on cash flows and exports. As mentioned, our identifying assumption (see Section 2 above) is that these aggregate shocks affect the exchange rate in the same direction; and that both the aggregate shock and the exchange rate change occur *after* the export production and hedging decisions have been made.

Main Estimation Results

The estimation results of the equations of the supply of exports (18) and foreign demand (19) with financing constraints (20) are depicted in Table 6. In general, the results support the theory. Almost all the coefficients have the correct signs and are statistically significant. Foreign demand is correctly estimated as downward sloping ($b > 0$). Consistent with our priors, the estimate of the parameter b tends to be higher in standardized products, like ordinary steel and metal machinery than in differentiated products, like automobiles. A rise in foreign costs raises export quantities ($k_F > 0$); while a rise in domestic costs lowers export quantities ($k_E > 0$), thus supporting the Cournot competition model adopted here.[17] The goodness of fit statistic (R-squared) for the export equation ranges up to 0.88, which is high for panel data.

Elasticities of exports with respect to exchange rates can be calculated from the estimated parameters and average values of the data. The average elasticities range from 0.02 for the auto industry to 2.9 for the boiler and turbine industry, with large heterogeneity *within* industries[18] (Table 7). Given the heterogeneity, one or two firm outliers can distort

[17] The markup in domestic prices is equal to $\frac{}{k_E}$. As seen from our estimation of k_E in Table 3, five out of fourteen industries have negative markups. Negative markups in domestic prices are not inconsistent with our model. In fact, Japanese firms in these industries may be incurring a loss in domestic markets, to be made up in profits in foreign markets.

[18] Although the parameters are the same for each firm in the industry, the export elasticities are heterogeneous, because each firm has different export quantities, costs, and sensitivities of cash flows to exchange rate fluctuations.

the average elasticities. To reduce the problem of outliers, we also examine the export elasticity for the median firm in each industry.

In general, our average and median export elasticities are larger than what has been reported in the earlier literature (Table 7). The earlier literature used mostly aggregate data for a single country or aggregate data over a cross-section of countries. Most of the literature has examined the impact of exchange rate volatility on export quantities.[19] In a study that reports the export elasticity of exchange rates, Thursby and Thursby (1987) report that the elasticity of exchange rates ranges from 0.129 to 4.87. Hooper, Johnson and Marquez (2000) estimate short-run aggregate export elasticities for the OECD countries. They find elasticities are uniformly small, and generally statistically insignificant from zero.

One explanation for the small estimated export elasticities in the earlier work is that exporters are keeping foreign prices constant, or that prices are sticky in the buyer's currency (Knetter, 1992; Engel, 2002). For example, when the yen appreciates, because of sticky prices in dollars, the prices of Japanese exports in the U.S. market do not change. Since the relative prices of Japanese and U.S. goods in the U.S. market do not change, U.S. demand does not switch from Japanese to U.S. goods, keeping Japanese export quantities relatively stable.

From our parameter estimates, we can calculate the elasticity of export prices to exchange rate changes, using equation (9). The calculated elasticities are generally very small. The average elasticities range from 0 for the auto industry to 0.01 for the musical instrument industry. Thus, when the yen depreciates, export prices decline, but the percentage changes in export prices are typically much smaller than the percentage change in the yen depreciation.

Thus, large changes in prices in the buyer's currency cannot explain our finding of sizeable export elasticities. Rather, we attribute our sizeable export elasticities to changes in financing constraints that are correlated with exchange rate fluctuations. For example, in 10 out of 14 industries, an exchange rate depreciation is on average related to a relaxation of financing constraints. In these industries, the relaxation of financing constraints will

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[19] That is, the studies have examined the elasticity of exports with respect to exchange rate volatility, $V_t = \sqrt{\frac{1}{m}\sum_{i=1}^{m}(\log e_{t+i-1} - \log e_{t+i-2})^2}$. Chowdhury (1993) reports that the export elasticity of exchange rate volatility ranges from a low of 0.77 in Italy to a high of 0.82 in Japan. Arize (1996) reports the elasticity of exchange rate volatility of 0.128 using Korean data for the period 1971-1991. Parsley and Wei (1993), and Frenkel and Wei (1994) among others find that volatility has no effect on trade. See the references in Wei (1999).

mean that firms can produce more for export, when their exchange rate is depreciated. In the remaining industries, an exchange rate depreciation is related to tightening financing constraints.

Effects of Financing Constraints, and Hedging on Export Elasticities

When $\tilde{\alpha}_{it} > 0$, an exchange rate depreciation is correlated with a loosened financing constraint, implying an expansion in exports. When $\tilde{\alpha}_{it} < 0$, financing constraints tighten when the exchange rate depreciates, constraining exports.

Prediction One of our model is that firms with positive and high $\tilde{\alpha}_{it}$ should have higher export elasticities than firms with negative $\tilde{\alpha}_{it}$.[20] Figure 3 depicts the cross-firm association between $\tilde{\alpha}_{it}$ and the export elasticities. As predicted by the model, the variables have a positive relationship. The regression coefficient of 0.27 is statistically significant at the 5 percent level.

A related implication of our model is that firms that are less financially constrained should have lower exchange rate elasticities. Thus, compared to the exports of non-*keiretsu* firms, the exports of *keiretsu* firms who are presumably less financially constrained, should have lower exchange rate elasticities. Of the 11 industries with both *keiretsu* and non-*keiretsu* firms, 9 industries have lower exchange rate elasticities –both average and median– for *keiretsu* firms (Table 8).

As a further test, we *interact* a dummy that takes on a value of one when the firm belongs to a *keiretsu* –the *keiretsu* dummy– with the financing constraint, (20), and re-estimated (18) and (19), along with this additional constraint. If *keiretsu* affiliation helps in lessening financing constraints, the coefficient on this interaction term should be negative. Of the 11 industries with both *keiretsu* and non-*keiretsu* firms, 5 industries have significantly negative coefficients on the interaction term (Table 8). In no industry was the interaction coefficient significantly positive.

As to the effect of hedging on export elasticities, Prediction Two of our model is that hedging firms will have lower export elasticities. Of the industries with both hedging and non-hedging firms, we find that hedging firms typically have lower export elasticities, thus supporting our model (Table 8).

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[20] We assume that hedging cannot fully offset the impact of the financing constraints. Thus, $\tilde{\alpha}_{it}$ has the same sign as α_{it}.

Surprisingly we find that *keiretsu* firms are more likely to hedge than non-*keiretsu* firms. However, as mentioned, forward foreign currency sales/purchases are a very incomplete measure of firm overall hedging activities, and our negative result may be more of an indication of incomplete data coverage, than a failure of our model.

Given the inadequate data on overall hedging activities, we compare the *actual* export elasticities with the *hypothetical* elasticities under the assumption that the firm hedges completely ($h_{it} = 1$). We set $h_{it} = 1$ in equation (16), and compare the export elasticities thus obtained (Table 9) with the actual export elasticities (Table 7). By this methodology, we can capture the extent of actual hedging, not only through financial means, but also through operational means such as foreign direct investment. In most industries, the elasticities under complete hedging are much lower than the actual elasticities. In only two industries –specially steel and ordinary steel– do firms appear to be hedging fully.

5. Conclusion

In this paper, we developed a microeconomic model of an exporting firm that experiences fluctuating exchange rates and shocks to its cash flow. The firm uses its cash flow and borrows from the financial markets to produce for export later in the period. The exchange rate and shocks to cash flow are correlated, but the correlation could be positive or negative. If, for example, they are negatively correlated, then the firm will suffer from low cash flows when its exchange rate is depreciated. That is, the firm's production will be constrained exactly at the time when its export opportunities are greatest. This provides the rationale for the firm to hedge against shocks to its cash flow.

We test and apply the model to firm level data on Japanese exporters. We estimate the model on 14 separate Japanese industries, and find that model fits the data for most industries. Our sample of 14 industries covers 90 percent of Japanese manufacturing export in terms of value; thus our sample is almost representative of the entire Japanese manufacturing export sector.

We show that financing constraints influence the sensitivity of export volumes to exchange rate fluctuations. Firms that are less financially constrained –that is, *keiretsu* firms– tend to have lower elasticities of exports with respect to exchange rates than non-*keiretsu* firms, which is consistent with the existence of financial constraints.

An important contribution of our paper is the calculation of the elasticity of exports with respect to changes in exchange rates, using firm level data. Most previous work has used data for a single country or a cross-section of countries to calculate such elasticities (See Hooper, Johnson, and Marquez, 2000). We find that average elasticities of exports with respect to exchange rates are quite high, ranging from 0.01 for the auto industry to as much as 2.9 for the boiler and turbine industry. In most industries, our calculated elasticities are generally higher than what have been found in previous work, using more aggregated data. Thus, our work casts some doubt on the prevailing wisdom –based on results from more aggregated data– that exchange rates have little effect on trade (Hooper, Johnson, and Marquez, 2000).

More broadly, an important puzzle in international macroeconomics is the *exchange rate disconnect* puzzle (Obstfeld and Rogoff, 2000). Based partly on the empirical findings of Baxter and Stockman (1989), Flood and Rose (1995) and others, nominal exchange rates seem to be *disconnected* from other macroeconomic variables, including export volumes. This paper relates nominal exchange rates to export volumes at the *firm level* and finds that export volumes are strongly affected by changes in exchange rates.

As in earlier work (see Engel, 2002 for a review), we too find that prices are sticky in the buyer's currency. In our model of exports, the strong response of export volumes to exchange rate fluctuations arises not because of changes in buyer currency prices, but because of a loosening of financing constraints, through the direct beneficial effect of exchange rate shocks on cash flows.

It may be interesting to estimate the response of exports to exchange rate changes at the firm level, using the data of other industrialized countries. Recent work by Gourinchas (1999) for France and by Goldberg and Tracy (1999) for the U.S. find that exchange rate fluctuations do impact real quantities –labor demand– at the disaggregate level.

Appendix:

We derive the hedging decision by the domestic firm. Maximizing (7) in the text with respect to h_t^E , we obtain:

$$E_t\left(\Pi_w \frac{dw_t^E}{dh_t^E}\right) = w_{t0}^E \alpha_t \operatorname{cov}\left(\Pi_w, \varepsilon_t\right) = 0$$

$$= w_{t0}^E \alpha_t E_t\left[\Pi_{ww} \frac{dw_t^E}{d\varepsilon_t} + \frac{\partial \Pi_w}{\partial \varepsilon_t}\right] \operatorname{cov}\left(w_t^E, \varepsilon_t\right) = 0 \qquad \text{(A1)}$$

Since $\operatorname{cov}(w_t^E, \varepsilon_t) \neq 0$, we get that:[21]

$$E_t\left[\Pi_{ww} \frac{dw_t^E}{d\varepsilon_t} + \frac{\partial \Pi_w}{\partial \varepsilon_t}\right]$$

$$= w_{t0}^E(1-h_t^E)\alpha_t E_t\left[\Pi_{ww}\right] + E_t\left\{\frac{\partial}{\partial \varepsilon_t}\left[e_{t+1}P_t \frac{dX_t^E}{dw_t^E} + e_{t+1}X_t^E \frac{dP_t}{dX_t^E}\frac{dX_t^E}{dw_t^E} - C_t^E \frac{dX_t^E}{dw_t^E} - \beta\delta^\beta\left(C_t^E X_t^E - w_t^E\right)^{\beta-1}\left(C_t^E \frac{dX_t^E}{dw_t^E} - 1\right)\right]\right\}$$

$$= w_{t0}^E(1-h_t^E)\alpha_t E_t\left[\Pi_{ww}\right] + e_t E_t\left[\frac{dX_t^E}{dw_t^E}\left(P_t + X_t^E \frac{dP_t}{dX_t^E}\right)\right] - E_t\left[C_t^E \frac{dX_t^E}{dw_t^E} + \beta\delta^\beta\left(C_t^E X_t^E - w_t^E\right)^{\beta-1}\left(C_t^E \frac{dX_t^E}{dw_t^E} - 1\right)\right] \qquad \text{(A2)}$$

must be equal to zero.

Simplifying (A2), we obtain the optimal hedge ratio in the text.

[21] If x and y are normally distributed and $g(y)$ is at least once differential function of y, $cov(x, g(y)) = E[g'(y)]\ cov(x, y)$. See Rubinstein (1976) for proof.

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Table 1 Descriptive Statistics[1)]

Industry	Export Quantity [2)]		Internal Cash Flows[3)]		Number of Firms	Average Export Ratios	Ratio of Firms in *Keiretsu*	Ratio of firms using hedging[4)]
	Average	S.D.[5)]	Average	S.D.[5)]				
Ordinary steel	2193	1576	72.25	63.41	7	0.20	1.00	0.43
Specialty steel	193	135	6.87	5.96	4	0.16	0.25	0.00
Boiler and turbine	1596	1835	21.11	37.92	8	0.34	0.75	1.00
Metal machinery	126	125	2.34	5.35	14	0.38	0.36	0.21
Textile machinery	93	108	1.75	2.03	8	0.31	0.38	0.13
Agricultural machinery	236	354	6.42	12.74	5	0.17	0.00	0.20
Construction machinery	741	1008	9.07	13.88	4	0.22	0.50	0.75
Office machinery	463	503	6.54	8.00	11	0.29	0.36	0.45
Communication equipment	128	158	2.72	3.53	12	0.22	0.42	0.17
Musical instrument	451	447	3.16	8.52	10	0.69	0.30	0.40
Autos	7989	8107	52.53	107.96	9	0.35	0.67	0.11
Measuring equipment	176	165	3.91	3.60	2	0.18	0.50	0.00
Optical instrument	1099	2093	9.85	24.01	9	0.55	0.33	0.67
Watches	638	507	4.85	5.05	2	0.59	0.00	0.00
All Industries	1271	3375	14.95	43.96	105	0.33	0.42	0.32

Note:

1) Averages, between 1982-1997 over all the firms in the industry.
2) Export Quantity=Export Value in Thousands of Yen / Export Price Index.
3) Millions of Yen.
4) Fraction of firms that engaged in forward exchange rate sales/and purchases in 1997.
5) Standard Deviation.

Table 2 Statistical Association of Changes in Internal Cash Flows with Changes in Exchange Rates ($\tilde{\alpha}_{it}$)[1)]

Industry	Average[2)]	Median[3)]	Max[4)]	Min[5)]
Ordinary steel	4.03	2.48	12.61	0.75
Specialty steel	-8.91	-1.43	1.58	-34.38
Boiler and turbine	-1.83	-1.03	9.23	-20.90
Metal machinery	2.05	2.15	25.97	-16.07
Textile machinery	1.54	1.49	8.80	-5.13
Agricultural machinery	0.30	0.48	3.57	-3.35
Construction machinery	-3.95	-4.63	5.28	-11.83
Office machinery	0.72	1.41	3.89	-7.37
Communication equipment	2.13	0.66	9.60	-1.33
Musical instrument	4.50	0.70	41.92	-33.28
Autos	1.85	1.93	4.82	-2.33
Measuring equipment	0.53	0.53	1.14	-0.08
Optical instrument	5.54	3.34	32.51	-4.43
Watches	-0.21	-0.21	0.58	-1.00

Note:

1) $\tilde{\alpha}_{it} = \dfrac{\operatorname{cov}\left(\dfrac{w_{it}}{w_{it-1}} - 1, \dfrac{e_t}{e_{t-1}} - 1\right)}{\operatorname{var}\left(\dfrac{e_t}{e_{t-1}} - 1\right)}$ for every t, 1983-1997.

2) $\dfrac{1}{N}\dfrac{1}{14}\sum_{i}^{N}\sum_{t=1983}^{1997}\alpha_{it}{}_{14\times N}$, where N is the number of firms in the industry.

3) Median over all the firms in the industry.

4) $\tilde{\alpha}_{it}$ for firm in the industry with the highest value of $\tilde{\alpha}_{it}$.

5) $\tilde{\alpha}_{it}$ for firm in the industry with the lowest value of $\tilde{\alpha}_{it}$.

Table 3: Exchange Rate Disconnect Puzzle with Macroeconomic Data

	Canada	France	Germany	Italy	UK	US	Japan
Constant	0.060 (6.45)**	0.052 (7.59)**	0.058 (5.43)**	0.030 (2.90)**	0.048 (6.64)**	0.047 (4.19)**	0.04 (2.93)***
Exchange Rate[1)]	-0.286 (-1.37)	0.018 (-0.08)	-0.364 (-1.45)	-0.454 (-2.99)**	-0.052 (-0.44)	-0.371 (-12.30)*	0.05 (0.37)
R-squared	0.0721	0.0003	0.0872	0.2711	0.0079	0.1808	0.006

Note 1) Nominal effective exchange rates. All terms are log differenced.
t-statistics are in parenthesis.
* and ** are significant at 5% and 1% significance levels respectively.

Table 4: Export Volume-Exchange Rate Correlations in Japanese Industries.

(Data Averaged Over All Firms in the Industry; Annual Data, 1982-1997)

	Constant	Exchange Rate	R-squared
All Industries	0.22 (0.11)	-0.11 (-0.51)	0.002
Ordinary steel	-0.04 (-0.07)	0.00 (0.01)	0.000
Specialty steel	-0.16 (-0.26)	-0.02 (-0.31)	0.002
Boiler and turbine	0.66 (0.79)	0.07 (0.78)	0.005
Metal machinery	0.07 (0.10)	0.01 (0.12)	0.000
Textile machinery	-0.23 (-0.32)	-0.03 (-0.32)	0.001
Agricultural machinery	-1.92 (-0.87)	-0.21 (-0.89)	0.010
Construction machinery	0.17 (0.17)	0.02 (0.21)	0.001
Office machinery	-1.73 (-2.28)**	-0.19 (-2.31)**	0.030
Communication equipment	-1.66 (-3.11)***	-0.20 (-3.28)***	0.071
Musical instrument	-0.44 (-0.50)	-0.05 (-0.49)	0.002
Autos	-0.67 (-0.82)	-0.07 (-0.82)	0.005
Measuring equipment	-1.68 (-1.20)	-0.20 (-1.22)	0.111
Optical instrument	0.11 (0.08)	0.01 (0.08)	0.000
Watches	-0.67 (-0.52)	-0.07 (-0.53)	0.009

Note: In log differenced terms.
t-statistics are in parenthesis.
* and ** are significant at 5% and 1% significance level respectively.

Table 5: Export Volumes and Exchange Rates With Japanese Firm Level Panel Data.

	OLS.		Fixed Effects Model	
	I	II	III	IV
Constant	-9.22	-9.41	-6.16	-6.05
	(-1.19)	(-1.17)	(-2.67)***	(-2.58)***
Exchange rate	-0.98	-0.86	-0.62	-0.59
	(-1.11)	(-3.13)***	(-1.05)	(-7.37)***
Industry Export prices	…	0.77	…	0.56
		(0.72)		(1.83)*
Oil price	…	-0.08	…	-0.06
		(-0.27)		(-0.70)
Metal price	…	0.03	…	-0.01
		(-0.12)		(-0.21)
Industry Wage	…	0.35	…	0.34
		(1.36)		(4.75)***
Labor Productivity		1.36		1.19
		(3.39)***		(10.41)***
R-squared: (overall)	0.33	0.67	0.44	0.66

Note: All variables are in logs.
Industry dummy variables are suppressed.
* significant at 10%; ** significant at 5%; *** significant at 1%
Number of Firms: 105.
Years: 1982-1997.

Table 6: Estimation Results by Industry (across firms in the industry, annual data for 1982-97)

Industry	Parameter Estimates				Goodness of Fit (R^2)	
	a	b	k_F	k_E	Eq (25)	Eq (26)
Ordinary steel	227.17***	0.38**	0.31***	0.36**	0.32	0.49
	(34.35)	(2.27)	(10.51)	(2.46)		
Specialty steel	218.70***	0.06*	0.09***	2.45**	0.28	0.26
	(43.41)	(1.88)	(4.03)	(2.13)		
Boiler and Turbine	197.85***	0.08***	0.02***	0.86***	0.75	0.10
	(251.68)	(4.59)	(5.37)	(4.88)		
Metal machinery	209.22***	2.77***	-0.03***	0.17***	0.03	0.04
	(194.75)	(8.61)	(-6.00)	(6.22)		
Textile machinery	204.15***	0.10	0.06***	1.80**	3.39^{E-3}	0.28
	(113.30)	(1.46)	(6.11)	(2.27)		
Agricultural machinery	225.62***	0.04***	0.05***	2.96***	0.88	0.17
	(81.02)	(3.70)	(3.66)	(4.02)		
Construction machinery	197.28***	0.02	0.06**	2.81	0.74	0.11
	(47.05)	(1.40)	(2.47)	(1.50)		
Office machinery	207.67***	0.19***	0.31***	0.49***	0.21	0.68
	(63.90)	(2.68)	(18.85)	(3.95)		
Communication equipment	155.74	1.20	1.89	0.37*	0.04	0.03
	(1.38)	(0.99)	(1.56)	(1.66)		
Musical instrument	253.50***	0.78***	0.30***	0.22***	0.08	0.48
	(43.50)	(2.76)	(10.70)	(4.27)		
Autos	215.34***	0.003	0.05***	12.57	0.49	0.26
	(123.63)	(0.28)	(6.85)	(0.29)		
Measuring equipment	206.95***	3.60***	0.02	0.03	0.59	4.17^{E-6}
	(14.25)	(6.09)	(0.12)	(0.14)		
Optical instrument	208.08***	0.03***	0.12***	1.36***	0.82	0.52
	(109.09)	(3.36)	(12.12)	(3.57)		
Watches	226.91***	0.02*	0.07***	2.12**	0.52	0.39
	(69.65)	(1.73)	(4.14)	(2.12)		

Note:
1) t-statistics in parenthesis.
2) ***, **, * denote significance at the 1, 5 and 10 percent levels, respectively
3) Estimation equations:

$$X_{it}^{E} = \left(1 + k_E^2 \frac{4}{3b}\frac{P_t^{d\,2}}{e_t}\right)^{-1}\left[\frac{a}{3b} + k_F \frac{P_t^f}{3b} - k_E \frac{2}{3b}\frac{P_t^d}{e_t} + k_E \frac{4}{3b}\frac{P_t^d}{e_t} w_{it}^E\right] + \eta_{it} \qquad (22)$$

$$P_t = \frac{1}{2}\left(a_1 - bX_{it}^E + k_F P_t^f\right) + \mu_{it} \qquad (23)$$

where $$w_{it}^E = w_{it0}^E\left(1 + \tilde{\alpha}_{it}\varepsilon_t\right) \qquad (24)$$

Table 7 Exchange Rate Elasticities of Exports and Export Prices (by Industry, in Percent)

Industry	Export Elasticity[1)]				Price Elasticity[2)]
	Average[3)]	Median[4)]	Max[5)]	Min[6)]	Average
Ordinary steel	0.739	0.139	3.837	0.063	-0.0047
Specialty steel	0.347	0.407	0.452	0.124	-0.0001
Boiler and turbine	2.894	0.374	15.306	0.062	-0.0013
Metal machinery	1.695	1.508	7.330	0.201	-0.0090
Textile machinery	1.754	1.096	5.608	0.308	-0.0002
Agricultural machinery	2.283	1.828	5.480	0.063	-0.0001
Construction machinery	1.615	1.547	3.306	0.060	-0.0001
Office machinery	2.447	1.107	9.578	0.217	-0.0022
Communication equipment	2.288	1.511	8.610	0.312	-0.0047
Musical instrument	1.964	1.860	5.015	0.364	-0.0097
Autos	0.015	0.007	0.043	0.001	0.0000
Measuring equipment	0.125	0.125	0.255	-0.005	-0.0002
Optical instrument	2.120	1.594	6.256	0.072	-0.0004
Watches	0.633	0.633	1.026	0.239	-0.0001

Note:

1) $\frac{dX_t}{X_t} \Big/ \frac{de_t}{e_t}$

2) $\frac{dP_t}{P_t} \Big/ \frac{de_t}{e_t}$.

3) Average over all the firms in the industry.

4) Median over all the firms in the industry.

5) Firm with the highest elasticity.

6) Firm with the lowest elasticity.

Table 8 Export Elasticities for *Keiretsu* and *Non-Keiretsu* Firms (by Industry, in Percent)

Industry	*Keiretsu* Firms[1), 3)]		*Non-Keiretsu* Firms[1), 2), 4)]		Firms using hedging		Firms w/o hedging		Coefficient on *Keiretsu* dummy × w_{it}^{E} [7)]	
	Average	Median	Average	Median	Average	Median	Average	Median		
Ordinary steel	0.32	0.06	n.a.	n.a.	0.05	0.06	0.52	0.30	0.11	(0.30)
Specialty steel	2.49	2.49	3.23	3.23	n.a.	n.a.	2.56	2.84	-0.19	(-1.09)
Boiler and turbine	0.94	0.35	2.72	2.72	1.14	1.02	n.a.	n.a.	-0.73	(-3.73)
Metal machinery	3.94	2.73	3.03	2.10	1.14	2.75	3.60	1.64	0.12	(0.21)
Textile machinery	4.66	5.34	4.83	5.91	2.34	2.34	4.82	3.86	-0.58	(-3.63)
Agricultural machinery	n.a.	n.a.	2.98	2.57	0.39	0.39	2.38	1.81	n.a.	n.a.
Construction machinery	2.22	2.22	2.78	2.78	1.61	0.40	2.16	2.16	0.61	(1.08)
Office machinery	2.84	1.10	1.57	0.39	0.33	0.23	2.44	1.65	-0.87	(-5.09)
Communication equipment	2.29	2.14	2.82	2.64	1.24	1.24	2.87	2.14	-0.85	(-2.05)
Musical instrument	0.77	0.54	2.24	1.64	2.47	0.72	1.35	1.61	-0.73	(-5.29)
Autos	0.48	0.36	0.31	0.04	0.35	0.35	0.49	0.23	0.74	(2.91)
Measuring equipment	3.33	3.33	4.92	4.92	n.a.	n.a.	3.62	3.62	1.92	(0.27)
Optical instrument	2.29	2.17	3.65	3.27	2.95	2.01	3.69	1.94	0.45	(1.11)
Watches	n.a.	n.a.	2.74	2.74	n.a.	n.a.	2.74	2.74	n.a.	n.a.

Note:

1) $\frac{dX_{it}^{E}}{X_{it}^{E}} \Big/ \frac{de_t}{e_t}$

2) Hedging=1, if the firm is using forward exchange rate sales and purchases in 1997.

3) Average over all the *Keiretsu* firms in the industry.

4) Average over all the *Non-Keiretsu* firms in the industry.

5) Average over all the firms using financial hedging (foreign exchange sales and purchases) in the industry.

6) Average over all the firms not using financial hedging (foreign exchange sales and purchases) in the industry.

7) Coefficient on (*keiretsu* dummy) × (Financing Constraint w_{it}^{E} in (24)), and *t*-statistics in parenthesis.

Table 9 Exchange Rate Elasticities of Exports when the Firm is Hedging Completely[1)] (by Industry, in Percent)

Industry	Export Elasticity			
	Average	Median	Max	Min
Ordinary steel	0.742	0.139	3.861	0.062
Specialty steel	0.347	0.407	0.452	0.124
Boiler and turbine	0.032	0.033	0.033	0.032
Metal machinery	0.007	0.008	0.008	0.006
Textile machinery	0.005	0.005	0.005	0.005
Agricultural machinery	0.006	0.006	0.006	0.005
Construction machinery	0.012	0.012	0.012	0.012
Office machinery	0.030	0.030	0.030	0.027
Communication equipment	0.013	0.013	0.013	0.012
Musical instrument	0.039	0.039	0.040	0.037
Autos	0.003	0.003	0.003	0.003
Measuring equipment	0.000	0.000	0.001	0.000
Optical instrument	0.029	0.029	0.029	0.029
Watches	0.022	0.022	0.022	0.022

Note:

1) $\dfrac{dX_{it}^{E}}{X_{it}^{E}} \Big/ \dfrac{de_t}{e_t}$ when $h_{it}^{E} = 1$.

Figure 1: The Association of $\tilde{\alpha}_{it}$ and Firm Export Elasticities