A Re-examination of the Exchange Rate Disconnect Puzzle: Evidence from Japanese Firm Level Data

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Abstract

The empirical literature that examined data at the aggregate or macroeconomic level has generally found small or insignificant effects of exchange rate fluctuations on export volumes. This lack of association between real quantities—such as export volumes—and the exchange rate is the so-called "exchange rate disconnect" puzzle. Studies using microeconomic or firm level data, however, have been more successful in finding relationships between export volumes and exchange rates. In this paper, we attempt reconciliation between the macroeconomic, aggregate evidence and the microeconomic, firm level evidence. We estimate our consistently aggregated, microeconomic model of exports and show that an exchange rate appreciation properly reduces export volumes.

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1. Introduction

After over three decades of exchange rate floating among industrialized countries, there is yet to emerge a consensus among academic economists regarding the impact of exchange rate fluctuations on real economic variables, such as exports. The empirical literature that examined data at the aggregate or macroeconomic level has generally found small or insignificant effects of exchange rate fluctuations on export volumes. For example, Mussa (1986); Baxter and Stockman (1989), and Flood and Rose (1995) showed that high exchange rate volatility is not related to high volatility of other macroeconomic variables, especially exports. Deardorff (1984), Hooper, Johnson, and Marquez (1998), and Thursby and Thursby (1987) regress the change in log export volumes on the change in log exchange rates and other variables, and find that the coefficient on log exchange rates is statistically insignificant. This lack of association between real quantities—such as export volumes—and the exchange rate is the so-called the "exchange rate disconnect puzzle."

Studies using microeconomic or firm level data, however, have been more successful in finding relationships between export volumes and exchange rates. Dekle and Ryoo (2002) estimate a structural model of the exporting firm using Japanese firm level data from 1982 to 1997, and find a large elasticity of export volumes to the exchange rate in many industries. Das, Roberts, and Tybout (2001) examine the export supply response of Columbian chemical industry manufactures to an exchange rate change on two margins: entry into and exit from export markets, and export production adjustments among incumbents. They find that entry is not important; in a 10 percent devaluation of the peso, over 90 percent of the export revenue is drawn by the expansion of volumes of existing exporters. Forbes (2002) studies the impact of a large devaluation on export sales of over 13,500 companies around the world, and finds that on average export sales improve by 4 percent, one year after the devaluation episodes.

In this paper, we attempt a reconciliation between the macroeconomic, aggregate evidence and the microeconomic, firm level evidence. We build a simple microeconomic model of the exporting firm, in which we derive the relationship between export volumes and exchange rates. We *consistently aggregate* the model, and show that in estimating the model, in addition to input and output prices, it is important to include variables representing firm level heterogeneity, such as firm-specific imported input shares and productivity. We show that unless these control variables are included, the relationship between aggregate exports and exchange rates is biased towards zero.

We first estimate the relationship between exports and exchange rates at the firm level, controlling for input and output prices, productivity, and other firm specific effects. We find that an appreciation of the exchange rate lowers export volumes in most specifications. We then estimate our *consistently* aggregated model of exports, and show that an exchange rate appreciation reduces aggregate export volumes. This result holds for most specifications, and even when export volume from macroeconomic statistics is used as an explanatory variable, instead of aggregated firm level exports.

Recently, like us, several authors in international finance have attempted to reconcile some macroeconomic evidence with conflicting microeconomic evidence. Imbs *et. al.* (2004) and Crucini and Shintani (2002) attempt to reconcile the high persistence of aggregate real exchange rates with the low persistence of disaggregated relative prices. Ruhl (2003) attempts to reconcile the low substitution elasticity between domestic and foreign goods found in aggregate high frequency time series data, with the high substitution elasticity found in data of a cross-section data of goods.[1]

The paper is organized as follows. In Section 2, the "exchange rate disconnect puzzle" is revisited at the aggregate level; and a benchmark model of firm behavior is presented. Here, we address the methodological issues of aggregation, i.e., how to link the firm level

[1] Ruhl (2003) presents evidence that estimates of the aggregate substitution elasticity are identified by temporary shocks, such as productivity shocks, while estimates of the cross-section elasticity are identified by permanent shocks such as trade liberalization. Thus, elasticity estimates are lower when the switch in consumption from foreign to domestic goods is driven by temporary shocks, as compared to when they are driven by permanent shocks. This is because consumers smooth their consumption of both domestic and foreign goods in response to temporary shocks.

In this paper, we estimate the elasticity of exports with respect to exchange rates. Since fluctuations in exchange rates are best described as a random walk (and permanent) process (Meese and Rogoff, 1983), permanent shocks drive the correlations between exchange rates and exports. Thus, in contrast to Ruhl, permanent shocks drive both our time-series and cross-section estimates of the elasticity of exports with specification with the aggregate, macroeconomic specification. We also examine the sources of aggregation bias. Section 3 describes the data we use for our estimation. We use Japanese data at the firm, industry, and aggregate levels. In Section 4, we present estimates of the elasticity of export volumes with respect to the exchange rate using firm level data. In Section 5, we show estimates of the elasticity of export volumes, using consistently aggregated firm level and macroeconomic data. In both types of aggregated data, when the relation between exports and the exchange rate is properly specified, an exchange rate appreciation results in a reduction of exports. Section 6 concludes.

2. Model

2.1 Revisiting the Exchange Rate Disconnect Puzzle

Table 1 reports the results of the simple regression of the change in 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 U.S.) for the period of 1975-2001,

$$\Delta \ln y_t = a + b \Delta \ln e_t + \varepsilon_t \qquad (1)$$

y_t denotes the export volume, e_t the nominal effective exchange rate, and ε_t the white noise error.[2] The last column "pooled" is when the country data are aggregated (with GDP as

respect to exchange rates; and the difference between our aggregate (time series) estimates and the panel (cross-section) estimates is not driven by the nature of shocks.

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

weights), and includes G-7 country dummy variables as additional regressors. An appreciation denotes a positive Δe_t. The estimated coefficients on the change in the exchange rate, b, are not significantly different from zero, except for Italy and the United States.

In Tables 2(a) and (b), for the same industrialized countries, we ran simple vector autoregressions of export volumes and exchange rates. In the levels specification (Table 2(a)), the exchange rate coefficients (the contemporaneous and lagged combined) are not significant, except for the United States and the "pooled" specification. In the first differenced specification (Table 2(b)), the exchange rate coefficients are significant for only Canada and Italy,

Thus, in aggregate or macroeconomic data in five or six of the G-7 countries, an appreciation of the domestic currency does not lower export volumes. This corroborates the earlier results of Baxter and Stockman (1989), Flood and Rose (1995) and others who find that most macroeconomic aggregates, including export quantities, are uncorrelated with the nominal exchange rate. Importantly, for Japan, the country of focus in this paper, exchange rates and exports are uncorrelated in all specifications.

2.2. Model of the Exporting Firm

Here we present a stylized model of the exporting firm, that is a price taker in export markets. The cost function is specified as Cobb-Douglass. In the Appendix, we present models for both price taking and price setting firms, under a generalized cost function. We show that the variables affecting export quantities in these generalized models are identical to those in the specialized model below, except that in the generalized price setting model, the export price becomes endogenous (see Appendix).

Consider an exporting firm i at date t that produces an export good y_{it}, by using domestic inputs x_{it}^d, and imported inputs x_{it}^f. It chooses the output level y_{it} to maximize its profit, given the firm-specific cost function C_{it}:

$$\max_{y_{it}} \frac{p_t^f}{e_t} y_{it} - C_{it}\left(w_t^d, \frac{w_t^f}{e_t}, y_{it} \right), \qquad (2)$$

where e_t denotes the exchange rate (defined as ratio of the foreign currency to the domestic currency), p_t^f, the foreign price of the export good, w_t^d the price index for domestic inputs x_{it}^d, and w_t^f the price index for imported inputs x_{it}^f. The domestic good is used as the numeraire. Each input x_{it}^d or x_{it}^f can be considered as either a single input good or a composite good of multiple inputs.

In competitive equilibrium, the optimal export volume is determined by marginal cost pricing, taking p_t^f as given, such that:

$$\frac{p_t^f}{e_t} = \frac{\partial C_{it}(w_t^d, \frac{w_t^f}{e_t}, y_{it})}{\partial y_{it}}. \qquad (3)$$

The supply function of the export good is characterized by inverting the marginal cost function in equation (3), such that:

$$y_{it} = f_{it}(e_t, w_t^d, w_t^f, p_t^f) \qquad (4)$$

We choose a specific form of the cost function:

$$C_{it}(w_t^d, \frac{w_t^f}{e_t}, y_{it}) = (w_t^d)^{\alpha_i} (\frac{w_t^f}{e_t})^{1-\alpha_i} (\frac{y_{it}^2}{a_{it}}) \qquad (5)$$

Note that with this cost function, a_{it} represents firm specific total factor productivity. The parameter α_i is the share of domestic inputs in production.

Given the above cost function, profit maximization implies that export volume is:

$$\ln y_{it} = \ln \frac{p_t^f}{2} - (1-\alpha_i) \ln w_t^f - \alpha_i \ln w_t^d - \alpha_i \ln e_t + \ln a_{it}. \qquad (6)$$

More compactly,

$$\ln y_{it} = -\alpha_i \ln e_t + \varphi_{it} + \ln a_{it}, \qquad (7)$$

where

$$\varphi_{it} \equiv \ln \frac{p_t^f}{2} - (1-\alpha_i) \ln w_t^f - \alpha_i \ln w_t^d.$$

That is, export volume is determined by three factors: the nominal exchange rate e_t, relevant market output and input prices φ_{it}, and productivity a_{it}.

In this model, a unit decrease in export revenues from the appreciation of the exchange rate is compensated by $1-\alpha$ units of cost reduction, because of the decline in imported input prices. Thus, the net response of export volumes to exchange rate movements is negative, with an elasticity of α, which is determined by the share of domestic inputs. That is, as the share of domestic inputs increases, the magnitude of the negative relationship between export volumes and the exchange rate increases. This magnitude may differ across firms (from (7)).

2.3. Aggregation Biases

The above model provides us with a framework to address the potential pitfalls in using aggregated or macroeconomic data to estimate the true relationship between export volumes and exchange rates. Time-series estimates with aggregated data cannot include firm specific effects, such as firm specific productivity, and imported input shares, as in (6). This may result in: 1) typical omitted variable biases; and 2) biases arising from the overrepresentation of firms with a high share of imported inputs.

These biases arising from using macroeconomic or aggregate data are possible sources of the exchange rate disconnect puzzle found in previous studies. With firm level data, we can control for these biases. We also show that in a consistently aggregated specification, the disconnect puzzle disappears. An exchange rate appreciation results in a decline in export volumes.

A. Omitted Variable Bias

First, suppose that all firms share a common cost function; the elasticity of export volumes, α 's are the same for all i's. Aggregate time series regressions do not allow for the inclusion of firm specific productivity variables such as a_{it}. This may result in omitted variable biases in the estimate of the exchange rate elasticity of export volumes, α (in (7)). The size of this bias depends on the distribution of a_{it}, and on the correlation between the mean value of a_{it} and the exchange rate.[3]

Taking expectations over firms in (7), we get

$$E_i(\ln y_{it}) = -\alpha \ln e_t + \varphi_t + E_i(\ln a_{it}), \tag{8}$$

where E_i denotes the expectation operator over all firms i, and φ_t is now common across firms, i.e.,

$$\varphi_t \equiv \ln \frac{p_t^f}{2} - (1-\alpha)\ln w_t^f - \alpha \ln w_t^d . \tag{9}$$

Suppose that,

$$a_{it} = \exp(\zeta_t + \eta_i + \gamma z_{it} + \varepsilon_{it}),$$

where ζ_t denotes time varying macroeconomic factors that commonly affect the

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[3] See Stoker (1984) for a general discussion, and Lewbel (1992) for the log-linear case.

productivity of all firms, η_i the time invariant firm specific characteristics, z_{it} the time varying firm specific variables, and ε_{it} the unobservable items that affect productivity (the error term). Then we have

$$E_i(\ln y_{it}) = -\alpha \ln e_t + \varphi_t + \zeta_t + E_i\eta_i + \gamma E_i z_{it} \tag{10}$$

Assuming that ε_{it} follows an i.i.d. normal distribution with standard deviation σ_t, the export volume y_{it} follows a log-normal distribution, conditional on the covariates, such that

$$E_i(y_{it}) = \exp\left(E_i(\ln y_{it}) + \frac{\sigma_t^2}{2} \right). \tag{11}$$

Thus, we have

$$\ln E_i(y_{it}) = E(\ln y_{it}) + \frac{\sigma_t^2}{2}$$
$$= -\alpha \ln e_t + \varphi_t + \zeta_t + E_i\eta_i + \gamma E_i z_{it} + \frac{\sigma_t^2}{2}. \tag{12}$$

Suppose as is typical, we regress aggregate export volumes on exchange rates, and some aggregate control variables:

$$\ln Y_t = -\tilde{\alpha} \ln e_t + \varphi_t + \Omega_t \tag{13}$$

where Y_t denotes the aggregate export volume; φ_t the output and input prices (9); and Ω_t, the other relevant aggregate control variables.

In fact, typical export volume--exchange rate regressions simply relate changes in export volumes to the changes in exchange rates, i.e. relate $\Delta \ln(Y_t)$ to $\Delta \ln(e_t)$, and even omit φ_t and Ω_t (in equation (13)).[4] For example, in our regressions depicted in Tables 1 and 2, we have not included output and input prices and other control variables.

Comparing the typical aggregate regression of equation (13) with the *consistently* aggregated regression of equation (12), there will be no aggregation bias if the variables included in the aggregate regression are:

$$\Psi_t = \zeta_t + E_i \eta_i + \gamma E_i z_{it} + \frac{\sigma_t^2}{2}. \tag{14}$$

That is, in addition to output and input prices, the aggregate regression should also include the productivity variables. Note that of the productivity variables, $E_i z_{it}$ and δ_t^2 depend on the distribution of the firm level observable and unobservable variables that can only be estimated from firm level data. For example, in our aggregate regression, we use as one of the variables in $E_i z_{it}$, the average export share. This average export share, $\frac{\sum_i \frac{\exp orts_{it}}{totalsales_{it}}}{N}$, depends on the distribution of exports and total sales across firms, whose calculation requires firm level data (N is the number of firms).

Suppose we estimate the aggregate model in (13), without including some or all of the

[4]See Baxter and Stockman, 1989.

variables in Ψ_t. Let's take Ψ_t as the omitted variable itself. Then, the coefficient from regressing export volumes on the exchange rate will be given by:

$$E(-\hat{\alpha}) = -\alpha + \frac{Cov(e_t, \Psi_t)}{V(e_t)}. \tag{15}$$

That is, the simple OLS estimate for the exchange rate elasticity of exports in equation (13) is not consistent, and tends to be downward-biased towards zero, when Ψ_t is positively correlated with e_t. This bias may explain the common empirical finding in macroeconomic data of zero correlation between export volumes and exchange rates.

Moreover, we can see from (15) that the higher the variance in exchange rates, the lower the omitted-variable bias; the estimate of α will be higher. In other words, we are more likely to observe the exchange rate disconnect puzzle for economies with stable exchange rates, than for economies with volatile exchange rates. This may explain why the exchange rate disconnect puzzle is usually found in OECD macroeconomic data, but not found in the macroeconomic data of emerging markets, with de facto flexible exchange rates, where exchange rates are far more volatile. For example, Tornell and Westermann (2002) among others find that output in many emerging markets fluctuate, along with fluctuations in the exchange rate. In emerging markets, an exchange rate devaluation often causes a sharp expansion in exports.

B. Composition Biases: Firms with Different Imported Input Shares

Now suppose that there are two types of exporting firms, with differing technologies. They are in industry 0 and industry 1. The firms within each industry share the same technology. Specifically, suppose that their imported input shares are different, i.e. $\alpha_0 < \alpha_1$. The firm specific supply function (8) can be re-written as:

$$\ln y_{it} = -\alpha_0 (1-d_i) \ln e_t - \alpha_1 d_i \ln e_t + (1-d_i)\varphi_{0t} + d_i \varphi_{1t} + \ln a_{it}, \tag{16}$$

where

$$\varphi_{0t} \equiv \ln \frac{p_t^f}{2} - (1-\alpha_0) \ln w_t^f - \alpha_0 \ln w_t^d,$$
$$\varphi_{1t} \equiv \ln \frac{p_t^f}{2} - (1-\alpha_1) \ln w_t^f - \alpha_1 \ln w_t^d,$$

and $d_i = 1$ if firm i belongs to industry 1, and $d_i = 0$, otherwise.

Again, the consistently aggregated microeconomic relation from (16) is obtained by averaging across all firms:

$$\begin{aligned} E_i(\ln y_{it}) &= -\alpha_0 (1-P_1) \ln e_t - \alpha_1 P_1 \ln e_t + (1-P_1)\varphi_{0t} + P_1 \varphi_{1t} + \zeta_t + E_i \eta_i + \gamma E_i z_{it} \\ &= -\overline{\alpha} \ln e_t + \overline{\varphi_t} + \zeta_t + E_i \eta_i + \gamma E_i z_{it}, \end{aligned} \tag{17}$$

where

$$\overline{\alpha} = \alpha_0 (1-P_1) + \alpha_1 P_1,$$
$$\overline{\varphi_t} = \ln \frac{p_t^f}{2} - (1-\overline{\alpha}) \ln w_t^f - \overline{\alpha} \ln w_t^d,$$

and P_1 denotes the fraction of exporting firms belonging to industry 1. Simplifying,

$$\ln E_i(y_{it}) = -\overline{\alpha} \ln e_t + \overline{\varphi_t} + \Psi_t, \tag{18}$$

where Ψ_t is given as before in (14). Assume that (18) is estimated including Ψ_t, that is, controlling for omitted variable bias.

With aggregated or macroeconomic data, the estimated exchange rate elasticity is the average elasticity, $\overline{\alpha}$. The average elasticity is affected by the composition of industries. For example, when industry 0, the industry with a high share of imported inputs is the dominant exporting industry, the estimated average exchange rate elasticity of exports will be close to zero. In other words, the higher the fraction of exporting firms in the economy with a high reliance on imported inputs, the more likely we are to observe the exchange rate disconnect puzzle.

This bias can worsen when the fraction of exporting firms with high input shares, P_1, is trending over time. Suppose P_1 trended in the same direction as the exchange rate, $P_{1t} = \chi + \kappa \ln e_t$. The exchange rate and $\overline{\alpha}$ will then be positively correlated. An appreciation in the exchange rate will raise $\overline{\alpha}$, and the estimate of -$\overline{\alpha}$ (in 18) will be biased towards zero. Even if the appreciation of the exchange rate lowered export volumes, because of the bias in the estimate of $\overline{\alpha}$, it may appear that exports and exchange rates are uncorrelated in the data.

2.4. Foreign Demand

Our model of the determination of export volumes assumes that firms are small; they can export as much as they can supply at the prevailing export or foreign price, p_t^f . That is, foreign demand is infinitely elastic, or flat. The export or foreign price is fixed, or shifts exogenously up and down with global shocks, such as shifts in global growth rates. In our estimation below, we thus instrument for the export price with an index of foreign GDP levels.

2.5. The Price Setting Case

In the Appendix, we derived the estimating equation (7), for the generalized price setting firm. In the price setting case, the export or the foreign price, p_t^f , becomes endogenous, and does not appear in the estimating equation. All other explanatory variables are the same, as in the price taking case.

We tried estimating the firm level regression (7), and the aggregate regression (18), after dropping the export price. The results were generally satisfactory with a negative and significant coefficient on the exchange rate (see Tables 7(a) and 7(b)) for the aggregate regression (18). However, since our model is partial equilibrium and we do not explicitly model foreign demand, it is difficult to interpret the price setting case, where export quantities depend on foreign demand. Thus, here we omit the empirical results for the price setting case.

3. Data Description

3.1. Firm and Industry Level Data

We use firm level annual data for Japanese four digit export industries for the years 1982-1997. Since we are interested in exporting firms, we only include industries with ratios of average export sales to total sales of over 12 percent. The firm level panel data are from the Japan Development Bank Corporate database; from our criteria, the usable number of exporting firms is 312. In terms of value, exports from these 312 firms comprise over 90 percent of total Japanese manufacturing exports.

As an exchange rate measure for the firm level analysis, 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, using their trade weights with Japan. Besides these 15 countries, less than 5 percent of Japan's trade is with other countries. For trade weighted GDP, we take Japan's top 15 trading partner's GDP, and weight their GDPs by their trade weights with Japan. The annual nominal exchange rates and foreign real GDPs are from the *International Financial Statistics* (IMF), and trade weights are computed from the *Japan Statistical Yearbook*. Export quantities are from the Japan Development Bank database. Export quantities are defined as export values divided by the export price deflator (base year= 1985) for the industry.[5] For industry specific Japanese export prices, we use industry specific export price indices – foreign currency bases – from the Bank of Japan Economic and Financial database. We assume that these prices are identical to the industry specific prices that appear in foreign demand.

For the prices of imported foreign inputs used in the Japanese firm's production, we take average spot crude oil market prices, and the metal price index from the *International Financial Statistics*. For industry specific domestic input prices, we take industry specific domestic wages from the Japan Statistical Yearbook. Industry specific labor productivity is defined as industry output divided by the labor employed in that industry. Imported import shares are calculated from the Japanese Input-Output tables (from Dekle (2005)).

3.2. Descriptive Statistics and the Export Volume--Exchange Rate Correlation in Japanese Firm Level Data

Table 3 shows some descriptive statistics of our data. Our 312 firms belong to 52 four digit level industries. We aggregate these industries into 6 two digit level industries. The largest export industry is transport equipment; the industry with the highest export share is precision equipment. Transport equipment also has the largest domestic sales.

[5] 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.

As a preliminary look at the firm level data, we run vector autoregressions of export volumes and exchange rates, for our two digit level industry categories (Tables 4(a) and 4(b)). The last column, "All Industries" pools all 6 industries. The data are annual and range from 1982 to 1997 (15 observations). In the "levels" specification, the exchange rate coefficients (contemporaneous and lagged combined) are significant, but have the wrong (positive) sign for all industries. In the differenced specification, the coefficients have the correct negative sign for the precision equipment industry, and for the "pooled" industries.

Comparing the results in Tables 2 and 4, the use of firm level data aggregated to the industry level is clearly more favorable to finding a negative relationship between exports and exchange rates than in country level data. In our industry level data, the heterogeneity across firms, for example, in import shares, will be lower than in country level data. This should lead to less composition bias in industry level data, and may explain the negative, significant correlation between exports and exchange rates in industry level data.

It is encouraging that for some industries, an exchange rate appreciation leads to a fall in export volumes. Below, we show empirically that when we control for the biases inherent in aggregation, the correct sign between export volumes and exchange rates can be retrieved even more regularly.

4. Estimation of Firm Level Exports

4.1 Estimates with Firm Level Data: Ordinary Least Squares

Rewriting (7), we obtain,

$$\ln y_{it} = \beta_0 - \beta_1 \ln e_t + \beta_2 \ln p_t^f - \beta_3 \ln w_t^f - \beta_4 \ln w_t^d + \ln a_{it} \qquad (20)$$

where e_t denotes the nominal exchange rate, p_t^f, the foreign price of the export good, w_t^d, the price index for domestic inputs, w_t^f, the price index for imported inputs, and a_{it}, total factor productivity (TFP), which includes ε_{it}, the error term, representing unobservable firm level productivity shocks. We assume the error term is stationary and serially uncorrelated. For domestic input prices, we use industry specific wages; and for foreign input prices, oil and metal price indices.

In most of our preliminary specifications, the coefficient on the foreign price of exports, β_2, was insignificant. If our benchmark model of the price taking, competitive Japanese firm is correct, then export prices are determined by foreign demand. If unobservable variables that drive foreign demand are correlated with the exchange rate or other explanatory variables, however, we cannot consistently estimate coefficients, including the coefficient on foreign demand, and we should use instrumental variables. We thus use the trade weighted foreign GDP level as an instrument for the foreign price of exports. As world growth—and demand—increases, export prices are bid up.

In addition, in our preliminary specifications, industry specific wages had the wrong (positive) sign. We initially attributed this to the correlation between industry specific wages and industry specific labor productivity. To remove this multicollinearity, we regressed wages on productivity, took the residual, and included this residual in the regressions. The "wage" variable in the regressions is thus "filtered" from productivity effects, and is uncorrelated with productivity. In all of our specifications, the export price is instrumented, and the "filtered" wage is included as an explanatory variable.

As for the observable firm specific productivity variables, a_{it}, we use industry specific labor productivity as a proxy for firm total factor productivity.[6] We also include as a determinant of productivity; the share of output that is exported. Increasing returns trade models such as Grossman and Helpmann (1991) predict that firms that export more are more productive. In a test of the Grossman and Helpmann model, Clerides, Lach and Tybout (1998) find using firm level data for Columbia, Mexico, and Morocco that firms with a high ratio of exports to production subsequently export more.[7] In our panel data

[6] Many studies use labor productivity as a proxy of TFP. (See Chinn (1995), Hsieh (1982), Marston (1990), and Rogoff (1992)).

[7] However, the inclusion of exports divided by output may induce spurious correlation, since exports would then appear in both sides of the equation. To reduce the possibility of spurious correlation, we construct a new export share variable. This new export share variable is the average export share in the four digit level industry that the firm belongs to, *excluding* the firm's own export share. For example, say there are 10 firms in the ordinary steel industry. The export share variable for firm i is the average export share of the 9 other firms, excluding firm i.

estimates, we also include unobserved firm level fixed or random effects as additional determinants of productivity.

Finally, to capture the effects of heterogeneity in imported input and export shares, we interact e_t with the *produc*t of the share of inputs that are imported (the import share) and the export share.[8] In the model, the firm was assumed to be a purely exporting firm. However, in practice, firms both export and sell domestically. Say there are two firms, one firm exporting 90 percent of its output, and another firm exporting 10 percent of its output, but both with the same share of imported inputs, at 30 percent. For the same exchange rate appreciation, the firm exporting 90 percent will have a larger decline in export quantities. Thus, we need to interact the imported input share with the export share, to control for differing export shares across firms. The coefficient on the import share interaction variable should have the opposite sign from $-\beta_1$, and be positive. In addition, while in the benchmark model, we allowed only for high α_1 and low α_0 import shares, more realistically in our empirical work below, we allow for α to be continuous.

The ordinary least squares estimates of equation (20) using firm level data are depicted in the first two columns of Table 5 (a). The coefficients on the exchange rate have the correct negative sign, and are highly significant. The productivity variables--labor

[8] We use the imported input shares by industry as calculated by Dekle (2005).

productivity, and the export share—are all highly significant and positive, implying that rapid productivity growth is associated with an expansion of exports. The price variables—export prices, oil prices, and wages—are all insignificant. The imported input share-export share-exchange rate interaction variable is also insignificant.

4.2 Estimates with Firm-Level Data: Panel Estimates

Since labor productivity and export shares are imperfect measures of firm level productivity, we estimate (20), controlling for unobserved firm specific effects, particularly, productivity effects. The firm specific variable, η_i that is a component of a_{it} in (20) can be either fixed or random. The random and fixed effects estimates of (20) are in Table 5(a). We performed Hausman specification tests to see whether the estimates of the random or the fixed effects model better fit the data. We found that the random effects model better fit the data, although the fixed effects results are very similar. We note that in all specifications, the coefficient on the exchange rate is negative, and highly significant. An appreciation of the exchange rate lowers export volumes.

Labor productivity is not significant, but the export share is highly significant. The export price and wages have the wrong sign, while an increase in oil (input) prices (correctly) depress export quantities. The imported input share interaction variable is highly significant, and has the correct, positive sign.

That the panel data estimates are (somewhat) superior to the cross-section estimates suggest that firm specific productivity effects may importantly affect the responsiveness of exports to exchange rates. If firm specific effects are important, then it would be difficult to retrieve, say, a firm level parameter such as the exchange rate elasticity of exports from aggregated data. In the aggregate regressions below, we control for these aggregated productivity effects by including the export share and the variance of the firm specific productivity shocks, $\frac{\delta_t^2}{2}$, as in (12).

4.3 Estimates with First Differenced Firm Level Data

In Table 5(b), we depict estimates of (20) when the firm level data are log first differenced. First differencing eliminates potential problems arising from data non-stationarity, and provides an additional robustness check.

In all three specifications (ordinary least squares, random and fixed effects), in the first differenced version, the coefficients on the exchange rate remain negative, and highly significant. An increase in productivity variables (labor productivity and export share) raises exports. The imported input share interaction variable is significant, but has the wrong sign. Wages also still have the wrong (positive) sign.

That the sign on wages is always positive suggests that Japanese firms may not be wage-takers, as assumed by the model. For example, suppose that the correct model is of the

Japanese firm and the union negotiating, and dividing up revenues (Aoki, 1988, Ch. 5). If firms with high exports have high revenues, then such high export firms may also pay higher wages, resulting in the positive correlation between wages and exports.

5. Estimation of Exports Using Consistently Aggregated Data

5.1. Estimates with Aggregated Data

We estimate the aggregate relation (18) between exports and exchange rates, using two aggregated dependent variables. First, using our firm level data, we average exports over all firms and take logs, $\ln E_i(y_{it})$. As our second source of aggregate export data, we use the annual export volume figures for Japan from the *International Financial Statistics,* and take logs.

For the explanatory variables, as before, we include the log exchange rate, and price variables. To control for the effects of time varying import shares, which may affect the exchange rate elasticity of exports, we again include the average import share interacted with the product of the average export share and the exchange rate. For the aggregate productivity variables, Ψ_t, we include average labor productivity and the average export share.[9] As in (18), we also include in the regression, the time varying firm specific error

[9] Recall that the average export share is defined as $\sum_i \frac{\exp orts_{it}}{totalsales_{it}} / N$, whose calculation requires firm level data.

(productivity), σ_t^2, which can be estimated from firm level data.[10] Again, the log export price is instrumented by trade weighted world GDP growth.

Tables 6(a) and 6(b) depict the estimates of the aggregated relation (18), using aggregated firm level data as the explanatory variable. (6(a) is in levels, and 6(b) is in first differences). It is especially important to estimate (18) in first differences, since the aggregate variables are likely to be non-stationary, possibly leading to spurious correlation among the variables. (The results of the Dickey-Fuller non-stationary tests are described below.) The exchange rate has a negative and significant sign. The exchange rate interaction term is insignificant in both specifications, suggesting that heterogeneous import shares are not the source of bias in the aggregate regressions. The export price, and the import prices have the right sign, again with the exception of wages. The productivity variables—labor productivity and the export share—are significant and have the correct sign. The time varying firm specific error (productivity) is significant in the levels specification, but insignificant in the first differenced specification.

Tables 7(a) and 7(b) depict the estimates of (18), using export volume data from the Japanese macroeconomic (IFS) statistics. The data used here for both export volumes and

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[10] $\hat{\delta}_t^2$ are the cross-section residual variances from the estimate of (20). Specifically, we take the estimated residual variances from the fixed effects model depicted in Table 5(a) for the levels specification, and in Table 5(b) for the first-differenced specification.

exchange rates are the same as those used in the simple correlations in Tables 1 and 2. (Table 7(a) is the levels specification; 7(b) is the first differenced specification.) For both 7(a) and 7(b), various sets of control variables are included to determine what variables matter in impacting export quantities. With the exception of (1), (3-2), and (6) for the levels specification, and (1), (2), (3-2), and (4) in the first differenced specification, the exchange rate is negative and significant.

Insignificant signs on the exchange rate appear in those regressions where the export share has been omitted. The variance of firm specific productivity also seems to impact the significance of the exchange rate. Thus, we conjecture that the omission of productivity variables, especially the export share, may be the reason for finding an insignificant sign on the exchange rate coefficient, in aggregate regressions of export volumes on exchange rates.

Although we do not depict the results here (to save space), we also estimated (18) using cointegration techniques. If the variables appearing in (18) are individually non-stationary, but are cointegrated, then (18) can be estimated in levels. Indeed, Augmented Dickey Fuller tests on all the individual variables appearing in Table 6(a) and 7(a) showed that the null of non-stationarity could not be rejected for any of the variables. However, for their first differences, the null of non-stationarity could be rejected. (Thus, the first differenced estimates in Tables 6(b) and 7(b) are econometrically consistent, but with the wrong standard errors). We thus re-estimated the specifications in columns (2) in Table 6(a) and (7) in Table 7(a) using Johansen's (1991) method, and found that the variables were cointegrated. The estimate on the exchange rate coefficient was still negative and significant (with the standard errors corrected).

In sum, with appropriate control variables, exchange rates do appear to influence export volumes at the aggregate level. When appropriate theoretically consistent explanatory variables are included in the regressions, and omitted variable biases are controlled for, an exchange rate appreciation appears to depress export volumes, even in aggregated or macroeconomic data.

6. Conclusion

We show by using firm level data, and consistently aggregated firm level data, that exchange rates have a statistically significant negative relationship with export quantities. An exchange rate appreciation lowers export volumes. We build a microeconomic model of the exporting firm, where we derive the relationship between export volumes and exchange rates. We consistently aggregate our model, and show that in estimating the aggregate model, it is important to control for output and input prices, productivity, and variables representing firm level heterogeneity, such as in imported input shares and in productivity. We show that unless these control variables are included, the relationship between aggregate exports and exchange rates is likely to be zero.

In our estimation, we found that it is crucial to include productivity variables, such as the export share to obtain the correct sign between exports and exchange rates. The omission of prices and import shares do not impact the coefficients on the exchange rate. However, when productivity variables are excluded, estimates with aggregate data suffer from classical omitted variable bias, resulting in a statistically insignificant relation between exports and exchange rates.

In the past, with macroeconomic data, finding a robust, negative simple correlation between quantities, say exports, and the nominal exchange rate was elusive. This finding has driven researchers to construct models in which nominal exchange rates are "disconnected" from real economic variables (for example, Obstfeld and Rogoff, 2000; Devereux and Engel, 2002). In particular, Duarte (2003) attempts to replicate the lack of correlation between export volumes and exchange rates, with a calibrated general equilibrium model. Duarte (2003) shows that by incorporating local currency pricing (LCP) and incomplete asset market assumptions, a conventional general equilibrium model can account for the disconnect puzzle. In her model, a positive monetary shock depreciates the nominal exchange rate on impact, but because of LCP, the relative prices of home and foreign goods are unchanged. The expenditure switching effect is eliminated; only a small wealth effect (from the increase in money supplies) remains. However, since local consumers have a bias towards local goods, the wealth effect on revenues is quantitatively small. Therefore, exchange rate changes have little apparent effect on consumer demands, and the volatility of home consumption (and the volatilities of other real variables) is separated from the volatility of the nominal exchange rate.

Our model is a microeconomic, partial equilibrium model of the firm; and the empirical results from our model cannot be directly compared to the results from the general equilibrium models.[11] However, our empirical results may point to some directions that may prove fruitful in future general equilibrium modeling. We too find that the *unconditional* correlation between exchange rates and exports (real quantities) is zero in macroeconomic data (Table 1). However, we show that the correlations between exchange rates and exports *conditional* on some variables, particularly, the distribution of firm level productivities and the export share, are significant and negative (Tables 6 and 7). It may be interesting to develop a general equilibrium model that captures *both* the zero unconditional correlation between exchange rates and exports, and this non-zero conditional correlation. The results in this paper suggest that in such a general equilibrium model, it may be important to account for firm level heterogeneities in productivities, and in particular, how such

[11] In our model, an exchange rate depreciation causes revenues to increase by more than costs, thereby inducing the firm to supply more exports. We do not explicitly model foreign consumers or demand, but rather

productivities are related to a firm's export share.

Appendix: A More General Model of the Exporting Firm

Assume that the exporting firm i at time t produces an export good y_{it} by combining domestic input x_{it} with imported input z_{it}, to maximize its profit, given firm i's cost function, $C_i(w_t, v_t / e_t, y_{it})$. (We drop a_{it}, firm specific productivity from the cost-function, but it can enter multiplicatively, with y_{it} as $a_{it} y_{it}$, without affecting the analysis). The first order condition for profit maximization is (dropping the time subscript):

$$\frac{m(y)}{e} = C_y(w, \frac{v}{e}, y),$$

where w is the price of the domestic input, v, the price of the imported input in the foreign currency, and e is the nominal exchange rate. $m(y) = \frac{dp(y)}{dy} y + p(y)$ indicates marginal revenue. We can solve for the export volume:

$$y = g(e, w, v) \qquad \text{(A1).}$$

Totally differentiating (A1), we get in elasticity form:

$$d \ln y = \varepsilon_{ye} d \ln e + \varepsilon_{yw} d \ln w + \varepsilon_{yv} d \ln v \qquad \text{(A2),}$$

where (A2) is the more general version of (7), the estimation equation in the text (without the productivity term, a_i). Note that unlike in (7), in (A2), when the firm sets the export price, p, the export price does not appear in the estimating equation, because the export price

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we assume that foreign demand is infinitely or highly elastic; that foreign prices do not depend on domestic becomes endogenous.

The elasticity of exports with respect to the exchange rate, ε_{ye} can be shown to equal:

$$\varepsilon_{ye} = \frac{\varepsilon_{zy}\alpha[\frac{1}{1-\varepsilon_d^{-1}}]-1}{\mu-\varepsilon_p} \qquad \text{(A3)}$$

where ε_d is the demand elasticity of exports, ε_p is the elasticity of marginal revenue, and μ is the slope of the marginal cost function, and ε_{zy} is the elasticity of imported input demand with respect to exports, and α is the imported input share.

For the price taking case, $\varepsilon_d = \infty$, $\varepsilon_p = 0$, and $\mu >= 0$. Thus, whether exports contract when the exchange rate appreciates depends on whether $\varepsilon_{zy} \prec 1/\alpha$. If $\varepsilon_{zy} >= 1/\alpha$, the exchange rate appreciation makes imported inputs, and export production so expensive, that exports contract. $\varepsilon_{zy} \prec 1/\alpha$ is typically satisfied in practice. For example, the industry with the highest imported input share in our sample, is the steel industry, with $\alpha = 0.20$. For exports to expand with an exchange rate appreciation, $\varepsilon_{zy} \geq 5$, which means that imported inputs by the steel industry have to increase by 50 percent when exports expand by 10 percent—which is unrealistic.

For the price setting case, whether exports contract when the exchange rate appreciates depends on whether $\varepsilon_{zy}[\frac{1}{1-\varepsilon_d^{-1}}] \prec \frac{1}{\alpha}$. Since $(\frac{1}{1-\varepsilon_d^{-1}})$ is always below unity,

firm supply. Thus, we are implicitly assuming that foreign expenditure switching is infinite or very high.

again in practice, an exchange rate appreciation should reduce exports at the firm level.

References

1. Aoki, M., 1988, *Information, Incentives, and Bargaining in the Japanese Economy.* New York: Cambridge University Press.
2. Baxter M., and A. C. Stockman, 1989, "Business Cycle and the Exchange Rate Regime: Some International Evidence", *Journal of Monetary Economics* 23, 377-400.
3. Bergoeing, R. and T. Kehoe, 2003, "Trade Theory and Trade Facts," mimeo., Federal Reserve Bank of Minneapolis.
4. Bernard, A., J. Eaton, J.B. Jenson, and S. Kortum, 1999, "Plants and Productivity in International Trade: A Ricardian Reconciliation", mimeo, Boston University.
5. Blackorby, C., D. Primont, R. R. Russell, 1978, *Duality, Separability, and Functional Structure: Theory and Economic Application*, Amsterdam, North-Holland.
6. Chinn, M., 2005, "Incomes, Exchange Rates, and the U.S. Trade Deficit, Once Again," manuscript, University of Wisconsin.
7. Crucini, M., and M. Shintani, 2002, "Persistence in the Law of One Price Deviations: Evidence from Microdata," manuscript, Vanderbilt University.
8. Chowdhury, A.R., 1993, "Does Exchange Rate Volatility Depress Trade Flows? Evidence from Error Correction Models", *The Review of Economics and Statistics*, 75, 700-706.
9. Clerides, S., Lach, S., and Tybout, J., 1998, "Is Learning by Exporting Important? Micro-dynamic Evidence from Columbia, Mexico, and Morocco," *Quarterly Journal of Economics*, pp. 903-947.
10. Cushman, D.O., 1983, " The Effects of Real Exchange Rate Risk on International Trade", *Journal of International Economics* 15, 45-63.
11. Das, S., Roberts, M., and J. Tybout, 2001, "Market Entry Costs, Producer Heterogeneity, and Export Dynamics", *NBER Working Paper* No. 8629.
12. Deardorff, A., 1989, "Testing Trade Theories and Predicting Trade Flows," in Ronald Jones and Peter Kenen (eds), *Handbook of International Economics.*
13. Dekle, R. , 2005, "Exchange Rate Exposure and Foreign Market Competition: Evidence from Japanese Firms," *Journal of Business,* 78, 281-299.
14. Dekle, R. and H. Ryoo, 2002, "Exchange Rate Fluctuations, Financing Constraints, Hedging, and Exports: Evidence from Firm Level Data", mimeo.
15. Devereaux, M. and C. Engel, 2002, "Exchange Rate Pass-Through, Exchange Rate Volatility, and Exchange Rate Disconnect," *Journal of Monetary Economics*, 49(5), 913-940.
16. Duarte, M., 2003, "Why Don't Macroeconomic Quantities Respond to Exchange Rate Variability," *Journal of Monetary Economics*, 50(4), 889-913.
17. Engel C., 2002, "Expenditure Switching and Exchange Rate Policy", *NBER Working Paper* No. 9016.

18. Forbes, K., 2002, "How Do Large Depreciations Affect Firm Performance?", *NBER Working Paper* No. 9095.
19. Flood, R. P., and A. K. Rose, 1995, “Fixing Exchange Rates: A Virtual Quest for Fundamentals”, *NBER Working Paper* No. 4503.
20. Frankel, J., 1984, *The Yen-Dollar agreement: Liberalizing Japanese Capital Markets,* Institute of International Economics, Washington, D.C.
21. Frankel, J., and S. Wei, 1994, “Trade Blocs and Currency Blocs”, *NBER Working Paper* No. 4335.
22. Goldstein, M. and M. S. Khan, 1985, "Income and Price Effects in Foreign Trade", *Handbook of International Economics*, vol. 2. R.W. Jones and P.B. Kenen, eds. Amsterdam: North-Holland.
23. Gotur, P., 1985, “Effects of Exchange Rates Volatility on Trade: Some Further Evidence”, *International Monetary Fund Staff Papers* 32, 475-512.
24. Grossman, Gene, M. and Elhanan Helpman, 1991, *Innovation and Growth in the Global Economy*, Cambridge: MIT Press.
25. He, J., and L. K. Ng, 1998, “The Foreign Exchange Exposure of Japanese Multinational Corporations”, *Journal of Finance* 53, 733-753.
26. Hooper, P., K. Johnson, and J. Marquez, 2000, "Trade Elasticities for G-7 Countries”, *Princeton Studies in International Economics* No. 87.
27. Hsieh, D., 1982, “The Determination of the Real Exchange Rate: The Productivity Approach”, *Journal of International Economics* 12, 355-362.
28. Imbs, J., Muntaz, H., Ravn, M., and Helena Rey, 2005, “PPP Strikes Back: Aggregation and the Real Exchange Rate,” *Quarterly Journal of Economics*, 120, 1-43.
29. International Monetary Fund, various years, *International Financial Statistics.*
30. *Japan Statistical Yearbook,* various years.
31. Johansen, S., 1991, “Estimation and Hypothesis Testing of Cointegrated Vectors in Gaussian VAR models,” *Econometrica*, 59(6), pp. 1551-1580.
32. Kenen, P. B., and D. Rodrik, 1986, “Measuring and Analyzing the Effects of short-Term Volatility in Real Exchange Rates”, *The Review of Economics and Statis*tics 68, 311-315.
33. Lewbel, A., 1992, “Aggregation with Log-Linear Models,” *Review of Economic Studies*, V. 59: 635-642.
34. Marston, R., 1990, “Systematic Movement in Real Exchange Rates in the G-5: Evidence on the Integration of Internal and External Markets”, *Journal of Banking and Finance* 14, 1023-1044.
35. Meese. R. and K. Rogoff, 1983, “Empirical Exchange Rate Models of the Seventies,” *Journal of International Economics*, 14, 3-24.
36. Mussa, M., 1986, “Nominal Exchange Rates Regimes and the Behavior of Real Exchange Rates: Evidence and Implications”, *Carnegie-Rochester Conference Series on Public Policy* 25, 117-216.

37. Obstfeld, M., 2002, “Exchange Rates and Adjustment: Perspectives from the New Open Economy Macroeconomics”, manuscript, University of California, Berkeley.
38. Obstfeld, M. and K. Rogoff, 2000, “The Six Major Puzzles in International Macroeconomics: Is there a Common Cause?” in Ben S. Bernanke and Kenneth Rogoff, editors, *NBER Macroeconomics Annual, 2000,* Cambridge: MIT Press.
39. Orcutt, G. H., 1950, “Measurement of Price Elasticities in International Trade”, The *Review of Economics and Statistics* 32, 117-132.
40. Parley, D., and S. Wei, 1993, "Insignificant and Inconsequential Hypotheses: The Case of U.S, Bilateral Trade", *Review of Economics and Statistics* 4, 606-615.
41. Pesaran, H. and R. Smith, 1995, “Estimating Long-Run Relationships from Dynamic Heterogeneous Panels, “ *Journal of Econometrics,* 68, 79-113,
42. Pozo, S., 1992, “Conditional Exchange Rate Volatility and the Volume of International Trade: Evidence from the Early 1900s”, *The Review of Economics and Statistics* 74, 325-329.
43. Rogoff, K., 1992, “Traded Goods Consumption Smoothing and the Random Walk Behavior of the Real Exchange Rates”, *NBER Working Paper* No. 4119.
44. Ruhl, K., 2003, “Solving the Elasticity Puzzle in International Economics, manuscript, University of Texas, Austin.
45. Stoker, T. M., 1984, “Completeness, Distribution Restrictions, and the Form of Aggregate Functions,” *Econometrica*, V. 52: 887-907.
46. Stoker, T.M., 1993, “Empirical Approaches to the Problem of Aggregation Over Individuals,” *Journal of Economic Literature*, pp. 1827-1874.
47. Thursby J.G., and M.C. Thursby, 1987, “Bilateral Trade Flows, the Linder Hypothesis, and Exchange Risk”, *The Review of Economics and Statistics* 69, 488-495.
48. Tornell, A. and F. Westermann, 2002, “Boom-Bust Cycles in Middle Income Countries: The Facts,” *IMF Staff Papers.*

Table 1: Disconnect Puzzle with Macroeconomic (IFS)Data (Log Differenced Data)

	Canada	France	Germany	Italy	UK	US	Japan	Pooled[2)]
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)***	4.14 (56.04)***
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)	-0.024 (-1.11)
R-squared	0.0721	0.0003	0.0872	0.2711	0.0079	0.1808	0.006	0.05

Note: All variables are in log terms. t-statistics are in parenthesis.
*, ** and *** are significant at 10%, 5% and 1% significance levels respectively.
1. Nominal effective exchange rates. All variables are log differenced.
2. Using G-7 countries with the country dummy.

Table 2(a): Disconnect puzzle with Macroeconomic (IFS) Data (Log Level Data)

	Canada	France	Germany	Italy	UK	US	Japan	Pooled[2)]
Constant	1.54 (4.44)***	-0.95 (-0.89)	4.93 (6.97)***	6.87 (7.44)***	0.88 (3.67)***	1.83 (5.62)***	3.46 (10.07)***	2.91 (20.16)***
Exchange Rate[1)]	-0.13 (-0.62)	1.09 (1.11)	0.30 (0.51)	-0.56 (-0.75)	0.02 (0.18)	0.51 (2.10)**	0.34 (1.13)	0.17 (0.96)
Lagged Export	0.75 (15.48)***	0.37 (5.35)***	0.19 (2.63)***	-0.16 (-2.25)**	0.68 (11.98)***	0.55 (9.52)***	0.08 (1.07)	0.34 (13.04)***
Lagged Exchange Rate[1)]	-0.04 (-0.20)	-0.47 (-0.49)	-0.75 (-1.23)	-0.01 (-0.01)	0.01 (0.06)	-0.63 (-2.55)**	-0.35 (-1.15)	-0.37 (-2.13)**
Trend	0.001 (5.09)***	0.003 (6.98)***	0.004 (8.66)***	0.004 (8.42)***	0.001 (5.55)***	0.002 (7.37)***	0.003 (7.06)***	0.003 (23.86)***
R-squared	0.99	0.85	0.85	0.74	0.98	0.97	0.70	0.92

Note: All variables are in log terms. t-statistics are in parenthesis.
*, ** and *** are significant at 10%, 5% and 1% significance levels respectively.
1. Nominal effective exchange rates.
2. Using G-7 countries with the country dummy.

Table 2(b) Disconnect puzzle with Macroeconomic Data (Log Differenced Data)

	Canada	France	Germany	Italy	UK	US	Japan	Pooled[2)]
Constant	0.01 (3.24)***	0.00 (0.28)	0.01 (0.77)	0.00 (0.17)	0.01 (3.34)***	0.01 (1.33)	0.00 (-0.50)	0.01 (-1.03)
Exchange Rate[1)]	0.04 (0.19)	1.67 (1.47)	1.09 (1.48)	-2.30 (-2.19)**	-0.09 (-0.76)	0.07 (0.26)	0.21 (0.56)	-0.04 (-0.22)
Lagged Export	-0.32 (-4.68)***	-0.31 (-4.44)***	-0.41 (-6.14)***	-0.47 (-7.31)***	-0.55 (-8.75)***	-0.32 (-4.57)***	-0.49 (-7.65)***	-0.42 (-17.10)***
Lagged Exchange Rate[1)]	-0.50 (-2.29)**	-0.97 (-0.85)	-1.19 (-1.64)	0.72 (0.69)	-0.05 (-0.39)	-0.14 (-0.52)	-0.12 (-0.33)	-0.13 (-0.63)
R-squared	0.12	0.10	0.18	0.24	0.29	0.10	0.24	0.18

Note: All variables are in log differenced terms. t-statistics are in parenthesis.
*, ** and *** are significant at 10%, 5% and 1% significance levels respectively.
1. Nominal effective exchange rates.
2. Using G-7 countries with the country dummy.

Table 3 Descriptive Statistics[1]

Industry Group	Average Exports[2)]			
	Mean	Min	Max	Max
Oil and Gas, Chemicals	16,541	141	152,491	45.3%
Steel	56,669	228	507,620	29.7%
Metal machinery	40,220	180	548,127	67.8%
Electric machinery	89,286	177	1,240,000	94.4%
Transport equipment	185,171	1,708	2,430,000	66.7%
Precision equipment	64,071	446	611,000	78.7%
All Industries	70,601	141	2,430,000	94.4%
Industry Group	**Average Domestic Sales**			**# of firms**
	Mean	Min	Max	
Oil and Gas, Chemicals	124,881	3,093	771,066	65
Steel	226,419	7,328	1,670,000	30
Metal machinery	99,544	3,468	1,660,000	67
Electric machinery	193,815	2,629	2,480,000	93
Transport equipment	284,600	9,648	4,110,000	38
Precision equipment	47,729	2,050	188,531	19
All Industries	164,506	2,050	4,110,000	312

Note 1. Firm averages between 1982-1997 in the industry.
2. In thousands of 1985 yen.

Table 4(a): Regression Results by Industry (Firms Aggregated by Industry; Log Level Data)

	Oil and Gas, Chemicals	Steel	Metal machinery	Electric machinery	Transport equipment	Precision equipment	All Industries
Constant	1.72 (4.56)***	-0.32 (-0.63)	1.08 (2.56)**	0.19 (0.46)	0.48 (1.08)	1.54 (1.93)*	0.70 (3.54)***
Exchange rate	1.48 (16.01)***	-0.65 (-4.41)***	0.15 (1.35)	2.15 (21.05)***	0.39 (3.25)***	0.78 (3.88)***	1.01 (19.57)***
Lagged export	-1.34 (-14.28)***	0.45 (3.06)***	-0.21 (-1.88)*	-2.43 (-23.57)***	-0.44 (-3.60)***	-0.74 (-3.67)***	-1.11 (-21.41)***
Lagged exchange rate	0.93 (81.74)***	0.96 (77.16)***	0.92 (74.51)***	0.91 (89.09)***	0.96 (83.81)***	0.92 (40.29)***	0.93 (178.76)***
R-squared	0.87	0.93	0.84	0.85	0.92	0.85	0.87

Note: All variables are in log terms. t-statistics are in parenthesis.
*, ** and *** are significant at 10%, 5% and 1% significance levels respectively.

Table 4(b): Regression Results by Industry (Firms Aggregated by Industry, Log Differenced Data)

	Oil and Gas, Chemicals	Steel	Metal machinery	Electric machinery	Transport equipment	Precision equipment	All Industries
Constant	0.07 (7.57)***	-0.04 (-1.81)*	0.02 (1.12)	0.15 (8.84)***	0.01 (0.69)	0.05 (1.83)*	0.06 (8.54)***
Exchange rate	0.23 (2.49)**	0.13 (0.59)	-0.05 (-0.30)	-0.09 (-0.57)	0.26 (1.57)	-0.16 (-0.60)	0.03 (0.43)
Lagged export	-0.13 (-2.92)***	-0.25 (-2.56)**	-0.06 (-0.79)	0.17 (2.10)**	-0.18 (-2.36)**	0.35 (2.96)***	0.01 (0.35)
Lagged exchange rate	-0.02 (-1.72)*	-0.12 (-3.86)***	-0.11 (-5.19)***	-0.02 (-1.30)	-0.08 (-3.11)***	-0.22 (-6.26)***	-0.06 (-6.22)***
R-squared	0.03	0.04	0.03	0.003	0.03	0.13	0.01

Note: All variables are in log differenced terms. t-statistics are in parenthesis.
*, ** and *** are significant at 10%, 5% and 1% significance levels respectively.

Table 5(a): Firm Level Estimation Results (Log Level Data)

	OLS		Random Effects Model		Fixed Effects Model	
	(1)	(2)	(1)	(2)	(1)	(2)
Constant	58.10 (0.19)	121.77 (0.39)	72.66 (0.83)	128.45 (1.46)	70.78 (0.80)	111.72 (1.26)
Exchange rate	-0.93 (-2.21)**	-0.70 (-1.56)	-0.83 (-7.01)***	-0.64 (-5.09)***	-0.83 (-7.00)***	-0.63 (-4.97)***
Exchange rate interaction[1]		0.14 (1.35)		0.13 (4.29)***		0.15 (4.51)***
Export price[2]	-1.60 (-0.42)	-2.46 (-0.63)	-1.77 (-1.64)	-2.53 (-2.32)**	-1.74 (-1.57)	-2.25 (-2.04)**
Oil price	-0.12 (-0.46)	-0.15 (-0.58)	-0.15 (-2.04)**	-0.17 (-2.33)**	-0.15 (-2.06)**	-0.19 (-2.49)**
Wage[3]	0.43 (1.67)*	0.45 (1.74)*	0.40 (5.50)***	0.43 (5.87)***	0.40 (5.50)***	0.43 (5.97)***
Labor productivity	0.00 (0.49)	0.00 (0.53)	0.01 (0.53)	0.02 (0.85)	0.02 (0.32)	0.11 (1.67)*
Export share[4]	0.98 (27.45)***	1.61 (3.45)***	0.88 (39.00)***	1.53 (9.97)***	0.87 (37.95)***	1.58 (9.94)***
R-squared: overall	0.17	0.17	0.17	0.17	0.17	0.14
between			0.15	0.15	0.15	0.12
within			0.37	0.38	0.37	0.38

Note: All variables are in log terms. Year dummies are included.
. t-statistics are in parenthesis.* significant at 10%; ** significant at 5%; *** significant at 1%.
1. Exchange rate interaction term is interacted with export share of output and import share of input.
2. Export price is instrumented by weighted sum of trading partner's GDP's.
3. Wage is a residual wage after filtering labor productivity out.
4. The firm's export share is corrected by excluding its own export share from the average export share in a industry.

Table 5(b): Firm Level Estimation Results (Log Differenced Data)

	OLS		Random Effects Model		Fixed Effects Model	
	(1)	(2)	(1)	(2)	(1)	(2)
Constant	0.078 (2.14)**	0.139 (3.70)***	0.078 (2.14)**	0.139 (3.70)***	0.078 (2.11)**	0.139 (3.63)***
Exchange rate	-1.061 (-12.33)***	-1.061 (-12.38)***	-1.061 (-12.33)***	-1.061 (-12.38)***	-1.061 (-12.11)***	-1.058 (-12.12)***
Exchange rate interaction[1]		-1.918 (-6.16)***		-1.918 (-6.16)***		-1.932 (-5.95)***
Export price[2]	0.757 (0.84)	1.908 (2.08)**	0.757 (0.84)	1.908 (2.08)**	0.779 (0.85)	1.911 (2.05)**
Oil price	-0.102 (-2.66)***	-0.163 (-4.15)***	-0.102 (-2.66)***	-0.163 (-4.15)***	-0.101 (-2.62)***	-0.163 (-4.08)***
Wage[3]	0.224 (3.43)***	0.287 (4.35)***	0.224 (3.43)***	0.287 (4.35)***	0.229 (3.45)***	0.293 (4.36)***
Labor productivity	0.182 (1.99)**	0.257 (2.79)***	0.182 (1.99)**	0.257 (2.79)***	0.195 (2.03)**	0.265 (2.76)***
Export share[4]	0.901 (35.44)***	0.954 (35.65)***	0.901 (35.44)***	0.954 (35.65)***	0.900 (33.86)***	0.951 (34.17)***
R-squared: overall	0.23	0.23	0.23	0.23	0.23	0.23
between			0.31	0.32	0.31	0.32
within			0.22	0.23	0.22	0.23

Note: All variables are in log terms. t-statistics are in parenthesis.
* significant at 10%; ** significant at 5%; *** significant at 1%.
1. Exchange rate interaction term is interacted with export share of output and import share of input.
2. Export price is instrumented by weighted sum of trading partner's GDP's.
3. Wage is a residual wage after filtering labor productivity out.
4. The firm's export share is corrected by excluding its own export share from the average export share in a industry.

Table 6(a): OLS Estimation Results Using Aggregated Firm Level Data (Log Level Data)

	(1)	(2)
Constant	-482.45 (-5.59)***	-483.64 (-5.22)***
Exchange rate	-1.31 (-8.97)***	-1.43 (-3.70)**
Exchange rate interaction[1]		-0.07 (-0.34)
Export price[2]	6.45 (5.18)***	6.45 (4.83)***
Oil price	-0.12 (-1.96)*	-0.11 (-1.48)
Wage[3]	0.33 (2.32)*	0.35 (2.06)*
Labor productivity	1.54 (6.53)***	1.49 (5.14)***
Export share[4]	1.39 (17.51)***	1.04 (1.02)
Sigma_squared	-0.19 (-2.61)**	-0.16 (-1.44)
R-squared	0.99	0.99

Note: All variables are in log terms. Year dummies are included.
t-statistics are in parenthesis.* significant at 10%; ** significant at 5%; *** significant at 1%.
1. Exchange rate interaction term is interacted with export share of output and import share of input.
2. Export price is instrumented by weighted sum of trading partner's GDP's.
3. Wage is a residual wage after filtering labor productivity out.
4. The firm's export share is corrected by excluding its own export share from the average export share in a industry.

Table 6(b): OLS Estimation Results Using Aggregated Firm Level Data (Log Differenced Data)

	(1)	(2)
Constant	0.23 (2.89)**	0.23 (2.58)**
Exchange rate	-1.58 (-7.61)***	-1.59 (-6.97)***
Exchange rate interaction[1]		-0.14 (-0.11)
Export price[2]	5.57 (2.45)**	5.52 (2.24)*
Oil price	-0.12 (-1.64)	-0.13 (-1.44)
Wage[3]	0.47 (2.42)**	0.48 (2.25)*
Labor productivity	1.40 (3.11)**	1.38 (2.65)**
Export share[4]	1.45 (11.59)***	1.45 (10.75)***
Sigma_squared	-0.12 (-0.45)	-0.14 (-0.46)
R-squared	0.96	0.96

Note: All variables are in log differenced terms. t-statistics are in parenthesis.
* significant at 10%; ** significant at 5%; *** significant at 1%.
1. Exchange rate interaction term is interacted with export share of output and import share of input.
2. Export price is instrumented by weighted sum of trading partner's GDP's.
3. Wage is a residual wage after filtering labor productivity out.
4. The firm's export share is corrected by excluding its own export share from the average export share in a industry

Table 7 (a): OLS Estimation Results Using Macroeconomic (IFS) Data (Log Level Data)

	(1)	(2)	(3)	(3-1)	(3-2)	(4)	(5)	(6)	(7)
Constant	346.02 (0.59)	-32.98 (-1.41)	-58.46 (-1.77)	46.88 (1.40)	-110.46 (-2.39)**	-36.82 (-0.17)	-522.34 (-5.56)***	-46.91 (-1.32)	-524.60 (-5.19)***
Exchange rate	-0.42 (-0.52)	-1.32 (-4.19)***	-0.78 (-4.67)***	-0.96 (-3.81)***	0.36 (1.24)	-1.82 (-5.54)***	-1.31 (-8.97)***	-0.32 (-0.63)	-1.42 (-3.59)**
Exchange rate interaction[1]		-0.26 (-7.59)***				-0.27 (-8.46)***		2.57 (1.58)	1.07 (1.03)
Export price[2]	-7.04 (-0.78)					-0.77 (-0.24)	8.49 (5.18)***		8.52 (4.84)***
Oil price	-0.39 (-0.85)					0.02 (0.12)	-0.12 (-1.96)*		-0.11 (-1.48)
Wage[3]	0.86 (1.06)					0.89 (3.12)**	0.33 (2.32)*		0.35 (2.05)*
Labor productivity			0.41 (1.25)	1.23 (3.04)**			1.54 (6.53)***	0.71 (1.54)	1.49 (5.15)***
Export share			1.06 (8.70)***	1.33 (8.19)***			1.39 (17.51)***	0.30 (0.93)	-0.07 (-0.30)
Sigma_squared			-0.44 (-4.17)***		-0.82 (-3.93)***		-0.19 (-2.61)**	-0.51 (-3.87)***	-0.16 (-1.43)
R-squared	0.76	0.94	0.98	0.96	0.86	0.97	0.99	0.99	0.99

Note: Year dummies are included. t-statistics are in parenthesis.* significant at 10%; ** significant at 5%; *** significant at 1%.

1. Exchange rate interaction term is interacted with export share of output and import share of input.

2. Export price is instrumented by weighted sum of trading partner's GDP's.

3. Wage is a residual wage after filtering labor productivity out.

Table 7(b): OLS Estimation Results Using Macroeconomic (IFS) Data (Log Differenced Ddata)

	(1)	(2)	(3)	(3-1)	(3-2)	(4)	(5)	(6)	(7)
Constant	-0.13 (-0.52)	0.06 (1.03)	0.06 (1.13)	0.02 (0.79)	-0.01 (-0.10)	-0.14 (-0.49)	0.23 (2.89)**	0.05 (0.73)	0.23 (2.58)**
Exchange rate	-0.19 (-0.32)	-0.08 (-0.17)	-1.31 (-5.35)***	-1.23 (-5.52)***	0.10 (0.22)	-0.20 (-0.32)	-1.58 (-7.61)***	-1.33 (-5.07)***	-1.58 (-7.04)***
Exchange rate interaction[1]		1.12 (0.35)				0.35 (0.09)		1.36 (7.87)***	1.45 (10.70)***
Export price[2]	-6.96 (-0.83)					-7.11 (-0.79)	7.33 (2.45)**		7.29 (2.23)*
Oil price	-0.03 (-0.12)					-0.02 (-0.07)	-0.12 (-1.64)		-0.13 (-1.42)
Wage[3]	0.55 (0.84)					0.53 (0.74)	0.47 (2.42)**		0.48 (2.24)*
Labor productivity			0.50 (1.03)	0.38 (0.83)			1.40 (3.11)**	0.55 (1.02)	1.38 (2.65)**
Export share			1.36 (8.43)***	1.33 (8.62)***			1.45 (11.59)***	0.43 (0.29)	-0.12 (-0.09)
Sigma_squared			-0.29 (-0.85)		0.49 (0.60)		-0.12 (-0.45)	-0.25 (-0.68)	-0.13 (-0.41)
R-squared	0.13	0.01	0.88	0.87	0.03	0.14	0.96	0.88	0.96

Note: All variables are in log terms. t-statistics are in parenthesis.

* significant at 10%; ** significant at 5%; *** significant at 1%.

1. Exchange rate interaction term is interacted with export share of output and import share of input.

2. Export price is instrumented by weighted sum of trading partner's GDP's.

3. Wage is a residual wage after filtering labor productivity out.