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The exchange rate and machinery and equipment imports: Identifying the impact of import source and export destination country currency valuation changes

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Abstract

This paper presents estimates of the impact of exchange rate movements on the quantity of machinery and equipment imports. Many countries have become increasingly reliant on imports of these types of products and evidence in a number of studies indicates that investment in machinery and equipment contributes to improved productivity and growth. Unlike previous studies, this study differentiates between exchange rate movements with respect to machinery and equipment import source and final good export destination countries. Data are employed for two machinery and equipment importing countries, Australia and Canada, and two exporting countries, Japan and the U.S. The results indicate that a currency depreciation with respect to an import source country has a *significant negative* effect on the quantity of machinery and equipment imports, while a depreciation with respect to a domestic final good export destination country has a *significant positive* effect. These findings imply that the net impact on the quantity of machinery and equipment imports of an exchange rate change with respect to a particular country will depend on the extent to which that country is a supplier of machinery and equipment imports and a market for domestic exports.
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1. Introduction

In the standard model of trade, a fall in the value of the domestic currency leads to an increase in the domestic currency price of imported goods and a decline in the quantity of imports

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(the direct cost effect). However, a currency depreciation also raises the domestic currency price of domestic exports, which provides firms with an incentive to expand production for export. As a consequence, demand for intermediate inputs rises, including demand for imported inputs (the derived demand effect). Since these two effects, the derived demand effect and the direct cost effect, are opposite in sign, the *net* impact of a currency valuation change on the quantity of imports may be positive, negative or not significantly different from zero.

This study investigates the impact of exchange rate movements on imports of machinery and equipment. An important contribution of the analysis is that, unlike previous studies of import demand, the estimates make it possible to identify both the derived demand effect and the direct cost effect of the exchange rate on imports. With the rapid growth of trade in intermediate inputs, identification of these two effects is becoming increasingly relevant to an understanding of the effect of the exchange rate on trade.[1]

As expected, the results indicate that a currency depreciation increases imports through the derived demand channel, but reduces imports through the cost channel. As the marginal effects are of similar size, a depreciation with respect to both import source and export destination countries does not have a significant impact on overall machinery and equipment imports. This result may explain why previous studies, which do not distinguish between the derived demand and direct cost effects, often find that currency valuation changes have little impact on imports (Chinn, 2005a,b; Hooper, Johnson, & Marquez, 2000; Rose & Yellen, 1989). However, most countries do not experience the same exchange rate movement with respect to all countries. The impact on machinery and equipment imports of a currency valuation change with respect to one country, rather than all countries, will depend on whether that country is a machinery and equipment import source country or a domestic final good export destination country.

The results of this study may be important from a public policy perspective since, as found by DeLong and Summers (1991), investment in machinery and equipment is associated with faster economic growth and, in recent years, many countries have become increasingly reliant on imports of machinery and equipment.[2] Further, Mazumdar (2001) shows that countries with a higher share of imported machinery experience higher growth, while Hasan (2002) and Basant and Fikkert (1996) find a positive impact of imported technology on firm productivity. Mody and Yilmaz (2002) show that imports of machinery lead to increased export competitiveness, while Coe, Helpman, and Hoffmaister (1997) and Xu and Wang (1999) find that capital imports facilitate the international transmission of technical innovations. Thus, as suggested by Porter (1990) and Martin and Porter (2001), by altering the quantity of machinery and equipment imports, exchange rate movements may affect future productivity growth.[3]

[1] Fergusson (2006) notes that approximately 45 percent of Canada–U.S. trade is intra-firm trade, and trade in intermediate products is becoming increasingly important.

[2] Machinery and equipment imports by Canada were equivalent to 144 percent of domestic machinery and equipment production in 2001 (up from 59 percent in 1970). Similarly, imports of machinery and equipment by Australia were equivalent to approximately 38 percent of Australian machinery and equipment production in 1970, but were 160 percent of production in 1999. See the OECD's *STAN 2000 Database* and *Bilateral Trade Database*. Caselli and Wilson (2004) and Eaton and Kortum (2001) note that most of the world's capital equipment is produced in just a few countries, principally the U.S., Germany and Japan, with the rest of the world relying on imports from these countries.

[3] Jones (1994) and Restuccia and Urrutia (2001) show that the relative price of capital has a significant impact on differences in capital accumulation across countries. A relationship between the exchange rate and productivity has often been identified by business and in the press. For example, journalist Stinson (2003) reports "Appreciation in the currency means falling costs of imported goods. Because about 80 percent of Canada's machinery and equipment is imported,

Indirect evidence suggests that the response to exchange rate changes may vary by type of import. For example, the estimated response to exchange rate movements varies significantly by industry for import prices (Mann, 1986), investment good prices (Landon & Smith, 2006), capital demand (Forbes, 2002) and labor demand (Branson & Love, 1988; Burgess & Knetter, 1998; Revenga, 1992).[4] These results suggest that, to gain an understanding of the impact of exchange rate changes on imports of machinery and equipment, it is necessary to focus specifically on machinery and equipment imports rather than aggregate imports.

To our knowledge, the impact of the exchange rate on machinery and equipment imports, and the identification of the derived demand and direct cost effects of the exchange rate on imports, have not been examined previously. A small number of studies investigate the impact of exchange rate movements on imports of intermediate inputs. Blonigen (2001) and Swenson (2000) both show that U.S. manufacturing firms change their imported intermediate input sourcing patterns when foreign prices and exchange rates change. However, Blonigen studies only automobile parts imports to the U.S., and Swenson examines only firms located in U.S. foreign trade sub-zones.

A significant feature of the empirical analysis undertaken here is that the data employed consist of bilateral trade flows and bilateral exchange rates. Previous studies typically use an exchange rate index.[5] It is only by distinguishing exchange rate and price movements with respect to import source and final good export destination countries that it is possible to identify the direct cost and derived demand effects. This requires the use of bilateral trade and exchange rate data rather than data on aggregate imports and multi-country exchange rate indices.

The empirical analysis employs data for two importing countries, Australia and Canada, and two exporting countries, Japan and the U.S. The choice of countries was determined entirely by data availability. Nevertheless, there are a number of advantages to using data for these four countries. Both Australia and Canada are sufficiently small that they rely to a great extent on imports of machinery and equipment. As well, both countries have experienced considerable exchange rate variation over the 1980s and 1990s. Further, the two exporting countries included in the analysis, Japan and the U.S., are major machinery and equipment exporters and are the two largest suppliers of machinery and equipment to Australia and Canada.[6]

The impact of exchange rate movements on machinery and equipment imports could potentially be large as exchange rates have fluctuated widely since the breakdown of the Bretton Woods system in the early 1970s. For example, between 1988 and 2000, the annual percentage change in the Canadian dollar and Australian dollar prices of the Japanese yen have varied from approximately −15 percent to over 20 percent, with the average absolute value of the annual change equal to 10 percent. The Australian and Canadian dollar prices of a U.S. dollar were also

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the higher dollar means 'The cost of staying productive decreases for Canadian companies,' said Craig Wright, chief economist at Royal Bank of Canada."

[4] Chinn (2005b) finds non-oil, non-computer imports are more sensitive to exchange rate changes than aggregate imports.

[5] See Branson and Love (1988), Revenga (1992), Burgess and Knetter (1998), Swenson (2000), and Slaughter (2001). These studies use a weighted exchange rate variable in their analyses of the influence of exchange rate movements on the demand for either imported intermediate goods or labor.

[6] While this study focuses on relatively few countries, the results may have wider applicability since recent work suggests differences across countries are small and insignificant relative to differences across industrial sectors (see the analyses of monetary policy by Dedola & Lippi, 2005 and Peersman & Smets, 2005).

quite variable during this period, although somewhat less variable than the two yen exchange rates.[7]

The plan of the paper is as follows. The next section outlines the analytical framework. The estimating equation is specified in Section 3 and the data are described in Section 4. Section 5 presents the estimates of the impact of exchange rate movements on the growth rate of the quantity of machinery and equipment imports and provides an analysis of the robustness of the estimates. The results are discussed in Section 6, while Section 7 gives a brief conclusion.

2. A model of machinery and equipment import demand

An estimable machinery and equipment import demand function is derived from a standard model of imported input demand. A representative firm, i, operating in the domestic country, country j, produces output that is sold in both domestic and export markets. The firm uses machinery imported from country k, M_{ijk}, which is combined with labor, L_{ij}, and domestic raw material inputs, R_{ij}, to produce output according to the production function:

$$Q_{ij} + Q_{ij}^{f} = f(L_{ij}, R_{ij}, M_{ijk}), \tag{1}$$

where Q_{ij} and Q_{ij}^{f} denote the output of firm i in country j produced for domestic and foreign markets, respectively. Following Marston (1990), demand for the firm's output depends on income and the price of the good produced by firm i relative to the aggregate price level:

$$Q_{ij} = Q_{ij}\left(\frac{P_{ij}}{P_j}, y_j\right), \qquad \frac{\partial Q_{ij}}{\partial (P_{ij}/P_j)} < 0, \qquad \frac{\partial Q_{ij}}{\partial y_j} > 0, \tag{2a}$$

$$Q_{ij}^{f} = Q_{ij}^{f}\left(\frac{P_{ij}^{f}}{P^{f}}, y^{f}\right), \qquad \frac{\partial Q_{ij}^{f}}{\partial (P_{ij}^{f}/P^{f})} < 0, \qquad \frac{\partial Q_{ij}^{f}}{\partial y^{f}} > 0, \tag{2b}$$

where P_{ij}, P_{ij}^{f} are the domestic firm's output prices in domestic and foreign markets, respectively, with P_{ij}^{f} denominated in foreign currency, y_j and y^f are domestic and foreign real income, P_j and P^f are the domestic and foreign general price levels, and Eqs. (2a) and (2b) are each homogeneous of degree zero in prices. The two demand equations imply inverse demand functions of the form:

$$P_{ij} = g_{ij}(Q_{ij},\ y_j)P_j, \qquad \frac{\partial g_{ij}(Q_{ij}, y_j)}{\partial Q_{ij}} < 0, \qquad \frac{\partial g_{ij}(Q_{ij}, y_j)}{\partial y_j} > 0, \tag{3a}$$

$$P_{ij}^{f} = g_{ij}^{f}(Q_{ij}^{f}, y^{f})P^{f}, \qquad \frac{\partial g_{ij}^{f}(Q_{ij}^{f}, y^{f})}{\partial Q_{ij}^{f}} < 0, \qquad \frac{\partial g_{ij}^{f}(Q_{ij}^{f}, y^{f})}{\partial y^{f}} > 0. \tag{3b}$$

Subject to the production function, Eq. (1), and using the two inverse demand functions to substitute for P_{ij} and P_{ij}^{f}, firm i in country j chooses its output and input quantities to maximize

[7] The annual percentage change in the Australian dollar price of a U.S. dollar varied from −10 to 18 percent, while the Canadian dollar change ranged from −7 to 7 percent. Relative to the U.S. dollar, the average annual percentage change (in absolute value) of OECD country currencies was 10.5 percent from 1981 to 2001 (OECD *Bilateral Trade Database*).

profits, π_{ij}:

$$\max_{Q_{ij},Q_{ij}^f,M_{ijk},L_{ij},R_{ij}} \pi_{ij} = P_{ij}Q_{ij} + e_{jf}P_{ij}^fQ_{ij}^f - w_jL_{ij} - p_j^{\text{raw}}R_{ij} - e_{jk}p_k^{\text{M}}M_{ijk}, \tag{4}$$

where e_{jf} is the exchange rate (the domestic currency price of one unit of foreign currency) with respect to the export destination country, e_{jk} is the exchange rate with respect to the source country for imported machinery, p_k^{M} is the foreign currency price of imported machinery from country k, w_j is the domestic wage, and p_j^{raw} is the domestic currency price of raw material inputs. This maximization problem yields an import demand function for machinery of the form:

$$M_{ijk} = M_{ijk}(e_{jk}p_k^{\text{M}}, w_j, p_j^{\text{raw}}, y_j, P_j, y^f, e_{jf}P^f). \tag{5}$$

Given standard assumptions with respect to the characteristics of the demand and production functions, the exchange rate affects the demand for machinery imports, M_{ijk}, through two channels. First, a currency depreciation with respect to the source country for imported machinery (a rise in e_{jk}) increases the domestic currency price of machinery imports, $e_{jk}p_k^{\text{M}}$, which leads to a reduction in the demand for these inputs. Second, a depreciation with respect to the export destination country raises the domestic currency value of domestic exports. In so doing, it causes firms to increase production for export which leads to an increase in the demand for all inputs, including imported machinery, an effect that is captured by the term $e_{jf}P^f$ in Eq. (5). These two exchange rate effects are opposite in sign and, thus, the impact on the demand for machinery imports of a depreciation with respect to both import source and export destination countries is uncertain.

The impact on the demand for machinery imports of the other arguments of the import demand function is also straightforward. An increase in the foreign currency price of machinery, p_k^{M}, causes a fall in the quantity of machinery imports, while increases in the prices of the two other inputs, w_j and p_j^{raw}, may increase or reduce imports of machinery depending on the degree of factor substitutability. Further, a rise in any of the domestic or foreign demand variables (y_j, P_j, y^f, and P^f) leads to an increase in machinery imports (as more imported inputs are required to satisfy the increased demand for the domestic final product).

3. Empirical specification

Taking the first difference of a linear-in-logs approximation to Eq. (5) yields an estimable equation that describes the change in the quantity of country j machinery imports from country k[8]:

$$\Delta M_{jkt} = \beta_0 + \beta_1\Delta(e_{jkt}p_{kt}^{\text{M}}) + \beta_2\Delta w_{jt} + \beta_3\Delta p_{jt}^{\text{raw}} + \beta_4\Delta y_{jt} + \beta_5\Delta P_{jt} + \beta_6\Delta y_t^f + \beta_7\Delta(e_{jft}P_t^f) + u_{jkt}, \tag{6}$$

where t denotes the time period, Δx denotes the natural log difference of the variable x, so $\Delta x \equiv \ln(x_t) - \ln(x_{t-1})$, and u_{jkt} denotes a mean zero random error. All the variables are as defined in Section 2 and the subscript i has been dropped for notational simplicity.[9]

[8] The first difference specification is standard and follows Marston (1990), Campa and Goldberg (1999), and Nucci and Pozzolo (2001). Other estimation strategies are not practical given the data available. For example, panel cointegration tests have very low power in samples of the size used here (Gutierrez, 2003).

[9] As with any estimated demand equation, an identification issue arises as both the demand and supply of machinery and equipment inputs are expected to depend on price. The identification assumption used here is that each individual

If the exchange rate varies with respect to the import source country only, the quantity of machinery imports changes by β_1, while, if the exchange rate moves with respect to the export destination country only, the quantity of imports changes by β_7. When the exchange rate varies by the same amount with respect to both the import source and export destination countries, the net impact on machinery imports is $\beta_1 + \beta_7$. As β_1 and β_7 are expected to be negative and positive, respectively, this net effect can have either sign.

4. The data

The focus of the current analysis is on machinery and equipment imports, because of the potential importance of these imports for productivity growth. As a result, data are employed only for imports of goods that are produced by sectors that the OECD classifies as either *Machinery and equipment* or *Transport equipment*.[10] While these sectors represent just 2 of 10 manufacturing sectors, imports from these sectors comprise a significant share of total imports. For example, in 2001, *Machinery and equipment* and *Transport equipment* together accounted for 48.3 percent and 54.4 percent of all imports to Australia and Canada, respectively (OECD *Bilateral Trade Database*).[11]

The data for the *Machinery and equipment* sector are available in a form that can be disaggregated into three sub-categories: *Machinery and equipment*, *nec* (not elsewhere classified); *Medical*, *precision and optical instruments*; and a grouping of three sub-industries of *Machinery and equipment* that are designated here as *Computing*, *electrical and communication equipment*.[12]

importing country represents a relatively small market for the machinery and equipment exporting country, so the supply of machinery and equipment imports can be viewed as being perfectly elastic to the importing country. Thus, shifts in the machinery and equipment supply schedule, as measured by movements in the price of machinery and equipment imports, trace out the demand schedule. The position of the machinery and equipment import demand schedule is determined by the prices of the other inputs, and the four output-demand variables. See Slaughter (2001) for a discussion of the need for an identification assumption in the context of input equation estimation.

[10] These two sectors are also identified by the OECD (2001) as producing "high-technology" or "medium-high-technology" products. The remaining manufacturing industries are classified as either "medium-low-technology" or "low-technology." See Hatzichronoglou (1997) or OECD (2001) for background on the OECD's classification system. The *Transport equipment* sector includes one "medium-low" technology sub-sector, *Building and repairing of ships and boats*, but this sub-sector is very small (it accounted for just half of one percent of all *Transport equipment* imports to Canada from the U.S. in 2000). Only one other manufacturing industry, *Chemical*, *rubber*, *plastics and fuel products*, incorporates any sub-sectors (*Chemicals and chemical product*s) that are classified as "high-" or "medium-high-technology."

[11] While it would be desirable to use data for imported *intermediate* inputs only, the necessary data are not available. (Disaggregated data on U.S. dollar values of bilateral trade flows, from which intermediate input imports might be roughly identified, are available from other sources, such as COMTRADE, but matching *price* data are not available from these sources.) However, Canadian data suggest that a considerable proportion of machinery imports are for intermediate use and/or fixed capital formation. For example, in 1997, imports of *Electrical, electronic and communication products* were $33.9 billion or 58 percent of the total Canadian supply. The quantity of these goods allocated to intermediate use, inventories and fixed capital formation represented 84 percent of total domestic use. See Statistics Canada *The Input–Output Structure of the Canadian Economy*, *1996 and 1997*, Cat. No. 15-201-XPB, page 18.

[12] The three sub-industries that comprise the category *Computing*, *electrical and communication equipment* are *Office*, *accounting and computing machinery*; *Electrical machinery and apparatus*, *nec*; and *Radio, television and communication equipment*. It is necessary to use an aggregate of these sectors as the dataset does not include separate price data for these three categories. Similarly, price data are unavailable for the industry sub-sectors of *Transport equipment*. The industrial categories used can be classified according to the *International Standard Industrial Classification of all Economic Activities*, ISIC Revision 3. The industry *Transport equipment* is ISIC categories 34–35; *Machinery and equipment*, *nec* is ISIC category 29; *Medical, precision and optical instruments* is ISIC category 33; and *Computing, electrical and communication equipment* represents ISIC categories 30, 31 and 32.

This disaggregation makes it possible to exploit variation in the data across sub-sectors and means that more observations are available for each country. The sources for the disaggregated industry-level data are two OECD databases – the *Bilateral Trade Database* and the *STAN 2000 Database*. The advantage of these datasets is that they can be used to calculate prices and import quantities for individual countries and industrial sectors.

For the empirical analysis to be meaningful, the sample should include data on imports from the importing country's major suppliers of machinery and equipment. Of the countries for which disaggregated import data are available, only Australia and Canada import significant quantities of machinery and equipment from countries (Japan and the U.S.) for which disaggregated country-specific price data are also available.[13] The U.S. and Japan were the two largest suppliers of imports to both Australia and Canada of each of the three sub-types of *Machinery and equipment* described above as well as *Transport equipment*. Together Japan and the U.S. accounted for 51 percent of Australian imports of these products and 78 percent of Canadian imports in 1995 (the midpoint of the sample). Thus, as a result of data availability, for each of the three sub-sectors of *Machinery and equipment* as well as *Transport equipment*, the empirical analysis employs data on four bilateral import flows, those from Japan and the U.S. to Australia and Canada.

Price and quantity data for each of the four import goods are not directly available, but can be constructed from OECD data. For each type of machinery and equipment, indexed by m, the domestic currency import price is given by the foreign currency price of the same good, p^M_{mk}, multiplied by the domestic currency price of the exporter's currency, e_{jk}. The foreign currency price of each import good (p^M_{mk}) is proxied by the price of the same product in the exporting country.[14] In a standard markup model, given the linear-in-logs form of the estimating equation, use of this proxy does not require that prices be identical in the importing and exporting countries (i.e., that there is complete pass-through), but only that the ratio of the exporter's markups in the two countries be constant (the markups may differ across countries).[15]

The quantity of machinery and equipment imports of type *m* imported by country *j* from country *k*, M_{mjk}, is constructed by dividing the domestic currency value of imports of good *m* to country *j* from country *k* by the domestic currency price of good *m*, $e_{jk}p^M_{mk}$.[16] The log first-difference of this index (ΔM_{mjk}) is used as the dependent variable in the estimating equation, Eq. (6). See Appendix A for further details on the sources and construction of the import quantity and price data, while Appendix B reports annual machinery and equipment price changes.

Estimation of import demand Eq. (6) also requires the specification of empirical counterparts to the other variables that determine import demand. The wage, aggregate price level and real income variables are constructed using the International Monetary Fund's *International Financial Statistics* database. As domestic exports go to more than one country, the foreign real income variable, Δy^f_t, is captured by the trade-weighted average of the log changes in the real GDP

[13] For many European countries, Germany was one of the two largest suppliers of machinery and equipment imports, but the *STAN 2000 Database* does not include the data needed to construct a price variable for these imports from Germany.

[14] This price is constructed from current and constant dollar production data for product m in the exporting country as given in the *STAN 2000 Database*.

[15] In the standard models of Feenstra (1989) and Marston (1990), this condition is satisfied if the demand elasticities are constant (although they may differ) in the importing and exporting countries. Importantly, Campa and Goldberg (2005) find that pass-through rates for manufacturing import prices are highly stable for the two decades of OECD (including Australia and Canada) data they examine.

[16] The *Bilateral Trade Database* provides data on the value of bilateral trade flows for each good denominated in U.S. dollars. These are converted to domestic currency values using the country *j* currency price of a U.S. dollar.

of the domestic country's (country *j*'s) two largest export destinations (Japan and the U.S. for both Australia and Canada). Similarly, the output price variable in the domestic country's export market, $\Delta(e_{jft} P_t^f)$, is the trade-weighted average of the log changes in the aggregate price levels, in terms of the domestic country's currency, of the two largest recipients of domestic country exports.

Import data from the *Bilateral Trade Database* are available from 1988, but the required *STAN 2000* data for Japan, necessary to construct p_{mk}^{M}, are available only through 2000. As a result, for each type of machinery and equipment and each importing country (Australia and Canada), 12 annual observations are available for the change in the log of the bilateral import flow from each of the two import-supply countries, Japan and the U.S. By pooling these data across importing countries (Australia, Canada) and source countries (Japan, U.S.), a total of 48 observations is available for each of the four types of machinery and equipment. Import equations are estimated for each of the four products separately, as well as with the data pooled across the three *Machinery and equipment* sectors, and pooled across all four sectors. These latter two pooled samples have 144 and 192 observations, respectively, and take advantage of the variation in price and quantity movements across sectors.[17]

5. Results and tests of robustness[18]

Table 1 reports estimates of import demand Eq. (6), when the data for the four types of imported products are pooled. The first column reports the estimates for the pooled sample of the three *Machinery and equipment* sub-sectors, while the second column reports coefficient estimates using a panel that includes the three sub-categories of *Machinery and equipment* as well as *Transport equipment*. Table 2 reports separate estimates for each of the four types of machinery and equipment imports. The estimates presented in Tables 1 and 2 explain a sizeable proportion of the variation in import quantity growth rates. The value of R^2 ranges from .380 to .637 and is above .5 in half the cases. These values are relatively high given that the sample consists of a pooled cross-section of first differences.

As expected, the estimated parameters reported in Tables 1 and 2 associated with the machinery and equipment import price variable ($\Delta(e_{jkt} p_{kt}^{\mathrm{M}})$) are negative, while the parameter estimates associated with the export price variable ($\Delta(e_{jft} P_t^f)$) are positive. Further, the parameter estimates are similar across the four import goods and a test indicates that the coefficients associated with each of the four individual imports do not differ significantly from the coefficients of the other three goods (see Table 1). The estimated coefficients on the other explanatory variables are also generally as predicted. The coefficients associated with the domestic demand factors (Δy_{jt} and ΔP_{jt}) are positive and statistically significant (although at only 90 percent in two cases) while the coefficient on the foreign income variable (Δy_t^f) is generally positive, and is always positive when significant.[19]

[17] When the sector-level data are pooled, dummy variables are added to allow the constant to differ across sectors. As well, to allow for differences across the destination and source countries, two dummy variables are employed, one for Australia and one for Japan.

[18] From this point in the text, as well as in the tables and appendices, the m subscript for the type of machinery and equipment is dropped, except where necessary for clarity.

[19] The signs of the parameters associated with the other two input prices, the wage (Δw_{jt}) and the raw material price ($\Delta p_{jt}^{\mathrm{raw}}$), are ambiguous in the theoretical model, but ten of the twelve estimated coefficients are negative and, of the seven

Table 1
Import demand coefficient estimates using pooled sectoral data (dependent variable: First difference of the log of the quantity of imports (ΔM_{jkt}))

Explanatory variables	Panel of the three Machinery and equipment sectors[a]	Panel of the three Machinery and equipment sectors and the Transport equipment sector
$\Delta(e_{jkt} p_{kt}^{\mathrm{M}})$	$-.6007^{**}$ (6.23)	$-.6032^{**}$ (6.35)
$\Delta p_{jt}^{\mathrm{raw}}$	$-.2465^{**}$ (2.32)	$-.2862^{**}$ (2.76)
Δw_{jt}	$-.8554^{*}$ (1.70)	−.7931 (1.61)
Δy_{jt}	1.907^{**} (4.30)	2.075^{**} (4.78)
ΔP_{jt}	2.684^{**} (4.83)	2.776^{**} (5.11)
Δy_t^f	1.035^{*} (1.67)	1.012^{*} (1.67)
$\Delta(e_{jft} P_t^f)$	$.4615^{**}$ (3.47)	$.4380^{**}$ (3.36)
Constant	−.0413 (1.48)	$-.0492^{*}$ (1.80)
Computing, electrical and communication equipment dummy	$.0414^{**}$ (2.18)	$.0412^{**}$ (2.19)
Medical, precision and optical equipment dummy	.0220 (1.31)	.0220 (1.32)
Transport equipment dummy		.0182 (0.66)
Australia dummy	−.0231 (1.28)	−.0232 (1.32)
Japan dummy	$-.0592^{**}$ (5.27)	$-.0566^{**}$ (5.16)
Number of observations	144	192
R^2	.527	.389
Likelihood ratio test that the sum of the coefficients on Δep^{M} and ΔeP^f is zero ($\chi^2(1)$)	1.85	2.73
AR1 test[†]	.39[b]	.67[b]
Likelihood ratio test that the variance is the same across sectors (χ^2 with degrees of freedom in parenthesis)	20.12[c] (2)	62.72[c] (3)
Heteroskedasticity test on the standardized residuals[††]	5.33[d] (11)	6.42[d] (12)
Reset test[†††]	.09[e]	.12[e]
Likelihood ratio test of the hypothesis that the coefficients associated with the following sectors are not significantly different from the coefficients of the remaining sectors (χ^2 with 9 degrees of freedom)		
(i) *Computing, electrical and communication equipment*	10.80[f]	11.73[f]
(ii) *Medical, precision and optical equipment*	9.94[f]	10.40[f]
(iii) *Transport equipment*		11.18[f]
Test of parameter constancy across Canada and Australia (import destination countries)[††††]	12.28[f] (10)	12.13[f] (11)
Test of parameter constancy across Japan and the U.S. (import source countries)[††††]	13.81[f] (10)	14.77[f] (11)

The numbers in parenthesis under each coefficient estimate are the absolute values of the *t*-statistics. The variance of the errors is allowed to differ across sectors but is assumed to be constant through time.

** The estimated coefficient is significant using a 95 percent confidence interval. * The estimated coefficient is significant using a 90 percent confidence interval.

† AR1 test: A *t*-test of the significance of the estimated lagged residual in a regression of the residuals on the lagged residuals and the explanatory variables. See Davidson and MacKinnon (1993, 358). This test regression uses the standardized residuals.

†† Heteroskedasticity test: Breusch–Pagan LM test for heteroskedasticity on the standardized residuals, where the residuals are standardized using the estimates of the sector-specific variances. The test statistic has a χ^2 distribution with the degrees of freedom given in parenthesis.

††† Reset test: A *t*-test of the significance of the squared predicted value when it is included as an explanatory variable in the estimating equation. Absolute value of test statistic reported.

†††† Parameter constancy test: A test that the coefficients are jointly equal, except for a shift dummy, across the two samples indicated. The test statistic has a χ^2 distribution with degrees of freedom indicated in parenthesis below the test statistic.

a The three *Machinery and equipment* sectors are: *Machinery and equipment, nec*; *Computing, electrical and communication equipment*; *Medical, precision and optical equipment*.

b Cannot reject the hypothesis of no serial correlation at 95 percent.

c Reject the hypothesis that the variances are equal across sectors.

d Cannot reject homoskedasticity at 95 percent.

e The Reset test does not reject the specification at 95 percent.

f Cannot reject parameter constancy at 95 percent.

Table 2
Import demand coefficient estimates by sector (dependent variable: First difference of the log of the quantity of imports for the sector indicated (ΔM_{jkt}))

Explanatory variables	*Machinery and equipment, nec*	*Computing, electrical and communication equipment*	*Medical, precision and optical equipment*	*Transport equipment*
$\Delta(e_{jkt} p_{kt}^{\mathrm{M}})$	$-.5912^{**}$ (2.03)	$-.6729^{**}$ (3.77)	$-.5323^{**}$ (3.53)	$-.5800$ (1.19)
$\Delta p_{jt}^{\mathrm{raw}}$	$-.5866^{**}$ (2.02)	.0572 (.30)	$-.3652^{**}$ (2.30)	$-.9598^{**}$ (2.12)
Δw_{jt}	-2.729^{**} (1.98)	$-.4489$ (.51)	$-.6060$ (.80)	.5210 (.24)
Δy_{jt}	3.620^{**} (2.98)	2.286^{**} (2.93)	1.166^{*} (1.76)	4.926^{**} (2.61)
ΔP_{jt}	4.518^{**} (2.98)	2.412^{**} (2.42)	2.401^{**} (2.91)	4.207^{*} (1.78)
Δy_t^f	1.2179 (.72)	$-.5044$ (.46)	2.067^{**} (2.22)	.5672 (.21)
$\Delta(e_{jft} P_t^f)$	.3972 (1.08)	$.4470^{*}$ (1.77)	$.4789^{**}$ (2.43)	$-.0403$ (.07)
Constant	$-.0780$ (1.18)	.0201 (.43)	$-.0298$ (.82)	$-.1662$ (1.61)
Australia dummy	.0057 (.11)	$-.0452$ (1.42)	$-.0158$ (.59)	$-.0289$ (.38)
Japan dummy	$-.0432$ (1.42)	$-.0587^{**}$ (2.60)	$-.0603^{**}$ (3.63)	$-.0119$ (.25)
Number of observations	48	48	48	48
R^2	.478	.637	.623	.380
Sum of the coefficients on $\Delta(ep^{\mathrm{M}})$ and $\Delta(eP^f)$ (t-statistic)	$-.1940$ (.69)	$-.2259$ (1.27)	$-.0534$ (.35)	$-.6203$ (1.42)
AR1 test†	.94[b]	.56[b]	1.04[b]	.28[b]
Heteroskedasticity test††	13.22[d] (9)	8.36[d] (9)	4.61[d] (9)	9.07[d] (9)
Reset test†††	.24[e]	.34[e]	.36[e]	.93[e]
Test of parameter constancy across Canada and Australia (import destination countries)††††	11.03[f] (8)	6.06[f] (8)	9.78[f] (8)	7.13[f] (8)
Test of parameter constancy across Japan and the U.S. (import source countries)††††	3.52[f] (8)	9.59[f] (8)	6.57[f] (8)	9.23[f] (8)

See notes to Table 1.

5.1. Tests of robustness

The appropriateness of the estimates is assessed using several specification and robustness tests. The hypothesis of no serial correlation is not rejected in all six cases. In addition, if a lagged dependent variable is added to the estimating equation, it is always insignificant. The results presented in Tables 1 and 2 also indicate that a Reset test does not reject the model and that the hypothesis of homoskedasticity is not rejected for the four sets of sector-level estimates given in Table 2.[20]

As described in Section 4, the data are pooled and so include observations for which Australia and Canada are the import destination countries and Japan and the U.S. the import source countries. Test statistics presented in Tables 1 and 2 show that the hypothesis that the coefficients for Canada and Australia are jointly equal (other than for a constant shift parameter) is not rejected in all six cases. Similarly, the hypothesis of parameter constancy across the import source countries, Japan and the U.S., is also not rejected.

By utilizing the import price variable, $\Delta(e_{jkt}p^{\mathrm{M}}_{kt})$, the empirical specification of Eq. (6) restricts the direct cost effect on imports of the exchange rate and the foreign price of the machinery import to be the same. If the model is re-estimated with the domestic currency price of the imported good, $\Delta(e_{jkt}p^{\mathrm{M}}_{kt})$, split into separate exchange rate and foreign price components, the estimated coefficient on the exchange rate, Δe_{jkt}, is insignificantly different from that on the foreign price variable, $\Delta p^{\mathrm{M}}_{kt}$.

To allow for possible substitution effects between imports of Japanese and U.S. machinery and equipment, the model is re-estimated with the price of the same type of machinery and equipment from the alternative source country included as an explanatory variable. For example, for observations associated with *Machinery and equipment*, *nec* imports to Australia from the U.S., the change in the Australian dollar price of Japanese *Machinery and equipment*, *nec* products is included as an additional explanatory variable. In all cases, the price variable of the alternate source country is statistically insignificant and its inclusion has little effect on the estimates.[21]

In order to assess the appropriateness of the empirical specification, two further generalizations are considered. The first allows the response of imports to vary across periods of currency appreciation and depreciation. For all six cases reported in Tables 1 and 2, the hypothesis of an asymmetric exchange rate response is rejected at the 95 percent confidence level. Following Goldfajn and Werlang (2000) and Goldfajn and Gupta (2003), the second generalization of the model tests whether the impact of the exchange rate through the import price variable differs between periods of currency under- and over-valuation (defined on a bilateral basis). The results indicate that the coefficient associated with $\Delta(e_{jkt}p^{\mathrm{M}}_{kt})$ is insignificantly different across these periods for all of the cases reported in Tables 1 and 2, except for the *Transport equipment* industry (for which it is significant and negative in periods of under-valuation). Thus, neither of these two generalizations yields results that are substantially different from those reported in Tables 1 and 2.

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significant coefficients, all are negative. If the domestic currency price of oil, rather than the raw material price index, is employed to proxy changes in the price of other inputs (as in Campa & Goldberg, 1999), the magnitude and level of significance of the estimates change by only a very small amount.

[20] The estimates in Table 1 allow the variance of the errors to differ across sectors. Using the estimated variances to standardize the residuals, the hypothesis of homoskedasticity cannot be rejected for the two cases in Table 1. If the variances are not allowed to vary across sectors, the hypothesis of homoskedasticity is rejected.

[21] Given the limited data available, it is not possible to test for potential substitution toward imports from other countries, but the finding of no substitution between the two largest import source countries suggests this effect may be small.

6. Discussion of the estimates

In Tables 1 and 2, the estimated parameters associated with the change in the machinery and equipment import price ($\Delta(e_{jkt}p_{kt}^{\mathrm{M}})$) range from −.5323 to −.6729. While the estimated coefficient for the *Transport equipment* industry is not significant, it is similar in size to the estimates for the other three sectors. These coefficient estimates imply that, holding everything else constant,[22] a 10 percent currency depreciation with respect to import source countries would lead to an approximately 6 percentage point fall in the machinery and equipment import growth rate. A change of this magnitude is relatively large, as it is approximately equivalent to the average annual import growth rate for the sample (5.5 percent).

Although a currency depreciation has a direct negative effect on machinery and equipment import demand through an increase in the domestic currency price of the import good, it also raises the domestic currency value of exports. As a consequence, a currency depreciation may encourage increased production for export and, thereby, induce an increase in the demand for imported machinery and equipment inputs. This effect is represented by the coefficient associated with $\Delta(e_{j\mathrm{f}t}P_t^{\mathrm{f}})$. The estimated value of this coefficient is positive, as expected, and significantly different from zero for both cases reported in Table 1 as well as for two of the four individual subcategories in Table 2. For the cases in which this coefficient is significant, a 10 percent depreciation with respect to domestic export destination countries, holding everything else constant, is predicted to raise the growth rate of machinery and equipment imports by approximately 4.5 percentage points.

An equal change in the exchange rate with respect to all import source and export destination countries would cause the import growth rate to change by the sum of the coefficients on $\Delta(e_{jkt}p_{kt}^{\mathrm{M}})$ and $\Delta(e_{j\mathrm{f}t}P_t^{\mathrm{f}})$. This net effect is negative for all six cases reported in Tables 1 and 2, but is insignificantly different from zero in every case. Thus, if the exchange rate moves relative to all export destination and import source countries, the positive derived demand and negative direct cost effects of exchange rate changes on machinery and equipment imports effectively cancel each other out.

6.1. Simulation of the impact of a currency depreciation with respect to a single country

The examples given above are relatively special. Most countries do not experience an equal exchange rate change with respect to all countries simultaneously, nor is the set of countries from which most countries import machinery and equipment distinct from the set of countries to which they export. To generalize the analysis, this section presents simulations of the impact on machinery and equipment imports of a depreciation with respect to a single country that is both a source of imports and an export destination.

An expression for the impact on machinery and equipment imports of a depreciation with respect to a single country can be derived using a modified version of Eq. (6). Suppose country j imports machinery and equipment from two countries ($k=1, 2$) and exports final goods to the same two countries ($f=1, 2$). Holding the explanatory variables other than the exchange rate constant, the percentage change in country j imports of machinery and equipment

[22] As with all other variables, the aggregate price level is held constant. While it may (eventually) respond to an exchange rate change, Frankel and Rose (1996) find, using a panel of 150 countries, that PPP deviations are eroded at a fairly slow rate (approximately 15 percent annually).

is:

$$\Delta M_j = \sum_{k=1}^{2} s_{jk} \Delta M_{jk} = \sum_{k=1}^{2} s_{jk} \left[\beta_1 \Delta e_{jk} + \beta_7 \left(\sum_{f=1}^{2} v_{jf} \Delta e_{jf} \right) \right], \quad (7)$$

where s_{jk} is the share of country j machinery and equipment imports from country k, and v_{jf} is the share of country j exports to country f. This expression implies, for example, that a change in the value of country j's currency by one percentage point with respect to country 1 (holding the value unchanged relative to country 2), causes a change in the growth rate of machinery and equipment imports equal to $s_{j1}\beta_1 + v_{j1}\beta_7$. Thus, the impact of an exchange rate change with respect to a particular country will depend on the import and export shares associated with that country. As these shares are likely to differ across countries, a currency depreciation with respect to one country may have a very different impact than the same magnitude depreciation with respect to another country.

In order to illustrate the importance of this result, simulations of the impact of a 10 percent depreciation on the machinery and equipment imports of Australia and Canada are presented in Table 3. These simulations use the coefficient estimates from Table 2, as well as country-specific average export and sector-level import shares from the OECD's *Bilateral Trade Database*. Simulations are undertaken for all three *Machinery and equipment* sectors, but not for the *Transport equipment* sector since, for this latter sector, both coefficients associated with the exchange rate are insignificant in Table 2. The first case in Table 3 gives the predicted impact on machinery and equipment imports of a depreciation with respect to *both* source and destination countries. As noted above in the discussion of the Table 2 results, and as indicated in Case 1 of Table 3, a depreciation of this type has a negative, but insignificant, net impact on machinery and equipment imports. The second and third cases in Table 3 examine the impact of separate depreciations with respect to the currencies of either Japan or the U.S. on the machinery and equipment import growth rates of Australia and Canada, respectively.[23]

Both Australia and Canada import a greater proportion of their machinery and equipment from the U.S. than from Japan, but they differ in that more than twice as many Australian exports go to Japan than to the U.S., while the overwhelming share of Canadian exports go to the U.S.[24] Hence, although a currency depreciation with respect to the U.S. dollar has a direct negative import price effect on machinery and equipment imports for both countries, it has a much smaller positive export effect for Australia than for Canada. Cases 2.2 and 3.2 of Table 3 show that, while the net impact on machinery and equipment imports of a depreciation relative to the U.S. dollar is negative for both countries, the magnitude of this effect is larger for Australia than for Canada, and only for Australia is the net effect significantly different from zero. Further, for the three sectors in Table 3, the net effects for Australia are economically large as they imply declines in the growth rates of imports of each good equivalent to from 25 to 100 percent of their respective average annual import growth rates.

A currency depreciation relative to the yen has a very different impact on Australia than Canada, because Australia's exports are weighted more heavily toward Japan than are Canada's.

[23] Note that, for Cases 2 and 3, the coefficients associated with each of the two exchange rate changes must sum to the corresponding coefficient in Case 1.

[24] In the sample period, on average, of total Australian (Canadian) imports from Japan and the U.S., Japan supplied 40.7 (9.4), 48.2 (14.9) and 26.1 (10.9) percent, respectively, of the three types of machinery and equipment listed in Table 3. Of total Australian (Canadian) exports to Japan and the U.S., approximately 70 (5) percent went to Japan.

Table 3
Predicted impact of a 10 percent currency depreciation on the growth rate of machinery and equipment imports (percentage points)

Machinery and equipment, nec	Computing, electrical and communication equipment	Medical, precision and optical equipment
Case 1: Effect on machinery and equipment imports of a depreciation with respect to the currencies of both Japan and the U.S.		
−1.940 (.69)	−2.259 (1.27)	−.534 (.35)
Case 2: Effect on the growth rate of Australian machinery and equipment imports of a		
2.1: Depreciation with respect to the Japanese yen only		
.488 (.23)	.013 (.01)	2.099* (1.71)
2.2: Depreciation with respect to the U.S. dollar only		
−2.427* (1.86)	−2.272** (3.49)	−2.634** (3.03)
Case 3: Effect on the growth rate of Canadian machinery and equipment imports of a		
3.1: Depreciation with respect to the Japanese yen only		
−.332 (1.60)	−.751** (3.89)	−.310** (2.47)
3.2: Depreciation with respect to the U.S. dollar only		
−1.608 (.61)	−1.508 (.89)	−.224 (.16)

Country j imports machinery from country k ($k=1, \ldots, K$) and exports domestic goods to country f ($f=1, \ldots, F$). Using Eq. (6), the percentage change in total country j imports of machinery is: $\Delta M_j = \sum_{k=1}^{K} s_{jk}\Delta M_{jk} = \sum_{k=1}^{K} s_{jk}\left[\beta_1 \Delta e_{jk} + \beta_7\left(\sum_{f=1}^{F} v_{jf}\Delta e_{jf}\right)\right]$, where the changes in all the explanatory variables in this equation, other than the exchange rates, have been set to zero, and s_{jk} and v_{jf} are the shares of country j machinery imports that come from country k and country j exports that go to country f, respectively. This expression implies that, for example, if the country j currency depreciates by one percentage point with respect to all other currencies, the change in machinery imports will equal $\beta_1+\beta_7$. If the currency depreciates by one percentage point with respect to import source countries, but stays unchanged with respect to all export destination countries ($\Delta e_{jk}=1$, $\Delta e_{jf}=0$, for all k and f), the growth rate of machinery and equipment imports changes by β_1. If the exchange rate is constant relative to import source countries, but depreciates by one percentage point relative to all export destination countries, the growth rate of machinery imports changes by β_7. If the exchange rate changes by one percentage point against country 1, but stays unchanged relative to all other countries, and country 1 is both an import source and an export destination country, the growth rate of machinery imports will change by $s_{j1}\beta_1 + \sum_{k=1}^{K} s_{jk} v_{j1}\beta_7 = s_{j1}\beta_1 + v_{j1}\beta_7$ since $\sum_{k=1}^{K} s_{jk} = 1$. The import and export shares used to calculate the values given in this table are country-specific sample averages calculated from the *Bilateral Trade Database*.

As indicated in Case 2.1 of Table 3, a depreciation of the Australian dollar relative to the yen raises the demand for machinery and equipment imports by Australia. In this case, the positive effect of the depreciation on export earnings outweighs the negative direct import price effect, although the net effect is only significant in one sector.[25] In contrast, as shown in Case 3.1 of Table 3, for two of three sectors, a depreciation of the Canadian dollar relative to the yen has a negative and significant effect on Canadian machinery and equipment imports. As the proportion of Canada's exports to Japan is smaller than the proportion of its machinery and equipment imports that are sourced in Japan, the positive export effect does not counteract the negative effect of the increase in the import price on machinery and equipment imports.

[25] For this sector, *Medical, precision and optical equipment*, Australia imports almost three times as many goods from the U.S. as from Japan, while for the other two sectors, Australian imports from Japan and the U.S. are more evenly balanced.

7. Concluding comments

This paper investigates the impact of exchange rate movements on the quantity of machinery and equipment imports using disaggregated bilateral trade and price data for Australia, Canada, Japan and the U.S. The empirical model controls for movements in the prices of labor and raw material inputs, as well as demand factors, such as domestic and foreign real incomes and price levels. The estimates are robust to several specification tests and generalizations of the model.

The results show that it is not possible to provide a general conclusion with respect to whether a depreciation has a positive or negative impact on machinery and equipment imports, as this depends on the destination of a country's exports and the source of its imports. Following a currency depreciation relative to import source countries only, there is a large negative effect on machinery and equipment imports, while a depreciation relative to export destination countries only causes a positive effect that is almost as large. In general, the impact on machinery and equipment imports of a depreciation with respect to a particular country will depend on the extent to which that country is a source of imports and a market for domestic goods.

The results presented here are important to the extent that machinery and equipment imports may improve an economy's future output and productivity growth. While a general movement in the exchange rate with respect to all countries is predicted to have a relatively neutral impact on these imports, a currency depreciation relative to import source countries only could have a negative effect on future productivity growth by generating a fall in machinery and equipment imports. For this reason, it may be important for policy makers to consider the possible impact on machinery and equipment imports of monetary and fiscal policies that lead to currency valuation changes.

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Appendix A. Data definitions and sources

$\Delta(e_{jkt}p_{kt}^{\mathrm{M}})$: Difference in the log of the domestic currency price of machinery and equipment imports. The domestic currency price is the product of the bilateral exchange rate and the foreign currency price of the good in the exporting country. The exchange rate data are from the OECD *Bilateral Trade Database*. The industry-specific foreign currency price is given by the ratio, for the source country, of nominal production to a volume production index from the OECD *STAN 2000 Database*.

$\Delta(e_{jft}P_t^f)$: Weighted average of the difference in the log of the aggregate price levels of the two largest recipients of the domestic (importing) country's exports (Japan and the U.S.) in terms of the domestic country's currency. The weights are calculated in the same fashion as for the variable Δy_t^f. Before the weighted average is calculated, the domestic country nominal exchange rate is multiplied by the foreign aggregate price index and the log difference is determined. The nominal exchange rate is from the OECD *Bilateral Trade Database* while the GDP price indices for the U.S. and Japan are from the IMF's *International Financial Statistics* CD-ROM. Japan GDP price index is IFS series 15899BIRZF; USA GDP price index is *IFS* series 11199BIRZF.

ΔM_{jkt}: Change in the log of the quantity of sector-level machinery and equipment imports by country *j* (Australia, Canada) from country *k* (Japan, the U.S.). The quantities were calculated using data on bilateral sector-level imports in U.S. dollars from the OECD *Bilateral Trade Database*, sector-level price data calculated using the OECD *STAN 2000 Database* and export exchange rates for Japan from OECD *Bilateral Trade Database*. Calculation of sector-level imports from the U.S.: To convert nominal imports to an import quantity, divide the sector-level value of imports (which are given in U.S. dollars) by the sector-level U.S. dollar price of the import good calculated from *STAN 2000* (using current and constant dollar sector-level production data for the U.S.). To calculate sector-level imports from Japan: Multiply the value of sector-level imports from Japan (which are given in U.S. dollars) by the yen/U.S. dollar exchange rate to transform the import value into yen terms. To convert to real imports, divide by the sector-level yen price of the good in Japan calculated using *STAN 2000* (using current and constant dollar sector-level production data for Japan).

$\Delta p_{jt}^{\text{raw}}$: Difference in the log of the raw material price index for the domestic (importing) country. For Australia: Taken from *DSI Database* (OECD source: Producer Prices, Input to production, Raw materials). For Canada: Taken from *Cansim II* database of Statistics Canada: Raw materials price index (Series V1576432). Annual average of monthly data.

ΔP_{jt}: Difference in the log of the domestic (importing) country GDP price index. Source: The IMF's *International Financial Statistics* CD-ROM. Australia series: 19399BIRZF; Canada series: 15699BIRZF.

Δw_{jt}: Difference in the log of the nominal wage of the domestic (importing) country. Source: The IMF's *International Financial Statistics* CD-ROM. Australia: wages, weekly earnings, series: 19365. . .ZF; Canada: wages: hourly earnings, series: 15665EY.ZF.

Δy_{jt}: Difference in the log of domestic (importing) country real GDP. Source: The volume GDP index from the IMF's *International Financial Statistics* CD-ROM, Australia: 19399BVRZF; Canada: 15699BVRZF.

Δy_t^f: Weighted average of the difference in the log of real GDP of the domestic (importing) country's two largest export destinations (Japan and the U.S.). The U.S. and Japan real GDP (RGDP) data are from the IMF's *International Financial Statistics* CD-ROM. Japan RGDP series: 15899BVRZF; U.S. RGDP series: 11199BVRZF. The weights are the share of the domestic country's "Total exports" to each of Japan and the U.S. in the previous year. The export data are from the OECD's *Bilateral Trade Database*.

Note: The test of whether the exchange rate effect differs for periods of over- and under-valuation is undertaken by interacting the machinery import cost variable, $\Delta(e_{jkt} p_{kt}^{\text{M}})$, with a dummy variable for currency misalignment (MDV). Let currency valuation be defined as: $V \equiv e_{jkt}/e_{jkt}^{\text{PPP}}$, where e_{jkt}^{PPP} is the purchasing power parity exchange rate of country *j* relative to country *k* at time *t*. The zero-one dummy variable, MDV, was constructed by splitting in half the sample for each of the four bilateral trade pairs on the basis of the value of *V*. Source: See above for the exchange rate. The PPP exchange rates were downloaded from the OECD web site "PPPs for GDP – Historical Series" in March 2003.

Appendix B

Table B.1
Percentage changes in machinery and equipment import prices

	U.S. dollar price of U.S. good	Australian dollar price of U.S. good	Canadian dollar price of U.S. good	Japanese yen price of Japanese good	Australian dollar price of Japanese good	Canadian dollar price of Japanese good
Machinery and equipment, nec						
1988	2.781	−8.340	−4.838	−0.251	0.920	4.777
1989	4.168	4.501	0.449	2.479	−4.175	−7.890
1990	3.424	3.762	2.006	3.274	−1.426	−3.094
1991	2.667	2.971	0.751	1.478	9.181	6.828
1992	1.626	7.678	7.125	0.261	13.258	12.673
1993	1.788	9.769	8.762	−0.989	21.555	20.444
1994	1.659	−5.738	7.627	−0.989	0.0444	14.235
1995	2.237	1.124	2.722	−0.803	6.626	8.304
1996	2.096	−3.383	1.418	−0.241	−18.741	−14.694
1997	1.177	6.889	2.799	1.119	−3.888	−7.572
1998	1.038	19.259	8.156	−0.019	9.424	−0.762
1999	1.044	−1.672	1.227	−2.920	8.141	11.336
2000	0.662	12.121	0.712	−1.732	15.748	3.966
Computing, electrical and communication equipment						
1988	−2.755	−13.279	−9.964	−4.811	−3.693	−0.017
1989	−2.206	−1.893	−5.697	−1.122	−7.538	−11.131
1990	−4.270	−3.959	−5.584	−1.435	−5.928	−7.510
1991	−3.555	−3.269	−5.354	−3.449	3.881	1.640
1992	−7.284	−1.764	−2.268	−2.339	10.320	9.749
1993	−6.208	1.145	0.216	−3.980	17.887	16.804
1994	−5.922	−12.769	−0.400	−3.236	−2.224	11.643
1995	−11.210	−12.177	−10.789	−4.450	2.702	4.323
1996	−13.127	−17.790	−13.703	−6.186	−23.581	−19.781
1997	−10.518	−5.466	−9.084	−4.314	−9.059	−12.538
1998	−14.903	0.442	−8.907	−2.475	6.744	−3.196
1999	−11.091	−13.482	−10.931	−6.729	3.894	6.961
2000	−9.244	1.087	−9.198	−5.323	11.523	0.169
Medical, precision and optical equipment						
1988	2.556	−8.541	−5.046	−0.859	0.304	4.142
1989	3.669	4.002	−0.030	−0.669	−7.119	−10.724
1990	2.896	3.230	1.483	−1.891	−6.357	−7.942
1991	2.205	2.508	0.299	0.365	7.984	5.658
1992	1.750	7.810	7.256	0.240	13.233	12.649
1993	1.473	9.428	8.424	−0.323	22.375	21.251
1994	1.071	−6.282	7.006	−1.610	−0.582	13.520
1995	1.077	−0.024	1.555	−1.870	5.478	7.140
1996	0.614	−4.786	−0.053	0.231	−18.352	−14.291
1997	0.501	6.174	2.112	0.564	−4.422	−8.078
1998	0.210	18.283	7.271	−0.237	9.192	−0.979
1999	−0.329	−3.009	−0.149	−2.303	8.825	12.043
2000	0.114	11.511	0.164	−1.215	16.362	4.515

Table B.1 (*Continued*)

	U.S. dollar price of U.S. good	Australian dollar price of U.S. good	Canadian dollar price of U.S. good	Japanese yen price of Japanese good	Australian dollar price of Japanese good	Canadian dollar price of Japanese good
Transport equipment						
1988	1.712	−9.294	−5.828	−1.435	−0.282	3.534
1989	3.185	3.515	−0.499	1.085	−5.477	−9.145
1990	2.487	2.820	1.082	1.096	−3.505	−5.137
1991	3.548	3.854	1.616	−0.188	7.387	5.073
1992	3.036	9.172	8.611	0.521	13.544	12.960
1993	2.365	10.391	9.378	−1.413	21.044	19.926
1994	2.335	−5.112	8.343	−2.033	−1.009	13.037
1995	1.458	0.353	1.938	−1.711	5.648	7.312
1996	1.007	−4.414	0.336	0.701	−17.970	−13.888
1997	−0.240	5.390	1.358	1.305	−3.716	−7.398
1998	−0.611	17.313	6.391	1.391	10.972	0.633
1999	0.633	−2.072	0.814	−3.784	7.177	10.338
2000	0.706	12.170	0.756	−2.974	14.281	2.660

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