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Abstract

Aggregate and sector-level investment equations that incorporate the exchange rate are estimated for a panel of 17 OECD countries using an error correction methodology. A real currency depreciation is found to have a significant negative effect on aggregate investment in both the short run and the long run. This effect is negative in all sectors in the short run, is significant in six of nine sectors, and is particularly persistent in service sectors, sectors that do not generally benefit directly from an expansion of demand following a currency depreciation. Movements in another explanatory variable, the real wage, have an insignificant impact on investment in the short run in most sectors, but a rise in the real wage has a significant negative long run effect on aggregate investment and on investment in six of nine sectors. A simulation shows that movements in the real exchange rate and the real wage can explain a large proportion of cross-country differences in investment.

JEL Classification: F3, F4, E22
Keywords: investment; exchange rate, open economy, wage rate.

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1. Introduction

Investment is a key factor in the determination of short run output fluctuations, productivity and growth. While there is a large empirical investment literature, much of this literature employs a closed economy framework and often focuses on just one country, typically the US.[1] For economies that are open, exchange rate movements can cause large changes in the profitability of production and incentive to invest. A currency depreciation, for example, may increase the demand for domestic goods, but may also raise the cost of imported capital and other imported inputs. Investment will rise following a currency depreciation only if the impact on demand is sufficient to outweigh the cost effect.

Since the 1970s, exchange rates have fluctuated widely and persistently.[2] Although inflation may eventually erode the impact of a nominal depreciation on the real exchange rate, the observed long periods of currency over- and under-valuation suggest that this may take considerable time and that, in the interim, exchange rate changes could have a significant impact on investment activity. The impact of the exchange rate on the cost of imported capital goods is likely to be important to all but the largest economies since most of the world's capital equipment is produced in just a few countries, chiefly the US, Germany and Japan, with the rest of the world depending on imports from these countries (Caselli and Wilson, 2004; Eaton and Kortum, 2001). Further, a link between imports and productivity growth is observed by Mazumdar (2001) and Halpern, Koren and Szeidl (2005), while Mody and Yilmaz (2002) show that increased imports of machinery lead to greater export competitiveness.[3]

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[1] See the reviews in Chirinko (1993) and Caballero (1999) as well as Bernanke, Bohn and Reiss (1988), Oliner, Rudebusch and Sichel (1995) and Gilchrist and Himmelberg (1995).

[2] For example, relative to the US 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*). Frankel and Rose (1996) find that, since 1970, the currencies of many countries have been under- or over-valued relative to their purchasing power parity levels for long periods.

[3] Other studies present indirect evidence that exchange rate movements affect investment. Landon and Smith (2006) find that a domestic currency depreciation (appreciation) causes a significant rise (fall) in the prices of the investment goods used in most industries, while 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. Rao, Tang and Wang (2003) find that the widening of the Canada-US productivity gap was due to an increase in the capital intensity gap, and that

Despite the potential importance of exchange rate movements for investment, the empirical literature on the impact of movements in the exchange rate on investment is relatively small. In an early contribution, Goldberg (1993) finds that currency appreciations led to a contraction of investment in the 1970s, but caused an expansion of investment in the 1980s. More recently, Campa and Goldberg (1999) show that a 10 percent currency depreciation leads to a one to two percent decline in manufacturing investment in the US. Similarly, Forbes (2002) finds that commodity firms with higher capital/labour ratios exhibit slower growth in capital investment following a currency depreciation.[4]

The current study adds to an understanding of the impact of the exchange rate on investment in several ways. The first contribution is to provide an analysis of the determinants of investment in nine individual sectors that together encompass the entire economy. Most empirical analyses of investment, both for closed and open economies, examine only aggregate (or total business) investment, or investment in manufacturing.[5] Given differences across sectors with respect to capital intensity, as well as export and import exposure, sector-level responses of investment to changes in the exchange rate may vary in direction and magnitude. If, for example, services sectors are more sensitive to exchange rate changes, currency movements may affect investment in these sectors relative to others and, as a result, exchange rate policy may operate as

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the depreciation of the Canadian dollar contributed to a rise in the real rental price of capital and, hence, to the widening of the capital intensity gap. Leung and Yuen (2005) find that a currency depreciation causes a decline in the capital-labour ratio in the Canadian manufacturing sector.

[4] Other open economy investment studies include Campa and Goldberg (1995), Bell and Campa (1997) and Nucci and Pozzolo (2001). A number of studies concentrate on the impact of changes in exchange rate variability on investment. Examples include Darby, Hughes Hallett, Ireland and Piscitelli (1999), Hughes Hallett, Peersman and Piscitelli (2004) and Byrne and Davis (2005).

[5] An open economy exception is Goldberg (1993). She estimates separate investment equations for individual US industries as well as for sub-sectors of US manufacturing. Hughes Hallett, Peersman and Piscitelli (2004) also estimate industry-level investment equations, but their focus is on exchange rate uncertainty. Campa and Goldberg (1995, 1999) use data for sub-sectors of manufacturing, but pool this data, rather than estimate separate investment equations for each sector (other than for "high-markup" and "low-markup" sectors). Although manufacturing remains important, it accounts for only a fraction of investment spending in most countries. For example, in 2001, gross fixed capital formation (GFCF) in manufacturing, as a percentage of non-agricultural business sector GFCF, was 13.8, 15.3 and 17.6 percent in Australia, Canada and the US, respectively. As indicated by Table A2 in Appendix A, on average, the two largest sectors are both services sectors, while services sectors in total account for approximately two-thirds of GDP.

a (perhaps unintended) instrument of industrial policy. Such differences could be important since, as noted by Triplett and Bosworth (2004, 3), most of the post-1995 productivity growth in the US occurred within services producing sectors.

Given that considerable time is often required to plan and execute investment projects, investment spending tends to adjust slowly. A second contribution of the present study is to provide estimates of both the short run and long run effects of the exchange rate on investment. This approach is useful since, even if the exchange rate does not have a long run impact on investment, the identification of a large short run effect that persists for many years may be important from a policy perspective. Earlier open economy studies, such as those of Campa and Goldberg (1995, 1999) and Nucci and Pozzolo (2001), estimate an investment equation in first difference form, and so identify only short run parameters.

Most empirical research on investment behaviour uses data for a single country.[6] A third contribution of this study is to employ industry level investment data that are pooled across countries.[7] As noted by Frankel (2006) and Frankel and Rose (1996), the use of a cross-country panel makes it possible to exploit variation in the data across countries, particularly variation in the exchange rate. Frankel (2006, 76-77) argues that "lots of the important questions in macroeconomics and international economics can only be satisfactorily answered with large data sets — either long historical time series, or wide cross-sections, or panel studies that combine the two." The alternative of estimating separate investment equations for each country is likely to lead to imprecise estimates as, for many countries, only relatively short data samples are available.

A crucial aspect of any empirical study of investment is the choice of control variables.

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[6] While Alesina, Ardagna, Perotti and Schiantarelli (2002) use a panel of countries, they note that most previous studies are country specific. Among the few other open economy studies of investment that use cross-country panel data are Hughes Hallett, Peersman and Piscitelli (2004) and Byrne and Davis (2005).

[7] Previous (non-investment related) studies that pool sector level data across countries include Peersman and Smets (2005) and Dedola and Lippi (2005). These studies show that, given the large differences across industries in the response of output to monetary policy disturbances, it is more appropriate to pool across countries than across industries within a single country. The evidence in Table A2 of Appendix A shows that the contribution of each sector to the GDP of each country is often quite similar across countries.

Most studies employ demand-side explanatory variables, such as sales or output, and some introduce cost factors, such as the user cost of capital or the price of oil. Surprisingly few investment studies incorporate the cost of labour, even though labour costs are generally the largest component of production costs, so wage changes could have a significant impact on the profitability of production and investment.[8] One exception is Alesina, Ardagna, Perotti and Schiantarelli (2002). They argue that the wage is an important determinant of investment and that government expenditure policy is an important determinant of the wage. In support of this hypothesis, they provide evidence of a relationship between government expenditure and investment, and between government expenditure and wages. In light of these findings, the analysis below incorporates the real wage as a control variable in addition to the exchange rate. This avoids omitting a potentially important variable, and allows for a comparison of the relative roles of the wage and the exchange rate as determinants of investment. As a check of the robustness of the results, the empirical analysis also addresses the issue of the possible endogeneity of the wage and the other explanatory variables.

A notable finding of this study is that, across all sectors, investment is observed to rise with a currency appreciation in the short run. This indicates that, in the year the currency appreciates, the impact on investment of an exchange rate-induced decrease in the cost of imported capital and other inputs overwhelms the impact of any exchange rate-induced fall in the demand for domestic output. In the long run, this result holds for total investment and, while the effect of the exchange rate on investment is not significant in the long run in most sectors, it tends to be persistent in services sectors. The finding that a currency appreciation has a greater positive effect on investment in service sectors seems plausible as these sectors typically are not large exporters and, therefore, do not experience a large contraction in demand for their output

[8] See, for example, Mariesse, Hall and Mulkay (1999) and the comparison of four models (including the accelerator, neoclassical and "Tobin's q" models) by Bernanke, Bohn and Reiss (1988).

following an appreciation.

A second noteworthy result is that a rise in the real wage has a significant negative long run effect on investment. This finding implies that, as suggested by Alesina, Ardagna, Perotti and Schiantarelli (2002, 573), a higher wage reduces firm profitability and causes a fall in investment.[9] Although the wage effect is generally insignificant in the short run, in several sectors, particularly the non-agriculture business sector, it materializes quickly — in a year or two. Further, a simple dynamic simulation exercise for Canada, a country in our sample that is characterized by an average level of openness, shows that the wage effect is relatively large in magnitude over much of the period investigated.

The plan of the paper is as follows. The next section outlines the general form of the investment equation. A long run open economy investment equation is derived from a simple theoretical model in Section 3 and the data and explicit form of the estimating equation are described in Section 4. Section 5 presents the estimates as well as a discussion of the magnitude and persistence of the impact of the exchange rate and real wage on investment. Section 6 provides a brief summary and discusses policy implications.

2. The General Analytical Framework

As investment projects generally take time to plan and implement, it is important to employ a methodology that incorporates slow adjustment and allows for different short run and long run effects. This study employs a general autoregressive distributed lag (ARDL) model that allows for very general adjustment dynamics.[10] In its error correction form, this model nests a

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[9] This result is also consistent with the hypothesis that a higher wage causes a fall in firm cash flow and that, as suggested by Gilchrist and Himmelberg (1995), the reduction in firm cash flow leads to a decline in investment.

[10] This empirical framework was introduced into the investment literature by Bean (1981) and is employed in a number of recent studies (Mairesse, Hall and Mulkay, 1999; Darby, Hughes Hallett, Ireland and Piscatelli, 1999; Mojon, Smets and Vermeulen, 2002; Schich and Pelgrin, 2002; Bond, Elston, Mairesse, Mulkay, 2003; Byrne and Davis, 2004, 2005; Ellis and Price, 2004; Hughes Hallett, Peersman, and Piscitelli, 2004; Alesina, Ardagna, Nicoletti, and Schiantarelli, 2005). Alternative estimation methods, such as the Euler equation and q-theory approaches, tend to be quite restrictive and do not perform well empirically (Bond, Elston, Mairesse, Mulkay, 2003; Dixit and Pindyck, 1994; Caballero, 1999; Oliner, Rudebusch and Sichel, 1995; Abel and Blanchard, 1986).

long-run theory-based specification for investment within a structure that permits the short-run investment dynamics to be data determined. This section describes the general features of the ARDL model, while the next section outlines a theoretical model of the determinants of investment in the long run.

As well as incorporating quite flexible short run dynamics, an advantage of the ARDL model is that OLS estimation yields consistent estimates of the parameters when the variables are all I(0) or all I(1), or when some are I(0) and some I(1), and a long-run relationship exists (Pesaran and Shin, 1998). Further, Pesaran and Smith (1995) show that standard inference can be carried out on the short run and long run parameters even if it is not known *a priori* which variables are I(0) and which are I(1). This implies that the data need not be pre-tested for unit roots (Pesaran, 1997), which is important as unit root tests, even the panel specific alternatives, generally have low power in samples of the type and length used here.[11] Finally, Pesaran and Shin (1998) show that the ARDL methodology is directly comparable to the fully-modified OLS method of Phillips and Hansen (1990), but exhibits better performance in Monte Carlo studies.[12]

An ARDL model of investment in sector j of country c during time period t (I_{jct}) can be written:[13]

$$I_{jct} = \lambda_j I_{jc,t-1} + \beta_{1j}\mathbf{X}_{jct} + \beta_{2j}\mathbf{X}_{jc,t-1} + \mu_{jc} + \eta_{jt} + \varepsilon_{jct}, \qquad (1)$$

where $\mathbf{X}_{jct}$ is a vector of regressors, ε_{jct} is an independently distributed and serially uncorrelated error term, λ_j, β_{1j} and β_{2j} are sector specific parameters, and μ_{jc} and η_{jt} are vectors of country

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[11] Evidence in Karlsson and Lothgren (2000) and Gutierrez (2003) on the power of panel unit root and cointegration tests, respectively, indicates that these tests have low power in samples of similar size to those used here. Panel unit root tests have also been shown to suffer considerable loss of power with the addition of a trend (Baltagi and Kao, 2000; Choi, 2001). This is particularly relevant for a variable such as investment that tends to trend upwards.

[12] See Pesaran, Smith and Akiyama (1998) and Pesaran and Shin (1998) for general discussions of the ARDL methodology.

[13] Only one lag is included in equation (1) for expositional simplicity but, during estimation, additional lags are considered.

and time period fixed effects, respectively.[14] For the purposes of estimation, it is convenient and standard to re-parameterize this model as:

$$\Delta I_{jct} = (\lambda_j - 1) I_{jc,t-1} + \beta_{1j} \Delta \mathbf{X}_{jct} + (\beta_{1j} + \beta_{2j}) \mathbf{X}_{jc,t-1} + \mu_{jc} + \eta_{jt} + \varepsilon_{jct}, \qquad (2)$$

where $\Delta I_{jct} \equiv I_{jct} - I_{jc,t-1}$, $\Delta \mathbf{X}_{jct} \equiv \mathbf{X}_{jct} - \mathbf{X}_{jc,t-1}$, and all variables are in log form, so ΔI_{jct} denotes the first-difference of the natural log of investment. To make the interpretation of the parameters straightforward, equation (2) is often written in the error correction form:

$$\Delta I_{jct} = \beta_{1j} \Delta \mathbf{X}_{jct} + (\lambda_j - 1) \left[I_{jc,t-1} - \frac{\beta_{1j} + \beta_{2j}}{1 - \lambda_j} X_{jc,t-1} \right] + \mu_{jc} + \eta_{jt} + \varepsilon_{jct}. \qquad (3)$$

The term in square brackets reflects the long run relationship between investment and the explanatory variables. Thus, the long run marginal effect of $\mathbf{X}_{jc}$ on $\mathbf{I}_{jc}$ is $\frac{\beta_{1j} + \beta_{2j}}{1 - \lambda_j}$, while the parameter ($\lambda_j$-1) determines the speed of adjustment to the long run, and β_{1j} represents the short run marginal impact of a change in $\mathbf{X}_{jc}$ on investment.[15]

3. An Open Economy Model of Long Run Investment

In order to estimate the ARDL, it is necessary to identify the determinants of investment, the elements of the **X** vector. Following Mairesse, Hall and Mulkay (1999) and Bond, Elston, Mairesse and Mulkay (2003), these are identified from the solution to the long run optimization problem of a firm. The theoretical framework used to describe the firm's long run investment decision is based on a standard neo-classical model that is augmented to allow the firm to both

[14] As individual year parameters can be identified in a panel, it is common to include year dummies in place of the trend variable that is often included in non-panel ARDL models. The country and time period parameters, as well as the other parameters, are indexed by j so that it is clear that they may differ across sectors.

[15] For there to exist a long run relationship between investment and **X,** the adjustment coefficient, λ_j-1, must differ from zero (Pesaran, Smith and Akiyama, 1998).

export output and import inputs. This framework follows the basic structure proposed by Campa and Goldberg (1999) and Nucci and Pozollo (2001), except that the investment good (capital) may be imported (rather than produced only domestically, as in those studies).[16]

A representative domestic firm in sector j utilizes both domestic and imported inputs and produces output that is sold in both domestic and export markets. The firm uses capital goods, K_j, that are combined with non-tradable domestic inputs, L_j, such as labour, and tradable intermediate inputs, M_j, such as raw materials, to produce output according to the production function:[17]

$$Q_j + Q_j^f = f(K_j, L_j, M_j), \tag{4}$$

where Q_j and Q_j^f denote the output of the firm in sector j produced for sale in domestic and foreign markets, respectively.

The firm chooses its output and input quantities to maximize the present discounted value of current and future real net cash flow:

$$\max_{Q_j, Q_j^f, K_j, I_j, L_j, M_j} \sum_{t=0}^{\infty} (1+r_t)^{-t} \left\{ \frac{P_{jt}}{P_t} Q_{jt} + \frac{eP_{jt}^f}{P_t} Q_{jt}^f - \frac{W_t}{P_t} L_{jt} - \frac{P_{Kjt}}{P_t} I_{jt} - \frac{eP_{Mt}^f}{P_t} M_{jt} \right\}, \tag{5}$$

subject to the production function, equation (4), and the capital accumulation constraint:

$$K_{jt} = (1-\delta) K_{j,t-1} + I_{jt}, \tag{6}$$

where P_j and P_j^f are the domestic firm's output prices in domestic and foreign markets, respectively, with P_j^f denominated in foreign currency; P is the domestic country general price level; e is the domestic currency price of one unit of foreign currency; W is the price of domestic

[16] Another difference with these, as well as many other investment studies, is that, in the approach taken here, the *theoretical* model describes only the long run and does not attempt to model the short run or the dynamics of adjustment, so it does not explicitly incorporate investment adjustment costs. The approach taken here is consistent with other investment studies that employ the ARDL methodology. (See the studies cited in footnote 10.)
[17] Except where necessary, time and country subscripts have been suppressed in this section to simplify the exposition.

non-tradable inputs (such as labour), and is assumed to be the same for all firms; P_{Kj} is the price of new capital used by the firm in sector j; P_M^f is the world price, in foreign currency, of the tradable intermediate input; I_{jt} represents the investment of the firm in sector j during period t; $(1+r_t)^{-t}$ is the discount factor at time t; and δ is the rate of capital depreciation (assumed constant).

Demand for the firm's output depends on relative prices and income (as in Marston (1990)), which imply inverse demand functions of the form:

$$P_j = \rho_j(Q_j, y)P, \qquad \frac{\partial \rho_j(Q_j, y)}{\partial Q_j} < 0, \qquad \frac{\partial \rho_j(Q_j, y)}{\partial y} > 0, \tag{7a}$$

$$P_j^f = \rho_j^f(Q_j^f, y^f)P^f, \qquad \frac{\partial \rho_j^f(Q_j^f, y^f)}{\partial Q_j^f} < 0, \qquad \frac{\partial \rho_j^f(Q_j^f, y^f)}{\partial y^f} > 0, \tag{7b}$$

where P^f is the foreign general price level, denominated in foreign currency; and y and y^f are domestic and foreign real income, respectively.

The cost of putting a new unit of capital in place (for example, a unit of a new manufacturing plant) is a function of the prices of the inputs required to produce the capital, such as the cost of the labour used in construction and the cost of the machinery and equipment that make up the physical component of the capital. It follows that the real per unit cost of the investment goods purchased by the representative firm in sector j will depend on the real price of non-tradable domestic inputs (W/P) and the real domestic currency price of tradable capital inputs, eP_K^f/P :

$$\frac{P_{Kj}}{P} = p_{Kj}\left(\frac{W}{P}, \frac{eP_K^f}{P}\right), \qquad \frac{\partial(P_{Kj}/P)}{\partial(W/P)} > 0, \quad \frac{\partial(P_{Kj}/P)}{\partial(eP_K^f/P)} > 0, \tag{8}$$

where P_K^f is the foreign currency price of tradable capital goods.

Solving the maximization problem of the firm, given equations (7a), (7b) and (8), yields an expression for the long run optimal level of capital:

$$K_j = K_j\left(\frac{eP^f}{P}, \frac{eP^f_K}{P}, \frac{eP^f_M}{P}, \frac{W}{P}, y, y^f, r, \delta\right). \tag{9}$$

To derive a long run investment function from equation (9), we follow Bean (1981) and assume that the growth rate of capital is constant and equal to g in the long run,[18] so:

$$I_j = (g + \delta)K_j. \tag{10}$$

Substituting equation (9) into (10), and using $\frac{eP^f_K}{P} = \left(\frac{eP^f}{P}\right)\cdot\left(\frac{P^f_K}{P^f}\right)$ and $\frac{eP^f_M}{P} = \left(\frac{eP^f}{P}\right)\cdot\left(\frac{P^f_M}{P^f}\right)$,

yields the long run investment function:[19]

$$I_j = I_j\left(\frac{eP^f}{P}, \left(\frac{eP^f}{P}\right)\cdot\left(\frac{P^f_K}{P^f}\right), \left(\frac{eP^f}{P}\right)\cdot\left(\frac{P^f_M}{P^f}\right), \frac{W}{P}, y, y^f, r, g, \delta\right). \tag{11}$$

The real exchange rate affects the level of investment, I_j, through three channels. First, a real currency appreciation (a fall in eP^f/P) reduces the domestic currency value of domestic exports and, in so doing, causes firms to decrease production for export. This leads to a fall in the demand for all inputs, including capital. Second, a real domestic currency appreciation decreases the domestic currency price of tradable capital, which tends to increase investment. Third, an appreciation reduces the domestic price of imported intermediate inputs. The impact of this price change on investment is uncertain, as it depends on the degree of substitutability (or complementarity) between these inputs and capital.[20] Because these three effects do not all have

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[18] Other studies that follow Bean (1981) include, for example, Darby, Hughes Hallett, Ireland and Piscatelli (1999), Ellis and Price (2004) and Byrne and Davis (2005).

[19] An advantage of estimating this investment equation, rather than the equation for the capital stock (as is done in Mairesse, Hall and Mulkay (1999) and Bond, Elston, Mairesse, Mulkay (2003)) is that estimation of equation (9) would necessitate the acquisition of capital stock data, while estimation of equation (11) does not. Although data on investment are available for up to 17 countries from the OECD's *STAN* database, data on capital, by sector, are available for only half of these countries. Further, as noted by Pelgrin, Schich and de Serres (2002, 18), "compared to gross investment, the reliability of aggregate capital stock data has in many countries been increasingly called into question, reflecting serious measurement difficulties."

[20] By interacting the exchange rate with the industry-specific export share and the share of imported inputs in production, Campa and Goldberg (1999) and Nucci and Pozollo (2001) identify separate channels by which the

the same sign, the net effect on investment of a real domestic currency appreciation is uncertain.

Despite the general ambiguity of the exchange rate effect on investment, the model suggests investment in some sectors may be more sensitive to exchange rate changes than investment in other sectors. For example, a currency appreciation would be more likely to lead to a rise in investment in service sectors as these sectors are generally not large exporters (and therefore experience a smaller negative demand effect following an appreciation), but would be expected to benefit from the appreciation-induced fall in the prices of imported capital and other imported inputs. In sectors where the output price is determined in world markets, such as commodities, exports are likely to be more sensitive to exchange rate movements and a currency appreciation would, therefore, be expected to cause a decline in investment. For firms that rely on both exports and imported inputs, as is typical of many manufacturing firms, the effect on investment of currency valuation changes could be either positive or negative.

4. Empirical Implementation and the Data

The ARDL model of investment given by equation (2) is estimated with the vector of explanatory variables, $\mathbf{X}_{jct}$, replaced by the explanatory variables in the long run theory-based investment function, equation (11). Data on investment (real gross fixed capital formation) are taken from the OECD's *STAN* database.[21] Investment equations are estimated for 13 different categories of investment: *Total* investment; investment in nine individual sectors that together comprise all economic activity, including services; as well as for three multi-sector aggregates (the *Non-agriculture business sector*, *Business sector services*, and *Total services*).[22] The data are

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exchange rate affects investment. However, as comparable cross-country industry-specific data for exports, imported intermediate and imported capital inputs are not available, it is not feasible to employ a similar methodology for the sample analyzed in this study.

[21] The new *STAN* database employs a standard industry list based on *ISIC* Rev. 3. It merges the OECD's *International Sectoral Database* (which is no longer updated) and the old *STAN Database for Industrial Analysis* (which was based on *ISIC* Rev. 2 and covered the manufacturing sector only).

[22] The *Non-agriculture business sector* includes all sectors except *Agriculture, hunting, forestry and fishing* and *Community, social and personal services* and the sub-sector *Real estate activities*. *Business sector services* comprises the three sectors: *Wholesale and retail trade, restaurants and hotels*; *Transport and storage and communication*; and

annual for 17 countries[23] and span the period from 1971 to 2003, but data for all countries and all sectors are not available for this entire period.[24] As a result, the panel is unbalanced. The use of an unbalanced sample made considerably more observations available than would have been the case if a balanced panel had been employed.

Data for 17 countries are available for *Total* investment, as well as for two of the three other multi-sector aggregates and 8 of the 9 individual sectors. The sample for the remaining industry has observations for 15 countries, while the sample for the final multi-sector aggregate includes data for 13 countries. Across the nine individual industries, the average number of observations available per country varies from 23 to 25, while the total number of observations employed in the sector-level regressions varies from 366 to 398. The maximum number of observations available for a single country is 33, while the minimum is seven. Table A1 of Appendix A provides the number of observations, the countries, and the exact sample periods employed for each sector.

In order to estimate the investment equation, empirical counterparts must be specified for the arguments of the theoretical model of investment, equation (11). The real exchange rate, eP^f/P, is represented by the log of the real effective exchange rate (measured as domestic currency units per unit of foreign currency) weighted by imports plus exports as a share of GDP.[25] A weighted exchange rate is employed as there exist large differences in the international exposure

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Finance, insurance, real estate and business services. *Total services* is equal to *Business sector services* plus *Community, social and personal services*.

[23] The 17 countries are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, and the US. Data for the remaining 13 member countries of the OECD were not employed either because data on real gross fixed capital formation were not available in the *STAN* database (Iceland, Japan, Luxembourg, New Zealand, Switzerland, the UK) or the countries were new members of the OECD and had very short data samples available and/or very different industrial structures than the other countries in the sample (Hungary, Mexico, Slovakia, Turkey, the Czech Republic, Korea, Poland).

[24] As of the end of August 2007, the OECD had not yet updated the *STAN* database to incorporate data for the years following 2003. See http://www.oecd.org/document/15/0,2340,en_2649_201185_1895503_1_1_1_1,00.html

[25] The weight is calculated using data for 1970, the year prior to the start of the sample, so that changes in the weight, as a result of movements in the exchange rate, do not mask part of the impact of the exchange rate on investment. If the weight employed is the average of the annual weights for the 1970-2003 period, the results do not change significantly.

of the countries in the sample, and the magnitude of the impact on investment of movements in the exchange rate is likely to depend on a country's import and export dependence (with respect to both inputs and final goods).[26]

The foreign currency prices of tradable inputs, such as machinery or oil, are assumed to be determined in world markets. As a result, $\frac{P_K^f}{P^f}$ and $\frac{P_M^f}{P^f}$ are the same for all countries at each point in time. This means that these two price ratios are perfectly co-linear with the vector of year dummy variables, η_{jt}, that captures factors that are common across countries, but that differ across time. As a consequence, the effect of the two tradable goods prices on investment is incorporated in the parameter estimates associated with the year dummies.[27]

The theoretical investment equation also includes real output, y, and the real price of the non-tradable domestic input, W/P, as arguments. The real non-tradable domestic input price is represented by the log of the ratio of the wage rate to the GDP deflator,[28] while real domestic output, y, is proxied by the log of real GDP. Country-specific fixed effects, μ_{jc}, are included in the estimating equation to represent the determinants of investment that differ across countries, but are constant through time.[29] These include, for example, the long run growth rate of capital (g)

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[26] It is necessary to use data on aggregate imports and exports because data on imported inputs or sector-level final good exports are not available for all sectors and all 17 countries for the sample period. Campa and Goldberg (1999) and Nucci and Pozzolo (2001) also use a weighted form of the exchange rate.

[27] Note that data on tradable investment good prices at the sector level are not available. While a price index for gross fixed capital formation is available by sector, because these price indices are for *total* investment expenditures in each sector, they incorporate the costs of both non-tradable and tradable investment goods.

[28] For 13 of 17 countries, the wage rate used is the average hourly wage in manufacturing as this is the most widely available wage rate data. For the other four countries, it is the "Wage rate, Business Sector" or "Wages Hourly Earnings" (see Appendix B). The results are fundamentally unchanged if the observations for these four countries are deleted from the sample, although some of the parameters are estimated less precisely. An alternative measure of the wage is *Compensation per employee in the business sector*, available in the OECD's *Economic Outlook*. A disadvantage with this measure is that it does not control for changes in the number of hours worked over the business cycle, or changes in the number of hours worked over time. This measure may also be affected by changes in the number of part-time employees through time and over the cycle. Conceptually, the hourly wage, since it measures the cost per unit of labour, corresponds more closely to the wage that appears in the model of Section 3.

[29] The inclusion of fixed effects in a dynamic model can lead to biased parameter estimates, although this bias falls as the length of the sample increases (Nickell, 1981). Monte Carlo evidence in Judson and Owen (1999) and Bun and Kiviet (2001) suggests that the magnitude of this bias is likely to be small in a sample of the size used here. Methods to correct for this bias are generally only appropriate for samples in which the number of time series observations is small relative to the number of members of the panel (Haque, Pesaran and Sharma, 2000), which is not the case here.

and the depreciation rate (δ).

The final two arguments of the long run investment equation are the foreign output variable, y^f, and the interest rate, r. If y^f is taken to be world output, it is the same for all countries in the sample in each time period and, as a result, can be represented by the set of year dummies, η_{jt}. Further, to the extent that the interest rate, r, is determined in world capital markets, it is also common to all countries and can also be captured by the year dummies. (See Bond, Elston, Mairesse and Mulkay (2003) and Gilchrist and Himmelberg (1995) for a similar approach.)[30]

Incorporating the variables described above in the ARDL model, equation (2), yields the estimable investment equation:[31]

$$\Delta I_{jct} = (\lambda_j - 1) I_{jc,t-1} + \gamma_{1j} \Delta(eP^f/P)_{ct} + \gamma_{2j} \Delta(W/P)_{ct} + \gamma_{3j} \Delta y_{ct} + \gamma_{4j} \Delta y_{c,t-1}$$
$$+ \gamma_{5j} (eP^f/P)_{c,t-1} + \gamma_{6j} (W/P)_{c,t-1} + \gamma_{7j} y_{c,t-2} + \mu_{jc} + \eta_{jt} + \varepsilon_{jct}, \quad (12)$$

where the parameters γ_{1j} and γ_{5j} each incorporate the three channels, as made explicit in equation (11), through which the exchange rate may affect investment. The parameters of equation (12) are estimated using data that has been pooled across countries for each industry. Potential heterogeneity across countries and time periods is represented by the country (μ_{jc}) and time period (η_{jt}) fixed effects.[32] Appendix B gives variable definitions and detailed sources for all the

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[30] Bond, Elston, Mairesse and Mulkay (2003, 155) state: "We assume that variation in the user cost of capital can be controlled for by including both time-specific and firm-specific effects." Similarly, Gilchrist and Himmelberg (1995, 548n) argue that time varying discount factors that differ by firm can be proxied by time effects and firm fixed effects.

[31] Most empirical investment equations employ relatively few explanatory variables, quite often only two. See, for example, Mairesse, Hall and Mulkay (1999), Alesina, Ardagna, Nicoletti and Schiantarelli (2005), Byrne and Davis (2005), Pelgrin, Schich and de Serres (2002), Bean (1981), Bond, Elston, Mairesse and Mulkay (2003), Schich and Pelgrin (2002) and Mojon, Smets and Vermeulen (2002).

[32] Pesaran and Smith (1995) emphasize the potential importance of allowing for heterogeneity in panel data estimation. While the addition of fixed effects, as used here, is one method of addressing heterogeneity, there are other methods as well. However, these generally involve estimating separate regressions for each member of the panel (in the current case, for each country). This is not practical here as the number of observations for several countries in the unbalanced panel is relatively small (there are fewer than 17 observations for five of the 17 countries in the sample). Small samples can lead to very imprecise estimates, and these can yield inaccurate heterogeneity corrected panel estimates (Pesaran, Smith and Akiyama, 1998). Pesaran, Smith and Im (1996) suggest that, if one is going to correct for potential heterogeneity using individual cross section regressions, a reasonable sample length for each regression is at least 25. For this reason, fixed effects, rather than one of these other methods, are employed.

data.

Equation (12) incorporates one lag of investment, and the current value and one lag of all the explanatory variables except for output (y), for which two lags are included. To simplify the analysis and interpretation of the results, the same dynamic specification is used for *Total* investment and all the sub-categories of investment.[33] The parameter estimates are similar when one or two lags of all the explanatory variables, or one lag of the dependent variable, are included in the estimating equation.

5. Parameter Estimates

Estimates of the parameters of the investment equation are presented in Tables 1 and 2. Table 1 gives the results for *Total* investment, as well as for investment in the *Manufacturing* sector and the three multi-sector aggregates (*Non-agriculture business sector*, *Total services*, and *Business sector services*). Results for the remaining eight individual sectors are presented in Table 2. Given that the dependent variable is a first difference and the sample is a pooled cross-section, the estimates explain a reasonable proportion of the variation in the difference of the log of investment. Further, the adjustment coefficient, λ-1, is negative as expected, the bounds test of Pesaran, Shin and Smith (2001) does not reject the existence of a long run relationship, and the speed of adjustment is either somewhat faster or similar to estimates found in other studies (Byrne and Davis, 2005, for example).[34] Test statistics provided in Tables 1 and 2 indicate that a Reset

[33] With samples of the length employed here, consideration of more than two lags is not generally feasible (Pesaran, Smith and Akiyama, 1998; Pesaran, Shin and Smith, 1999). Out of all possible lag structures with up to two lags of each explanatory variable, the lag structure employed minimizes the Schwartz-Bayes information criteria using data for each of the four multi-sector aggregates and *Manufacturing*. For some of the other eight individual sectors, dropping some lags yields a lower Schwartz-Bayes criteria. As noted in Pesaran (1997) and Pesaran and Shin (1998), it is important to include a sufficient number of lags in the ARDL and, thus, the specification in equation (12) may err somewhat on the side of including too many lags for some individual sectors.

[34] As noted by Pesaran, Shin and Smith (2001, 313n) the t-statistic associated with the lagged dependent variable (the adjustment coefficient, λ-1) does not have a standard t-distribution. As an alternative to pre-testing for unit roots and cointegration, they provide a bounds test for the significance of the adjustment coefficient that is valid whether the variables are I(0) or I(1). Using the critical values for this test, the adjustment parameter is either conclusively significantly different from zero (seven of 13 cases at 95 percent and nine at 90 percent) or the test statistic falls in the inconclusive range. Although this bounds test is used here to analyze a panel, it was developed in a non-panel setting.

test does not reject the model and that the hypothesis of no serial correlation cannot be rejected (in 11 of 13 cases at 95 percent and in all 13 cases at 99 percent for both tests). In addition, the coefficient estimates associated with the output (y) variable are generally positive and, therefore, consistent with expectations.[35] Finally, the estimates are robust to several generalizations of the model in that none of the basic conclusions change if the estimating equation is altered as follows: the data for the US and Germany, both large producers of machinery and equipment, are deleted from the sample; the real interest rate, cyclically adjusted government expenditure, the standard deviation of the exchange rate and an alternative measure of labour costs are individually included as explanatory variables in the estimating equation (see Appendix C for details).

As the estimating equation incorporates the current values of the change in the real exchange rate, the real wage, and real GDP, there exists the potential for the parameter estimates to be subject to endogeneity bias since the errors (ε_{jct}) may be correlated with these variables. Pesaran (1997) and Pesaran and Shin (1998) show that the ARDL estimation method yields consistent estimates even if the explanatory variables are correlated with the error term as long as the estimating equation is augmented with a sufficient number of lagged changes of the explanatory variables. Further, a Hausman-Wu test (Davidson and MacKinnon, 1993, 237-39) for the endogeneity of the current values of each of the three explanatory variables does not reject the hypothesis that the errors are not correlated with the contemporaneous explanatory variables in all 13 of the investment regressions. This result is not surprising as the potentially endogenous explanatory variables are economy-wide output and the exchange rate, as well as the average wage for a major sector, while the dependent variable in the estimating equation is investment in aggregate or in an individual sector, both of which represent relatively small proportions of total economic activity. (For example, investment in aggregate represented only 14.4 percent of US

[35] In the agricultural sector, the long run output coefficient is negative and significant at 90 percent. This is not surprising as this sector has tended to shrink as opportunities improve in the rest of the economy.

GDP in 2001, while investment in each of the nine individual sectors ranged from only .2 to 3.6 percent of GDP.)

Exchange Rate Parameter Estimates

The estimates of the short run and long run exchange rate parameters for *Total* investment, reported in Table 1, are negative and significant, indicating that a real domestic currency depreciation (a rise in the real exchange rate) leads to a reduction in investment. This implies that, in aggregate, the impact on investment of an exchange rate-induced increase in the cost of imported capital and other inputs outweighs the impact of any exchange rate-induced rise in the demand for domestic output.

As shown in Tables 1 and 2, the estimated short run exchange rate coefficient is also negative in all twelve sub-categories of investment, and is significant in all three multi-sector aggregates and in six of the nine individual sectors (although in three of these at only a 90 percent confidence level). Similarly, the estimated long run exchange rate parameter is negative in 11 of 13 cases, although it is insignificant in most sectors. Thus, in almost all sectors, investment appears to react quickly to exchange rate changes, but the level of investment appears to be unaffected by the level of the real exchange rate in the long run.

Although the exchange rate has an insignificant long run effect on investment in most sectors, the significant short run response may be important if it both appears quickly and persists. In order to gain a sense of the persistence of the exchange rate effect, Table 3 presents dynamic simulations of the impact on investment of a one percent permanent rise in the real exchange rate (a one percent real currency depreciation), holding all other variables constant, and evaluated at the mean of the international exposure weight. The exchange rate effect tends to persist in the *Total services* and *Business sector services* sectors as well as in three of the individual service sectors: *Finance, insurance, real estate and business services*; *Wholesale and retail trade, restaurants and hotels*; and *Community, social and personal services*. These sectors typically have few exports and, thus, do not benefit from a direct increase in demand following a depreciation, but may be affected negatively by a rise in the prices of imported capital and other imported inputs.[36] As these sectors comprise a large part of the economy (approximately 57 percent, on average, as shown in Table A2 of Appendix A), and have generally larger (in absolute value) coefficients associated with the exchange rate than the other sectors, it is possible that the impact of the exchange rate on investment in these sectors is driving the significant and persistent coefficients for *Total* investment and investment in the *Non-agriculture business sector*.

The results in Table 3 show a diverse range of long run exchange rate effects, but in the short run, a one percent currency depreciation (rise in the real exchange rate) leads to an impact on investment in most sectors that is fairly close to the coefficient for the *Total* economy ($-.29$), with the *Construction* sector exhibiting a somewhat stronger response, and *Manufacturing* and *Community, social and personal services* a weaker response. The insignificant (and medium-term positive) effect in *Manufacturing* is plausible given that manufacturing firms are typically involved in exporting output, as well as importing inputs, so the positive output demand effect of a currency depreciation may be relatively important in this sector. A large export demand response is also a possible explanation for the positive medium and long run effect observed in *Mining and quarrying*, given that the price of exports from this sector would typically be determined in world commodity markets, so export demand is likely to be highly sensitive to exchange rate movements.

Several differences and similarities between the impact of the exchange rate on investment at the aggregate and sector levels become apparent with the use of sector-level data. First, the results indicate that many sectors respond to movements in the exchange rate in a similar fashion, particularly in the short run, and that the *Total* industries estimate appears to be an appropriate

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[36] While the exchange rate may not directly affect demand in some sectors, particularly services, it could have an indirect affect on demand if exchange rate movements alter total output in the economy, and output movements affect demand.

indicator of the short run response in most sectors. Second, the results imply that *Manufacturing*, with a small and insignificant negative short run and positive long run coefficient estimate, is somewhat of an outlier relative to the other sectors, so general predictions should not be made on the basis of estimates for the *Manufacturing* sector alone. Finally, although most of the signs of the aggregate and sector level exchange rate coefficients are negative, the sector-level estimates reveal the few exceptions, including the positive (and significant) long run coefficient in the *Mining and quarrying* sector, and the positive long run coefficient in the *Manufacturing* sector.

While this paper presents new sector-level findings, the results are also consistent with the existing literature on investment undertaken for individual countries or for the manufacturing sector alone. For the US, Goldberg (1993) shows that a real dollar depreciation was associated with a reduction in investment in most sectors after 1980, a finding that corresponds to the negative effect on investment of a currency depreciation found here. Further, our estimates are similar to those of Campa and Goldberg (1999), who focus on the manufacturing industry alone. Using data for 20 US manufacturing sub-sectors, they find that a 10 percent domestic currency depreciation causes investment to fall by one percent (for high markup industries) to two percent (for low markup industries), which is comparable to the estimated (although not statistically significant) 1.3 percent current year fall in investment in the *Manufacturing* sector shown in Table 3.[37] For other countries, Campa and Goldberg find an investment response that is weak and negative (for the UK and Japan) or insignificant (for Canada), consistent with the negative and insignificant short run coefficient estimate for *Manufacturing* reported in Table 1.

The results presented here may be relevant for policymakers. First, the finding that a currency depreciation has a short run negative impact on investment in all sectors suggests that there is an overall decline in investment across the economy, which may have long run negative

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[37] Campa and Goldberg (1999) estimate their model in first difference form, so their coefficient estimates capture only the short run effect.

implications for future output and productivity growth. Second, the negative effect of a currency depreciation is often long-lasting, particularly in the services sectors. As a consequence, a weak currency may have implications for intersectoral investment reallocation, which can have an impact on economy-wide productivity growth since the services sectors, such as wholesale and retail trade and financial services, have been observed to be the main contributors to aggregate productivity in recent years. (See Triplett and Bosworth's (2004) study of the US.)

As noted above, the countries included in the data set are characterized by different degrees of export and import exposure. These differences cause the magnitude of the effect of the exchange rate on investment to vary across countries. For the most open economy, Belgium, a one percent real currency depreciation is predicted to cause a .569 percent fall in *Total* investment in the current year. In contrast, for the least open economy, the US, this effect is equal to just .064. From a policy perspective, even for sectors in which the exchange rate has a significant and persistent effect on investment, exchange rate movements will be less important to a country that is relatively closed (such as the US). On the other hand, these effects will be greater than the estimates in Table 3 would imply for countries that are more open than average.

Wage Rate Parameter Estimates

The parameter estimates reported in Tables 1 and 2 indicate that an increase in the real wage reduces investment in most sectors and that this effect tends to strengthen over time. While the real wage coefficient is often insignificant in the short run, in the long run it is negative and significant for *Total* investment, for the three multi-sector aggregates, and in six of the nine individual sectors. The significance of the long run wage coefficients illustrates the importance of the wage in the determination of long run investment and is consistent with the results in Alesina, Ardagna, Perotti and Schiantarelli (2002).

As the real wage is generally an insignificant determinant of investment in the short run, but has a significant long run effect, it is useful to determine the time required for a significant effect to materialize. Table 4 presents simulations of the impact of a permanent one percent real wage increase on investment through time. Although a change in the wage does not have a significant impact on *Total* investment in the year in which the change occurs, in the following year, and in all succeeding years, the impact of the wage change is significant and the magnitude of this impact rises quickly over time. Similarly, the impact of the real wage on investment in the *Non-agriculture business sector* takes two years to become statistically significant, but then grows rapidly in magnitude.

At the sector level, there is some variation in the speed with which changes in the real wage affect investment. For the three sectors that comprise *Business sector services* (*Transport, storage and communication*; *Wholesale and retail trade, restaurants and hotels*; and *Finance, insurance, real estate and business services*) a significant effect materializes either immediately or within a year. On the other hand, it takes the real wage from three to four years to have a significant effect on investment in the goods producing industries: *Mining and Quarrying*; *Electricity, gas and water supply*; and *Manufacturing*. The most rapid response of investment to the real wage, and the largest long run impact, is in the sector *Wholesale and retail trade, restaurants and hotels*. This is perhaps not surprising, given that production in this sector is likely to be relatively labour-intensive and, therefore, investment in this sector would be expected to be more responsive to wage changes.

The Economic Significance of the Parameter Estimates: An Example

In order to illustrate the economic significance of the parameter estimates described above, a comparison is made of the relative levels of investment in Canada and the US, and the extent to which differences between these can be explained by differences in the movements of the real exchange rate and, for the purpose of comparison, the real wage. The US and Canada were chosen *ex ante* because they are closely related economically, have many similar economic characteristics and have been compared extensively. Figure 1 illustrates real investment in the *Non-agriculture* *business sector* for Canada and the US, where each country's real investment has been normalized to one in 1970. For almost the entire 1971-2001 period, the path of investment in the US was above the path in Canada. By the end of 2001, US investment was slightly more than 40 percent greater than Canadian investment.

In order to provide a basis against which to compare the effect of the exchange rate, the first simulation examines the impact on investment in Canada of movements in the real wage. Using the parameter estimates given in Table 1 for the *Non-agriculture business sector*, Canadian investment is dynamically simulated with the percentage change in the Canadian real wage restricted to equal the percentage change in the US real wage for each year from 1971 through 2001. Figure 1 shows that the simulated level of Canadian investment is above the actual level for the entire period. This result arises because the Canadian real wage rose relative to the US real wage in the mid-1970s and then again in the early 1990s.[38] In 2001, the difference in real wages accounted for over 70 percent of the Canada-US investment gap. Hence, differences in real wages may be an important part of the explanation for cross-country variation in investment.[39]

To illustrate the importance of the exchange rate as a determinant of investment, the level of Canadian investment is dynamically simulated with the percentage change in the Canadian real exchange rate restricted to equal the annual percentage change in the US real exchange rate. As can be seen in Figure 1, the simulated path for Canadian investment is relatively close to the actual level of investment. There are periods during which simulated investment is above the actual level, for example, the late 1990s, and periods during which the simulated value is below actual

[38] Johnson and Kuhn (2004) find evidence consistent with a higher degree of labour market inflexibility in Canada than in the US which, they suggest, may be due to differences in minimum wages, social programs and the degree of worker unionization. According to evidence given in Card, Lemieux and Riddell (2003), in 1999, the union membership rate of wage and salary workers was 32.6 percent in Canada, but only 13.5 percent in the US. These factors may have facilitated the relative increase in Canadian real wages.

[39] While real wage growth in Canada was only 1.1 percent over the period 1994-2001, compared to 8.1 percent in the US, real wages rose much more quickly in Canada than in the US from 1989 through 1993 (9.3 percent compared to .4 percent). It would take several years of relatively higher US real wage growth to offset this previously established differential. This, in addition to the slow adjustment of investment, accounts for the finding that real wage growth differentials could explain a large proportion of the Canada-US investment gap in the late 1990s and even up to 2001.

investment, such as the late 1980s and early 1990s. The movements above and below the US investment level are not surprising as, over the sample period, the level of the Canadian real exchange rate fluctuated around the US rate. While the Canadian and US real effective exchange rates were approximately equal in 1996 (when adjusted to a common 1970 base year), by 2001, the real value of the Canadian currency had fallen by 9 percent, while the real value of the US currency had appreciated by 22 percent. The simulation indicates that, if this gap had not appeared and the two real exchange rates had followed the same path, the difference between investment in Canada and the US would have been 23 percent smaller in 2001. This result suggests that a real currency depreciation can have an impact on investment that is both statistically significant and relatively large in magnitude.

6. Concluding Comments

Using data for a panel of OECD countries and an error correction methodology, a domestic currency depreciation is found to have a significant negative effect on aggregate investment in both the short run and the long run. In the short run, the effect of a depreciation on investment is also negative in all sectors and significant in a majority of sectors. The negative sector-level effect can last for several years and is particularly persistent in service sectors, sectors that do not generally benefit directly from an increase in the demand for their output following a fall in the value of the domestic currency. On the other hand, the exchange rate does not have a significant impact on investment in *Manufacturing*, plausibly because this sector may experience an increase in demand following a currency depreciation that counteracts the increased cost of imported capital and other inputs.

Movements in the real wage have an insignificant impact on investment in the short run in most sectors, but have generally a significant long run effect. In several sectors, the negative impact of a wage rise on investment materializes rapidly and grows quickly. The significant effect of the real wage is not unexpected as labour costs comprise a large proportion of total input costs.

A negative effect of the wage on investment is consistent with a rise in labour costs reducing firm profitability and/or firm cash flow. The impact of the real wage on investment, in terms of magnitude and the time required for a significant effect to materialize, varies across sectors. Not unexpectedly, the largest impact is in the labour intensive *Wholesale and retail trade, restaurants and hotels* sector.

In order to illustrate the economic significance of the results, a comparison is undertaken of private sector non-agricultural investment in the US and Canada. A large fraction of the gap between Canadian and US investment, approximately 70 percent in 2001, can be explained by the relative increase in the Canadian real wage over the sample period. Movements in the real exchange rate account for a significant, but smaller, fraction of the investment gap. Part of the reason for this smaller effect is that the Canadian real exchange rate has not persistently deviated from the US rate over the sample. Nevertheless, following a large decline in the real value of the Canadian dollar relative to the US dollar in the latter part of the sample period, in 2001 the real exchange rate differential is shown to account for almost one quarter of the investment gap.

The results presented above suggest that policies that generate movements in the exchange rate or the real wage may have important consequences for investment. While a currency depreciation may have a positive impact on aggregate demand, it may be important for policy makers interested in future growth to take into account the negative short run impact of a depreciation on investment. Further, the effect of a currency depreciation is shown to be particularly persistent in the services sectors, and this may have implications for future productivity growth as these sectors have been observed to be important contributors to aggregate productivity in recent years. Finally, since real wage movements are shown to affect investment in the medium and long run, particularly in the non-agricultural private sector, policies that increase the real wage costs of firms may hinder investment and, potentially, future growth.

References

Abel, A.B. and O. J. Blanchard (1986) "The Present Value of Profits and Cyclical Movements in Investment," *Econometrica* 54:2, 249-73.

Alesina, A., S. Ardagna, R. Perotti, and F. Schiantarelli (2002), "Fiscal Policy, Profits, and Investment," *American Economic Review* 92, 571-89.

Alesina, Alberto, Silvia Ardagna, Giuseppe Nicoletti, and Fabio Schiantarelli (2005) "Regulation and Investment," *Journal of the European Economic Association*, June 3(4): 791-825.

Atella, V., G. Atzeni and P. Belvisi (2003) "Investment and Exchange Rate Uncertainty," *Journal of Policy Modeling* 25:8, 811-24.

Baltagi, B.H. and C. Kao (2000), "Nonstationary Panels, Cointegration in Panels and Dynamic Panels: A Survey," in B.H. Baltagi, ed., *Nonstationary Panels, Panel Cointegration and Dynamic Panels*, Volume 15, Elsevier, 7-51.

Bean, C.R. (1981) "An Econometric Model of Manufacturing Investment in the UK," *Economic Journal* 91, March, 106-21.

Bell, G.K. and J.M. Campa (1997) "Irreversible Investments and Volatile Markets: A Study of the Chemical Processing Industry," *Review of Economics and Statistics*, 79-87.

Bernanke, B.S., H. Bohn and P.C. Reiss (1988) "Alternative Non-Nested Specification Tests of Time-Series Investment Models," *Journal of Econometrics* 37:3, 293-326.

Bond, S., J.A. Elston, J. Mairesse and B. Mulkay (2003) "Financial Factors and Investment in Belgium, France, Germany and the United Kingdom: A Comparison using Company Panel Data," *Review of Economics and Statistics* 85:1, February, 153-65.

Brynjolfsson, Erik and Lorin M. Hitt, (2000) "Beyond Computation: Information Technology, Organizational Transformation and Business Performance," *Journal of Economic Perspectives*, 14: 4, 23-48.

Bun, M.J.G. and J.F. Kiviet (2001) "The Accuracy of Inference in Small Samples of Dynamic Panel Data Models: Simulation Evidence and Empirical Results," Working Paper, University of Amsterdam, 9 January.

Byrne, J.P. and E.P. Davis (2004) "Permanent and Temporary Inflation Uncertainty and Investment in the United States," *Economics Letters* 85, 271-7.

Byrne, Joseph P. and E. Philip Davis (2005) "The Impact of Short- and Long-run Exchange Rate Uncertainty on Investment: A Panel Study of Industrial Countries," *Oxford Bulletin of Economics and Statistics*, 67:3, 307-329.

Caballero, R.J. (1999), "Aggregate Investment," in J.B. Taylor and M. Woodford, eds., *Handbook of Macroeconomics* (Elsevier), 813-62.

Campa, J. and L.S. Goldberg (1995), "Investment in Manufacturing, Exchange Rates and External Exposure," *Journal of International Economics* 38 (1995), 297-320.

Campa, J.M. and L.S. Goldberg (1999), "Investment, Pass-Through, and Exchange Rates: A Cross-Country Comparison," *International Economic Review* 40:2, May 1999, 287-314.

Card, D., T. Lemieux and W.C. Riddell (2003) "Unionization and Wage Inequality: A Comparative Study of the US, the UK, and Canada," NBER Working Paper 9473.

Caselli, Francesco and Daniel J. Wilson (2004) "Importing Technology," *Journal of Monetary Economics*, 51, 1-32.

Chirinko, R.S. (1993) "Business Fixed Investment Spending: A Critical Survey of Modeling Strategies, Empirical Results, and Policy Implications," *Journal of Economic Literature* 31, 1875-1911.

Choi, I. (2001) "Unit Root Tests for Panel Data," *Journal of International Money and Finance* 20, 249-72.

Darby, J., A. Hughes Hallett, J. Ireland and L. Piscitelli (1999) "The Impact of Exchange Rate Uncertainty on the Level of Investment," *Economic Journal* 109, March, C55-C67.

Davidson, R. and J.G. MacKinnon (1993) *Estimation and Inference in Econometrics*, New York, Oxford University Press.

Dedola, Luca and Francesco Lippi (2005) "The Monetary Transmission Mechanism: Evidence from the Industries of Five OECD Countries," *European Economic Review*, 49, 1543-1569.

DeLong, J. B. and L.H. Summers (1991) "Equipment Investment and Economic Growth," *Quarterly Journal of Economics* 106:2, 445-502.

Dixit, A. and R. Pindyck (1994) *Investment Under Uncertainty*, Princeton, Princeton University Press.

Eaton, Jonathan and Samuel Kortum (2001) "Trade in Capital Goods," *European Economic Review* 45, 1105-1235.

Ellis, C. and S. Price (2004) "UK Business Investment and the User Cost of Capital," *Manchester School*, Supplement, 72-93.

Forbes, Kristin J. (2002) "Cheap Labor meets Costly Capital: The Impact of Devaluations on Commodity Firms," *Journal of Development Economics* 69, 335-65.

Frankel, J.A. (2006) "Comments on Richard Baldwin's 'The Euro's Trade Effects'," European Central Bank Working Paper No. 594, March.

Frankel, J.A. and A.K. Rose (1996) "A Panel Project on Purchasing Power Parity: Mean Reversion Within and Between Countries," *Journal of International Economics* 40, 209-24.

Gilchrist, S. and C.P. Himmelberg (1995) "Evidence on the Role of Cash Flow for Investment," *Journal of Monetary Economics* 36, 541-72.

Goldberg, L.S. (1993), "Exchange Rates and Investment in United States Industry," *The Review of Economics and Statistics* 75:4, 575-88.

Gutierrez, Luciano (2003) "On the Power of Panel Cointegration Tests: A Monte Carlo Comparison," *Economics Letters*, 80, 105-11.

Halpern, L., M. Koren and A. Szeidl (2005) "Imports and Productivity," CEPR Discussion Paper 5139.

Haque, N.U., M.H. Pesaran and S. Sharma (2000) "Neglected Heterogeneity and Dynamics in Cross-Country Savings Regressions," in J. Krishnakumar and E. Ronchetti, eds., *Panel Data Econometrics: Future Directions*, Elsevier.

Hughes Hallett, Andrew, Gert Peersman, Laura Piscitelli (2004) “Investment Under Monetary Uncertainty: A Panel Data Investigation,” *Empirica*, 31, 137-162.

Johnson, S. and P. Kuhn (2004) “Increasing Male Earnings Inequality in Canada and the United States, 1981-1997: The Role of Hours Changes versus Wage Changes,” *Canadian Public Policy* 30:2, 155-75.

Jones, Charles I. (1994) "Economic Growth and the Relative Price of Capital," *Journal of Monetary Economics*, 34, 359-82.

Judson, R.A. and A.L. Owen (1999) "Estimating Dynamic Panel data Models: A Guide for Macroeconomists," *Economics Letters* 65, 9-15.

Karlsson, S. and M. Lothgren (2000) “On the Power and Interpretation of Panel Unit Root Tests,” *Economics Letters* 66, 249-55.

Landon, Stuart and Constance Smith (2006) “Exchange Rates and Investment Good Prices: A Cross-Industry Comparison.” *Journal of International Money and Finance* 25, 237-56.

Leung, Danny and Terence Yuen (2005) “Do Exchange Rates Affect the Capital-Labour Ratio? Panel Evidence from Canadian Manufacturing Industries,” Bank of Canada Working Paper 2005-12, Ottawa.

Mairesse, Jacques, Bronwyn H. Hall and Benoit Mulkay (1999) “Firm-Level Investment in France and the United States: An Exploration of What we have Learned in Twenty Years,” NBER Working Paper 7437.

Marston, Richard C. (1990) “Pricing to Market in Japanese Manufacturing,” *Journal of International Economics*, 29, 217-236.

Mazumdar, J. (2001) “Imported Machinery and Growth in LDCs,” *Journal of Development Economics*, 65:1, 209-224.

Mody, A. and K. Yilmaz (2002) “Imported Machinery for Export Competitiveness,” *The World Bank Economic Review*, 16:1, 23-48.

Mojon, B., F. Smets and P. Vermeulen (2002) “Investment and Monetary Policy in the Euro Area,” *Journal of Banking & Finance* 26, 2111-29.

Nickell, S. (1981) "Biases in Dynamic Models with Fixed Effects," *Econometrica* 49:6, November, 1417-26.

Nucci, F. and A.F. Pozzolo (2001) "Investment and the Exchange Rate: An Analysis with Firm-Level Panel Data," *European Economic Review* 45, 259-83.

Oliner, S., G. Rudebusch and D. Sichel (1995) "New and Old Models of Business Investment: A Comparison of Forecasting Performance," *Journal of Money, Credit and Banking* 27:3, 806-26.

Peersman, Gert and Frank Smets (2005) “The Industry Effects of Monetary Policy in the Euro Area,” *The Economic Journal*, 115, 319-342.

Pelgrin, F., S. Schich and A. de Serres (2002) “Increases in Business Investment Rates in OECD Countries in the1990s: How Much Can be Explained by Fundamentals?” OECD Economics Department Working paper ECO/WKP(2002)13, 15 April.

Pesaran, M.H. (1997) "The Role of Economic Theory in Modelling the Long Run," *Economic Journal* 107, January, 178-91.

Pesaran, M.H. and Y. Shin (1998) "An Autoregressive Distributed-Lag Modelling Approach to Cointegration Analysis," in S. Strom, ed., *Econometrics and Economic Theory in the 20th Century*, Econometric Society Monograph 31, Cambridge University Press.

Pesaran, M.H., Y. Shin and R. Smith (1999) "Pooled Mean Group Estimation of Dynamic Heterogeneous Panels," *Journal of the American Statistical Association* 94:446, June, 621-34.

Pesaran, M.H., Y. Shin and R. Smith (2001) "Bounds Testing Approaches to the Analysis of Level Relationships," *Journal of Applied Econometrics* 16, 289-326.

Pesaran, M.H. and R.P. Smith (1995) "Estimating Long-Run Relationships from Dynamic Heterogeneous Panels," *Journal of Econometrics* 68, 79-113.

Pesaran, M.H., R.P. Smith and T. Akiyama (1998) *Energy Demand in Asian Developing Economies*, Oxford University Press.

Pesaran, M.H., R.P. Smith and K.S. Im (1996) "Dynamic Linear Models for Heterogeneous Panels," in L. Matyas and P. Sevestre, eds., *The Econometrics of Panel Data*, Second Revised Edition, Kluwer.

Phillips, P.C.B. and B. Hansen (1990) "Statistical Inference in Instrumental Variables Regression with I(1) Processes," *Review of Economic Studies* 57, 99-125.

Rao, Someshwar, Jianmin Tang and Weimin Wang (2003) "Canada's Recent Productivity Record and Capital Accumulation," Micro-Economic Policy Analysis Branch, Industry Canada.

Restuccia, Diego and Carlos Urrutia (2001) "Relative Prices and Investment Rates," *Journal of Monetary Economics*, 47, 93-121.

Schich, S. and F. Pelgrin (2002) "Financial Development and Investment: Panel Data Evidence for OECD Countries from 1970 to 1997," *Applied Economics Letters* 9, 1-7.

Serven, L. (2003) "Real Exchange Rate Uncertainty and Private Investment in Developing Countries," *Review of Economics and Statistics* 85:1, 212-7.

Appendix A: Table A1: Observations Per Country for Each Sector

	Sample 1		Sample 2		Sample 3		Sample 4	
	Years	Obs	Years	Obs	Years	Obs	Years	Obs
Australia	73-01	29	73-01	29	73-01	29	73-01	29
Austria	77-03	27	77-03	27	77-03	27	77-03	27
Belgium	71-03	33	71-03	33			71-03	33
Canada	71-03	33	71-03	33	71-03	33	71-03	33
Denmark	72-03	32	94-01	8	94-00	7	94-01	8
Finland	76-03	28	76-03	28	76-03	28	76-03	28
France	79-02	24	79-02	24	79-02	24		
Germany	93-03	11	93-03	11	93-02	10	93-03	11
Greece	96-03	8	96-03	8	96-03	8	96-03	8
Ireland	87-03	17	87-03	17			87-03	17
Italy	71-03	33	71-03	33			71-03	33
Netherlands	71-03	33	71-03	33	71-02	32	71-03	33
Norway	71-03	33	71-03	33	71-03	33	71-03	33
Portugal	89-03	15	96-03	8				
Spain	71-02	32	71-02	32	71-02	32	71-02	32
Sweden	94-03	10	94-03	10	94-03	10	94-03	10
USA	71-01	31	71-01	31	71-01	31	71-01	31
Total		429		398		304		366
Average		25.2		23.4		23.4		24.4

The sectors for which each sample is applicable are:

Sample 1: *Total*;

Sample 2: *Total services*; *Business sector services*; *Manufacturing*; *Electricity, gas and water supply*; *Transport, storage and communication*; *Finance, insurance, real estate and business services*; *Agriculture, hunting, forestry and fishing*; *Construction*; *Wholesale and retail trade, restaurants and hotels*; *Community, social and personal services*;

Sample 3: *Non-agriculture business sector*;

Sample 4: *Mining and quarrying*.

Appendix A: Table A2: Relative Sector Size (percent)

	Non-agriculture business sector	Total services	Business sector services	Manufac-turing	Electricity, gas and water supply	Transport, storage and communication	Finance, insurance, real estate and business services	Agriculture, hunting, forestry and fishing	Mining and quarrying	Construc-tion	Wholesale and retail trade; restaurants and hotels	Community, social and personal services
Australia	67.0	63.0	43.2	16.4	3.2	8.5	21.9	5.4	5.3	7.1	12.8	19.8
Austria	68.8	63.4	42.6	21.5	2.9	7.6	17.3	3.8	0.8	7.6	17.7	20.9
Belgium	64.4	64.9	41.8	22.5	3.1	7.0	21.5	2.4	1.2	5.8	13.4	23.1
Canada	64.8	63.2	42.4	18.5	2.8	7.7	20.7	3.6	5.3	6.5	14.1	20.8
Denmark	59.8	69.0	43.7	17.7	1.9	7.3	20.8	4.6	1.0	5.8	15.6	25.3
Finland	54.9	62.2	50.3	19.9	5.3	14.5	27.8	9.8	0.6	2.2	8.0	11.9
France	61.2	73.6	49.6	16.8	1.9	6.2	31.0	2.6	na	5.0	12.4	24.0
Germany	65.9	67.3	45.9	23.1	2.1	5.8	28.2	1.3	0.4	5.8	11.8	21.4
Greece	58.8	62.5	45.5	15.8	2.1	7.3	18.6	10.9	0.8	7.9	19.7	16.9
Ireland	na	55.3	36.8	28.9	1.9	5.8	18.0	7.0	0.8	6.1	13.0	18.5
Italy	67.0	61.3	43.3	24.9	1.9	7.0	19.7	4.8	0.5	6.5	16.5	18.0
Netherlands	65.0	65.0	40.6	18.9	2.2	6.9	19.1	4.1	3.6	6.3	14.6	24.4
Norway	68.0	61.1	40.8	15.0	2.9	10.6	16.7	3.6	12.0	5.3	13.5	20.4
Portugal	na	70.4	43.2	16.5	2.8	6.7	19.2	3.7	na	6.7	17.2	27.2
Spain	67.8	63.2	44.1	20.7	2.8	8.0	18.1	5.0	0.7	7.7	18.0	19.1
Sweden	61.1	64.9	40.5	22.3	2.8	8.4	19.7	3.7	0.5	5.8	12.4	24.4
USA	65.3	68.5	47.2	19.5	2.7	6.7	22.6	2.2	2.2	4.5	17.8	21.4
Average	64.0	64.6	43.6	19.9	2.7	7.8	21.2	4.6	2.4	6.0	14.6	21.0

Notes: The relative size of each sector is calculated by taking the average of the ratio of sector value-added to a country's total value added for all the years for which *STAN* data are available for the country and sector. As the data available for each sector and each country can differ, the number of years of data used to generate the value for each sector and country can also differ across countries and sectors.

na – *STAN* data are not available for this sector.

Appendix B: Variable Definitions and Data Sources

Principal Variables:

I_j – natural log of real investment in sector j. OECD *STAN Database for Industrial Analysis* **-** volume index of gross fixed capital formation (gfcfk).

eP^f/P – weighted real effective exchange rate (domestic currency units per unit of foreign currency). Natural log of the inverse of the annual real effective exchange rate index from the OECD's *Main Economic Indicators* database weighted by the 1970 value for current imports plus exports divided by current GDP. The data used to construct the weight are from the OECD *Annual National Accounts – Main Aggregates*.

y – natural log of real output. OECD *Economic Outlook* database – annual "Gross Domestic Product, (Market prices), volume" in millions of base year national currency units.

W/P – natural log of the real wage. Source for the nominal wage (**W**): OECD *Main Economic Indicators* database – index of average hourly wage in manufacturing. Of the wage data available, data for this wage were available for the greatest number of countries and years in the sample, thirteen of seventeen (Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Norway, Sweden, United States), accounting for 80 percent of the observations for the *Total* sector. Data on the Wage Rate, Business Sector, from the OECD *Economic Outlook* database, were used for Australia, Portugal and Spain. As the 1988-94 observations for this variable were missing for Portugal, the wage variable was approximated using the change in the Portugal consumer price index from the IMF *International Financial Statistics* database. The data calculated using this approximation were only needed when the model was estimated for the *Total* sector. The wage data for Greece are the Wages Hourly Earnings data from the IMF *International Financial Statistics* database although, due to missing data, this variable was approximated using the change in the consumer price index for 1999-2003. In order to determine whether the use of different wage data for some countries was important, the model was re-estimated using data only for the thirteen countries for which average hourly earnings data in manufacturing are available. In general, there were few changes to the results. Most importantly, if the wage was negative and significant in the long run, it remained negative and significant (although now at 10 percent in two cases). Source for the price level (**P**): The deflator for GDP at market prices from the OECD *Economic Outlook* database.

Variables Used to Test Robustness:

Cyclically adjusted government expenditure to GDP ratio. The government expenditure is "Current Disbursements Government, Excluding Interest" from the OECD *Economic Outlook* database. This is the only government expenditure or tax variable, comparable to the data used in Alesina, Ardagna, Perotti and Schiantarelli (2002), which is available for all the countries and years in our sample. These data are cyclically adjusted and converted to a ratio of GDP using the method described in Alesina, Ardagna, Perotti and Schiantarelli (2002, 586-7). The GDP data used in the denominator of the share are calculated using data for constant dollar GDP and the GDP price deflator described above.

Real interest rate. The annual nominal yield minus the inflation rate from the previous to the current year calculated using the GDP deflator (**P**). Long nominal yields were used when available. Nominal yield data sources are: Austria, Belgium Canada, Denmark, Finland, France, Italy, Netherlands, Norway, Portugal, Spain, Sweden, USA - interest rate long term, OECD *Economic Outlook*; Greece, Ireland - interest rate short term, OECD *Economic Outlook*; Australia, 15 year Treasury bonds, IMF *International Financial Statistics* database (19361...ZF); Germany, Government Bond Yield, IMF *International Financial Statistics* database (13461...ZF).

Compensation per employee, private sector. OECD *Economic Outlook*.

Weighted standard deviation of the exchange rate. Standard deviation of the quarterly differences in the log of the nominal effective exchange rate over the current and seven previous quarters, where the current quarter is the last quarter in the current year, weighted by the 1970 value for current imports plus exports divided by current GDP. Source: OECD, *Economic Outlook*.

Appendix C: Model Specification and Robustness

To check the robustness of the estimates, a number of alternative specifications were considered (the parameter estimates associated with these alternatives are not reported to conserve space). Two of the countries in the sample, Germany and the USA, are large producers of machinery and equipment, and so may be less reliant on imports of these goods than the other countries in the sample. As an indicator of whether the results are sensitive to the inclusion of these two countries in the sample, the parameters of Tables 1 and 2 were re-estimated with the observations for the US and Germany removed from the sample. In not a single case did the significant parameter estimates change sign and, for all sectors but one, those coefficients that were significant remained significant (although in a few cases at a slightly lower level of significance).

Several additional explanatory variables that have been suggested as possible determinants of investment were added individually to the estimating equation in order to gauge the robustness of the estimates. If the real interest rate is included in the estimating equation, the coefficient estimates associated with this variable are insignificant in every sector except for *Finance, insurance, real estate and business services* and the two service sector aggregates, where it is negative and significant in the long run at 10 percent, and in *Construction*, where it is positive and significant in the short run. In terms of signs and significance, none of the other estimated coefficients change, except in *Total services*, where the wage coefficient, negative and significant at 10 percent in the short run in Table 1, becomes insignificant. The insignificance of the interest rate variable found here is consistent with many previous studies that have found the user cost of capital to be an insignificant determinant of investment (see Chirinko (1993)).

As Alesina, Ardagna, Perotti and Schiantarelli (2002) find that public spending has a negative effect on aggregate investment in a panel of OECD countries, the cyclically adjusted government expenditures to GDP ratio is also included as an explanatory variable in the investment equation.[40] In contrast to the results in Alesina, Ardagna, Perotti and Schiantarelli (2002), this variable is only significant in one sector, *Community, social and personal services*. Further, the estimated coefficient for this sector is positive, contrary to expectations. This positive coefficient may result because this sector includes many services supplied by government (public administration and defense, education, health and social work). Inclusion of the public spending variable causes no change in the other parameter estimates in terms of sign or significance except in *Mining and quarrying* and *Community, social and personal services* where the exchange rate becomes insignificant in the long run. Since Alesina, Ardagna, Perotti and Schiantarelli (2002) argue that government spending affects investment through its impact on the wage, the investment equations were re-estimated with the cyclically adjusted government spending variable used in place of the wage. The only impact of this change on the results is that this fiscal variable now becomes negative and significant in the *Mining and quarrying* sector.[41]

Theoretical studies suggest that exchange rate uncertainty may affect investment, although the direction of this effect is uncertain, and empirical studies of the impact of exchange rate volatility on investment have yielded a variety of results (see, for example, Goldberg, 1993; Darby, Hughes Hallett, Ireland and Piscatelli, 1999; Hughes Hallett, Peersman, Piscitelli, 2004; Byrne and Davis, 2005; Campa and Goldberg, 1995; Bell and Campa, 1997; Serven, 2003; Atella, Atzeni and Belvisi, 2003). When an exchange rate volatility measure is added to the investment equation, it is insignificant in every sector except for *Electricity, gas and water supply*, where it has a negative long run impact.[42] None of the wage or exchange rate parameters change in terms of sign or significance when the volatility variable is added to

[40] This variable is calculated using the methodology described in Alesina, Ardagna, Perotti and Schiantarelli (2002). Alesina, Ardagna, Perotti and Schiantarelli (2002) consider a number of government expenditure and tax variables, but this is the only variable for which data are available for all the countries and years in our sample.

[41] The results found here may differ from those in Alesina, Ardagna, Perotti and Schiantarelli (2002) because the estimating equation used here includes the exchange rate, and the ARDL methodology is quite different from the approach used by Alesina, Ardagna, Perotti and Schiantarelli (2002). Alesina, Ardagna, Nicoletti and Schiantarelli. (2005) also find that public spending does not have a significant direct effect on investment in seven regulated industries after controlling for regulatory factors in product markets.

[42] Volatility is measured as the quarterly standard deviation of the percentage change in the exchange rate over the previous two years. This is similar to other measures of volatility used in the literature. For example, Bell and Campa (1997) use the standard deviation of the change in the log of the trade weighted exchange rate for the previous 24 months. See also, Campa and Goldberg (1995), Darby, Hughes Hallett, Ireland and Piscatelli (1999) and Hughes Hallett, Peersman and Piscitelli (2004).

the estimating equations. One reason why the volatility measure may be insignificant here, unlike in some other studies, is that the estimating equation includes both year and country fixed effects and controls for macroeconomic effects (wages, the exchange rate) that are not included in many other studies.

An alternative measure of labour costs is the OECD's "Compensation per employee, business sector", data that have been used by Alesina, Ardagna, Perotti and Schiantarelli (2002), for example. To examine whether this compensation per employee data can explain movements in investment that cannot be explained by the hourly wage data, both variables are included in the estimating equation.[43] The only impact of this change on the significance of the hourly wage variable is that it becomes negative and significant in the long run in the *Construction* sector. The "Compensation per employee" variable is never significant in the short run, but is significant, although unexpectedly positive, in three sectors in the long run. These results suggest that the "Compensation per employee" data are not superior to the hourly wage data in terms of contributing to a better understanding of investment behaviour.[44]

[43] As data on labour compensation is available for a slightly shorter period for some countries than the hourly wage data, the sample is slightly smaller when the compensation variable is included in the model.

[44] One possible explanation for the positive coefficient estimates may be that the "compensation per employee" data have not been adequately adjusted for part time vs. full time employees, while the proportion of employees who are full time rises in a boom, so that compensation per employee also rises.

Table 1: Investment Equation Estimates: Aggregated Sectors and Manufacturing

Dependent Variable: First difference of the natural log of investment

Explanatory Variables	Total	Non-agriculture business sector[a]	Total services[b]	Business sector services[c]	Manu-facturing
Short run coefficients					
Real exchange rate ($\Delta(eP^f/P)$)	-.5636** (5.00)	-.6446** (2.81)	-.5567** (4.70)	-.6569** (4.30)	-.2466 (.74)
Real wage ($\Delta(W/P)$)	-.1591 (1.43)	.1665 (.86)	-.2083* (1.68)	-.4028** (2.61)	.3071 (1.18)
Output (Δy)	1.9575** (13.76)	1.5985** (5.70)	1.8584** (10.71)	2.0166** (8.82)	1.7301** (4.61)
Output lagged (Δy_{-1})	.6182** (4.02)	1.0457** (3.97)	.4847** (2.45)	.5549** (2.22)	1.1921** (2.96)
Long run coefficients					
Real exchange rate (eP^f/P)	-.9708** (2.32)	-1.0728* (1.81)	-1.0803 (1.43)	-.7897 (.78)	.8041 (1.28)
Real wage (W/P)	-1.3154** (4.74)	-1.9322** (4.91)	-1.4094** (2.74)	-1.4568** (2.15)	-.9014** (2.38)
Output (y)	.7448** (2.60)	.1596 (.29)	.8487 (1.54)	.4373 (.61)	.0735 (.18)
Adjustment Coefficient (λ-1)	-.1420[††5] (5.75)	-.2055[††5] (5.39)	-.0894[†5] (3.74)	-.0850[†10] (3.39)	-.2427[††5] (6.95)
$\overline{R}^2$	.627	.528	.553	.514	.467
Number of observations	429	304	398	398	398
Number of countries	17	13	17	17	17
AR1 Test[‡]	1.56[d]	0.63[d]	1.19[d]	.89[d]	1.58[d]
Reset Test[‡‡]	0.06[f]	0.59[f]	0.55[f]	0.07[f]	0.90[f]

The number in brackets under each coefficient estimate is the absolute value of the heteroscedasticity corrected t-statistic. The test statistics for the long run coefficients are computed using the delta method as recommended by Pesaran and Shin (1998).

** The estimated short run or long run coefficient is significant using a 95 percent confidence interval.
* The estimated short run or long run coefficient is significant using a 90 percent confidence interval.

[††5] Conclusively non-zero at 95 percent using the critical values for the bounds test from Table CII, Case V of Pesaran, Shin and Smith (2001). This is the case least favourable to finding conclusive significance.
[††10] Conclusively non-zero at 90 percent.
[†5] In the inconclusive range of the bounds test at 95 percent.
[†10] In the inconclusive range of the bounds test at 90 percent.

[‡] 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).

[‡‡] 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.

[a] The sector *Non-agriculture business sector* comprises the *Total* of all industries excluding *Agriculture, hunting, forestry and fishing*; *Community, social and personal services*; and *Real estate activities*.

[b] The sector *Total services* comprises the four sectors *Wholesale and retail trade, restaurants and hotels*; *Transport, storage and communication*; *Finance, insurance, real estate and business services*; and *Community, social and personal services*.

[c] The sector *Business sector services* includes the three sectors: *Wholesale and retail trade, restaurants and hotels*; *Transport, storage and communication*; and *Finance, insurance, real estate and business services*.

[d] Cannot reject the hypothesis of no serial correlation at 95 percent.

[e] Cannot reject the hypothesis of no serial correlation at 99 percent, but reject at 95 percent.

[f] The Reset test does not reject the specification at 95 percent.

[g] The Reset test does not reject the specification at 99 percent, but rejects at 95 percent.

Table 2: Investment Equation Estimates: Individual Sectors Other Than Manufacturing

Explanatory Variables	*Electricity, gas and water supply*	*Transport, storage and communication*	*Finance, insurance, real estate and business services*	*Agriculture, hunting, forestry and fishing*	*Mining and Quarrying*	*Construction*	*Wholesale and retail trade; restaurants and hotels*	*Community, social and personal services*
Short run coefficients								
Real exchange rate ($\Delta(eP^f/P)$)	-.6309*	-.5237	-.7310**	-.6400*	-1.2432*	-1.4818**	-.6749**	-.1931
	(1.65)	(1.41)	(4.14)	(1.92)	(1.94)	(2.41)	(2.26)	(1.13)
Real wage ($\Delta(W/P)$)	.2089	-1.0083**	-.3956**	-.4280	-.1884	.6686	-.3195	.1875
	(.41)	(2.30)	(2.19)	(1.38)	(.36)	(1.29)	(1.18)	(1.10)
Output (Δy)	-.0307	1.3490**	2.2736**	1.7598**	1.6665**	4.5321**	2.3200**	1.4639**
	(.06)	(2.35)	(7.17)	(4.48)	(1.99)	(5.47)	(4.64)	(5.78)
Output lagged (Δy_{-1})	1.4240**	.5401	.7533**	-.4019	.9164	1.7721**	.4643	.3724
	(2.85)	(1.05)	(2.65)	(.99)	(1.27)	(2.09)	(1.08)	(1.64)
Long run coefficients								
Real exchange rate (eP^f/P)	-.5898	-.1768	-1.5634	-.4220	1.8110*	-1.2143	-1.7200	-1.9129*
	(1.05)	(.18)	(1.38)	(.56)	(1.75)	(.91)	(1.55)	(1.70)
Real wage (W/P)	-1.1933**	-1.6099**	-.8263	-.6181	-1.1180*	.0502	-2.7790**	-1.1570**
	(3.79)	(2.19)	(1.27)	(1.41)	(1.87)	(.07)	(4.98)	(2.07)
Output (y)	2.2274**	.2538	.7457	-.9392*	1.1783	.7758	.2587	2.1855**
	(5.04)	(.39)	(.91)	(1.86)	(1.53)	(1.24)	(.39)	(2.92)
Adjustment Coefficient (λ-1)	-.3296[††10]	-.2051[†5]	-.0862[††5]	-.2094[††5]	-.2765[††5]	-.2458[††10]	-.1612[††5]	-.0954[†5]
	(4.23)	(3.87)	(4.93)	(5.94)	(7.23)	(4.10)	(7.04)	(3.55)
$\bar{R}^2$	.118	.203	.501	.278	.218	.360	.321	.249
Number of observations	398	398	398	398	366	398	398	398
Number of countries	17	17	17	17	15	17	17	17
AR1 Test[†]	1.78[d]	.54[d]	2.01[e]	1.05[d]	1.31[d]	.46[d]	.33[d]	2.38[e]
Reset Test[††]	2.37[g]	.21[f]	.05[f]	.61[f]	.85[f]	1.46[f]	.99[f]	2.14[g]

See notes to Table 1.

Table 3: Impact on Investment of a 1 Percent Increase in the Real Exchange Rate (a Currency Depreciation)

Years Following Change	*Total*	*Non-agriculture business sector*	*Total services*	*Business sector services*	*Manufacturing*
Current Year	-.29**	-.33**	-.28**	-.33**	-.13
1	-.32**	-.37**	-.31**	-.34**	.01
2	-.34**	-.41**	-.33**	-.34**	.10
3	-.36**	-.44**	-.35**	-.35**	.18
4	-.38**	-.46**	-.37**	-.35**	.23
5	-.40**	-.48**	-.38**	-.36*	.28
6	-.41**	-.49**	-.40**	-.36	.31
7	-.42**	-.50**	-.41**	-.37	.33
8	-.43**	-.51**	-.42**	-.37	.35
9	-.44**	-.52*	-.43*	-.37	.36
Long Run	-.49**	-.55*	-.55*	-.40	.41

Years Following Change	*Electricity, gas and water supply*	*Transport, storage and communication*	*Finance, insurance, real estate and business services*	*Agriculture, hunting, forestry and fishing*	*Mining and Quarrying*	*Construction*	*Wholesale and retail trade; restaurants and hotels*	*Community, social and personal services*
Current Year	-.32*	-.27	-.37**	-.33*	-.63*	-.75**	-.34**	-.10
1	-.31*	-.23	-.41**	-.30*	-.20	-.72**	-.43**	-.18*
2	-.31	-.20	-.44**	-.28	.11	-.69*	-.50**	-.26*
3	-.31	-.18	-.47**	-.27	.33	-.68	-.56**	-.33*
4	-.30	-.16	-.50**	-.26	.49	-.66	-.61**	-.39*
5	-.30	-.15	-.53**	-.25	.61	-.65	-.65*	-.44*
6	-.30	-.13	-.55**	-.24	.70	-.64	-.69*	-.49*
7	-.30	-.13	-.57**	-.24	.76	-.64	-.72*	-.54*
8	-.30	-.12	-.59**	-.23	.80*	-.63	-.74*	-.58*
9	-.30	-.11	-.61*	-.23	.84*	-.63	-.77*	-.62*
Long Run	-.30	-.09	-.79	-.21	.92*	-.62	-.87	-.97*

**Significant at 5 percent.
*Significant at 10 percent.
Note: These simulations are undertaken using the average value of the openness measure.

Table 4: Impact on Investment of a 1 Percent Increase in the Real Wage

Years Following Change	*Total*	*Non-agriculture business sector*	*Total services*	*Business sector services*	*Manufacturing*
Current Year	-.16	.17	-.21*	-.40**	.31
1	-.32**	-.26	-.32**	-.49**	.01
2	-.46**	-.61**	-.41**	-.57**	-.21
3	-.59**	-.88**	-.50**	-.65**	-.38
4	-.69**	-1.10**	-.58**	-.72**	-.50*
5	-.78**	-1.27**	-.66**	-.78**	-.60*
6	-.85**	-1.40**	-.72**	-.84**	-.67**
7	-.92**	-1.51**	-.79**	-.89**	-.73**
8	-.98**	-1.60**	-.84**	-.94**	-.77**
9	-1.02**	-1.67**	-.89**	-.98**	-.80**
Long Run	-1.32**	-1.93**	-1.41**	-1.46**	-.90**

Years Following Change	*Electricity, gas and water supply*	*Transport, storage and communication*	*Finance, insurance, real estate and business services*	*Agriculture, hunting, forestry and fishing*	*Mining and Quarrying*	*Construction*	*Wholesale and retail trade; restaurants and hotels*	*Community, social and personal services*
Current Year	.21	-1.01**	-.40**	-.43	-.18	.67	-.32	.19
1	-.25	-1.13**	-.43**	-.47*	-.45	.52	-.72**	.06
2	-.56	-1.23**	-.47**	-.50*	-.63	.40	-1.05**	-.06
3	-.77**	-1.31**	-.50**	-.52*	-.77*	.32	-1.33**	-.16
4	-.91**	-1.37**	-.53**	-.54*	-.86*	.25	-1.56**	-.26
5	-1.00**	-1.42**	-.55*	-.56*	-.93*	.20	-1.76**	-.34
6	-1.07**	-1.46**	-.58*	-.57*	-.98*	.16	-1.92**	-.42
7	-1.11**	-1.49**	-.60*	-.58	-1.02*	.14	-2.06**	-.49*
8	-1.14**	-1.51**	-.62	-.59	-1.05*	.11	-2.18**	-.55*
9	-1.16**	-1.53**	-.63	-.60	-1.07*	.10	-2.27**	-.61*
Long Run	-1.19**	-1.61**	-.83	-.62	-1.12*	.05	-2.78**	-1.16**

**Significant at 5 percent.
*Significant at 10 percent.

Figure 1: Real Investment Non-Agriculture Business Sector