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# Exchange Rate Volatility and Investment, A Panel Data Cointegration Approach

Diallo Ibrahima Amadou\*

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## Abstract

This paper examines the link between the real exchange rate volatility and domestic investment by using the panel data cointegration techniques. In the first part of the paper, we study the theoretical link between the exchange rate, its volatility and the investment in a small open economy. The model shows that the effects of exchange rate volatility on investment are nonlinear. In the second part, we examine the empirical link between the exchange rate volatility and the investment. The results illustrate that the exchange rate volatility has a strong negative impact on investment. This outcome is robust in low income and middle income countries, and by using an alternative measurement of exchange rate volatility

*Keywords:* Exchange rate volatility; Investment; Appreciation; Depreciation; Panel data cointegration; Dynamic Optimization; Capital goods; Expectations

*JEL:* O11; O16; O19; O24; O57

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# 1 Introduction

Multiple efforts have been deployed by governments and international organizations to maintain a stable macroeconomic environment in developing countries but, unfortunately, instability still remains one of their greatest economic problems. Figure 1 in appendix D illustrates that instability is far higher in developing countries than in developed ones even in recent years. The case of 1984-1989 period is particularly striking because instabilities (exchange rate instability, exports instability and terms of trade instability) are particularly high<sup>1</sup>. At the same time, figure 2 in appendix D shows that for the whole period 1975-2004, investment in developing countries is less important than in industrialized countries. This brings us to ask the following questions: can volatility, particularly real exchange rate volatility, lessen investment in developing countries? What are the channels through which exchange rate and exchange rate volatility affect investment? The paper attempts to analyze these issues.

The theoretical literature on the link investment-exchange rate concentrates on the adjustment costs of investment theory which state the existence of costs attached to the acquisition of new capital. Most studies focus on internal adjustment costs. For example, costs associated with the installation of new capital and/or training of employees to the use of the new equipments. To study the link exchange rate-investment, Campa and Goldberg (1999), Nucci and Pozzolo (2001), Harchaoui, Tarkhani and Yuen (2005), with minor differences in their formulations, employ discrete dynamic optimization problems with a standard adjustment-cost model of a firm which operates in an imperfect uncertain environment. The firm sells one part of its production in the domestic market and exports the other part abroad. In both of these markets the firm has a markup power, which means it can influence the prices. The firm also imports some part of its inputs from abroad. The common findings of these studies can be classified in three categories. First, exchange rate affects investment through domestic and export sales. When currency depreciates, domestic goods become less expensive than imported goods, resulting to an increase of demand on domestic goods. In the same way, exports increase because they are cheaper. For a given capital and labor, marginal revenue products of capital and labor increase as a result of convenient demands situations. The firm responds by increasing its investment in capital and, consequently, labor. Second, exchange rate acts on investment through the prices of imported inputs. Depreciation rises total production costs which results in lower marginal profitability. The impact of the exchange rate on the marginal profitability is proportional to the share of imported inputs into production. Third, in their results, Harchaoui et al. (2005) shows that exchange rate can also affect investment through the price of imported investment via adjustment-cost. Depreciation causes an increase of investment price, resulting to higher adjustment costs and lower investment. Overall, it is important to note that the global impact of exchange rate on investment is not obvious because it depends on which of these previous effects prevail and the values of elasticities of demands.

The theoretical link investment-exchange rate volatility has also been the subject of many studies. Campa and Goldberg (1995) apply the same formulation as above and assume that the exchange rate is log-normally distributed. The model predicts that the effects of exchange rate uncertainty on profits are ambiguous. Increases in exchange rate

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<sup>1</sup>We will employ without distinction the terms instability and volatility. Instabilities presented in figure 1 are from Guillaumont (2006) (variable *Instability*, 6 previous years ex-post, global adjustment; see Guillaumont (2006) for further details). In the econometric section, we use Autoregressive Conditional Heteroskedasticity Family (ARCH-Family) methods to compute the exchange rate instability, see subsection 3.2. Furthermore, in figure 1 we do not present other instabilities like GDP instability and Inflation instability due to legibility problems.

augment expected profit if the firm exports more than it imports and lower expected profit in the opposite case. Goldberg (1993), using a duality theory, and Darby, Hallett, Ireland and Piscitelli (1999) an adapted model of Dixit and Pindyck (1994), found the same threshold effects of exchange rate uncertainty on investment.

The empirical relation between the exchange rate, its volatility and investment has been analyzed both in developed and developing countries.

For developed countries almost all studies are in the industry-level. Various methods are used for the empirical investigation: OLS, Two-stage Least Squares, VARS, GMM, etc. Utilizing a large sample of industries, Goldberg (1993) discovered that the effects of exchange rate and its volatility on investment in the United States are more visible in the 1980s than in the 1970s. In the 1980s, the dollars had significant differentiated impacts on industries. While the dollars had ambiguous effects on nonmanufacturing industries, its depreciations (appreciations) decreased (increased) investment in manufacturing nondurables sectors. After Goldberg (1993), Goldberg, Campa and other researchers conducted numerous works to investigate the relation investment-exchange rate in industrialized countries. The main results of these studies are first, the effect of exchange rate on investment depends on industries external exposure (United States, Japan and Italy). On the one hand, industries which rely heavily on imports are more likely to record decreases in investment after exchange rate depreciation. On the other hand, industries which have large export shares tend to increase investment after exchange rate depreciation. Second, industries with lower pricing power (lower markups) are significantly influenced by appreciation and depreciation (United States, United Kingdom and Japan). Contrary, industries with higher markups tend to be insensitive to exchange rate movements (Campa and Goldberg (1995), Campa and Goldberg (1999), Nucci and Pozzolo (2001), and Atella, Atzeni and Belvisi (2003)<sup>2</sup>). Third, persistent exchange rate volatility contributes to investment volatility in the United States, Campa and Goldberg (1999). Fourth, differences in investment response across countries and industries could be partially explained by institutional factors: access to credit market, belonging to an industrial group, etc. Moreover, Campa and Goldberg (1999), Lafrance and Tessier (2001), and Harchaoui et al. (2005) have found that investment does not respond to exchange rate in Canada. But further investigations of Harchaoui et al. (2005) highlight the existence of nonlinear effects of exchange rate on investment. Exchange rate depreciations (appreciations) have positive (negative) effects on investment when the exchange rate volatility is low. This reveals the necessity of differentiating investment response between high and low exchange rate volatility in Canada.

Beside these studies on industries or firm levels, Darby et al. (1999) utilize aggregated investment data for five countries (France, Germany, Italy, the United Kingdom and the United States) and find that exchange rate volatility has a large negative effect on investment. Its impact is more important than that of exchange rate misalignment. Exchange rate stability would rise investment in Europe, in general, although France and Germany would benefit more, while Italy and United Kingdom would enjoy only temporarily gains.

Empirical investigations of the relation between the exchange rate, its volatility and investment in developing countries use, in general, OLS, Two-Stage Least Squares, Fixed effects, GMM and system GMM. Oshikoya (1994) results illustrate that exchange appreciation had a positive impact on private investment for four African middle-income countries (Cameroon, Mauritius, Morocco and Tunisia). For the effects of Real effective exchange rate (Reer) volatility, a significant negative impact of exchange rate volatility on investment is reported by the major part of the studies (Serven (1998), Bleaney and Greenaway (2001), and Serven (2002)). The impact of exchange rate instability on in-

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<sup>2</sup>Nucci and Pozzolo (2001) and Atella et al. (2003) use firm-level panel data.

vestment is nonlinear. The effect is large when, firstly, volatility is high and secondly, when there is large trade openness combined with low financial development. Contrary, in an environment with low openness and high financial development, exchange rate volatility tends to act positively on investment, Serven (2002). Furthermore, Guillaumont, Guillaumont Jeanneney and Brun (1999) find that “primary” instabilities (climatic, terms of trade and political instabilities) act on Africa growth through the negative effect that “intermediate” instabilities (instability of real exchange rate and instability of the rate of investment) exert on growth.

This paper fits in these researches of the links between the investment and the exchange rate. But but it distinguishes itself by several ways. Initially, in the theoretical part we introduce a model of a small open economy. In line with previous works, we assume the presence of internal adjustment costs of investment but we consider first, that prices and interest rates are given and second, that the firm imports capital goods rather than intermediate goods. We believe that these assumptions are more in line with the realities of developing countries than assuming the existence of pricing power for their firms. Less importantly, the model is formulated in continuous time, contrary to the discrete time specification of previous studies. The model illustrates that the impacts of exchange rate and exchange rate volatility on investment are nonlinear depending on which of between the revenue and cost channel prevail and the values of elasticities of imports and exports. In the second place, we apply panel data cointegration techniques to study the empirical relation between investment and exchange rate volatility for 51 developing countries (23 low-income and 28 middle-income countries) from 1975 to 2004<sup>3</sup>. There are some previous studies which employ microeconomic panel data methods (Fixed Effects, GMM, etc.) on annual data with a relatively long period. But given the existence of potential unit roots in variables, these estimations could be seriously affected by spurious regressions effects<sup>4</sup>. This is why we think using panel data cointegration methods is more appropriate<sup>5</sup>. The application of panel data cointegration techniques has several advantages. Initially, annual data enable us not to lose information contrary to the method of averages over subperiods. Then, the addition of the cross sectional dimension makes that statistical tests are normally distributed, more powerful and do not depend on the number of regressors in the estimation as in individual time series. Among the panel data cointegration techniques, we utilize Pedroni (1999) *Fully Modified Ordinary Least Squares* (FMOLS) estimator which deals with possible autocorrelation and heteroskedasticity of the residuals, takes into account the presence of nuisance parameters, is asymptotically unbiased and , more importantly, deals with potential endogeneity of regressors. The results demonstrates firstly, that exchange rate volatility has a strong negative impact on investment, secondly, the effect of Reer volatility is higher in countries which rely heavily on imports. Furthermore, robustness checks shows that this negative impact of Reer volatility on investment is stable to the use of an alternative measurement of Reer volatility and on subsamples of countries (low-income and middle-income developing countries).

The remaining of the paper is organized as follow: section 2 presents the theoretical

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<sup>3</sup>Countries and time period selection depend on the availability of data. See table 7 in appendix D for a list of countries.

<sup>4</sup>See Kao (1999) for further details on spurious regressions in panel data

<sup>5</sup>Colophon:

This document is writing in L<sup>A</sup>T<sub>E</sub>X, open source licence. For this study we use the original Program of Pedroni (1999) converted in RATS<sup>®</sup> Procedure by Estima Corporation (<http://www.estima.com/Panel.shtml>). Kao and Chiang (2000) have put together a set of GAUSS<sup>®</sup> subroutines called NPT, for studying nonstationary panel data (<http://www.maxwell.syr.edu/maxpages/faculty/cdkao/working/npt.html>). The latest version of Eviews<sup>®</sup> (Eviews 6) also provides many tests on panel data cointegration.

model of the link investment-exchange rate, section 3 deals with empirical investigations and section 4 concludes.

## 2 Theoretical Framework

In this section, we present successively the model, exchange rate pass-through and the role of volatility.

### 2.1 The model

In this section, we develop a model of a small open economy in which investment is subject to adjustment costs. We consider a firm which chooses its investment,  $I^6$ , to maximize the present value,  $V(0)$ , of future profits. The production technology is neoclassical<sup>7</sup> and is a function of capital goods,  $K^8$ .

$$Y = F(K) \quad (1)$$

Capital goods are homogenous but can be produced domestically or imported from abroad. The change in the firm's capital stock is given by

$$\dot{K} = I - \delta K \quad (2)$$

where  $\delta$  is the rate of depreciation of capital goods. The cost of each unit of investment is 1 plus an adjustment cost<sup>9</sup>.

$$C(I) = I \left( 1 + \phi \left( \frac{I}{K} \right) \right) \quad (3)$$

The price of each unit of capital goods, in real terms, is  $(r + \delta)^\theta \left( \epsilon \frac{p_{mk}}{p^*} \right)^{1-\theta}$ . Where  $r$  is the real interest rate,  $\epsilon$  the real exchange rate,  $p_{mk}$  the nominal price of imported capital goods,  $p^*$  the foreign price index and  $\theta$  a weighting factor. As  $0 < \theta < 1$ , the price of capital is a geometric mean of domestic price of capital,  $r + \delta$ , and foreign price of capital, expressed in real terms,  $\epsilon \frac{p_{mk}}{p^*}$ . Similarly, the price of one unit of output, in real terms, is  $\left( \epsilon \frac{p_{xf}}{p^*} \right)^{1-\rho}$ . Where  $p_{xf}$  is the nominal price of exported output and  $\rho$  a weighting factor ( $0 < \rho < 1$ ).

The profits in real terms are:

$$\Pi = \left( \epsilon \frac{p_{xf}}{p^*} \right)^{1-\rho} F(K) - (r + \delta)^\theta \left( \epsilon \frac{p_{mk}}{p^*} \right)^{1-\theta} K - C(I) \quad (4)$$

As we mentioned earlier, the firm's objective is to choose  $I$  at each period to maximize

$$V(0) = \int_0^\infty e^{-rt} \left\{ \left( \epsilon \frac{p_{xf}}{p^*} \right)^{1-\rho} F(K) - (r + \delta)^\theta \left( \epsilon \frac{p_{mk}}{p^*} \right)^{1-\theta} K - C(I) \right\} dt \quad (5)$$

subject to:

<sup>6</sup>we ignore time subscripts to simplify the notation. To certain extents, the model presented here could be viewed as an extended version of Eisner and Strotz (1963) model. For a broad survey on business investment modeling methodologies see Chirinko (1993).

<sup>7</sup>See appendix A for the properties of the neoclassical production function.

<sup>8</sup>Domestic labor,  $L$  is normalized to unity.

<sup>9</sup>See Barro and Sala-i Martin (2004), pp.152-160.

equation (2)  
 $K(0) = K_0 > 0$ , given

To simplify the presentation, we assume as in Barro and Sala-i Martin (2004) that  $\phi\left(\frac{I}{K}\right) = \frac{\beta}{2}\left(\frac{I}{K}\right)$ . Equation (3) become

$$C(I) = I\left(1 + \frac{\beta}{2}\left(\frac{I}{K}\right)\right) \quad (3.1)$$

The Hamiltonian of this dynamic optimization problem, in current-value, is

$$\widehat{H} = \left(\epsilon \frac{p_{xf}}{p^*}\right)^{1-\rho} F(K) - (r + \delta)^\theta \left(\epsilon \frac{p_{mk}}{p^*}\right)^{1-\theta} K - I\left(1 + \frac{\beta}{2}\left(\frac{I}{K}\right)\right) + q(I - \delta K) \quad (6)$$

where  $q$  is the current-value shadow price of installed capital in units of contemporaneous output. The maximization conditions are:<sup>10</sup>

derivative of the Hamiltonian with respect to control variable  $I$

$$\widehat{H}_I = -1 - \frac{\beta I}{K} + q = 0 \quad (7)$$

equation of motion for  $K$

$$\begin{aligned} \dot{K} &= \frac{\partial \widehat{H}}{\partial q} \\ \dot{K} &= I - \delta K \end{aligned}$$

this last expression is equation (2). The equation of motion for  $q$  is

$$\dot{q} = -\frac{\beta I^2}{2K^2} + q(r + \delta) + (r + \delta)^\theta \left(\frac{p_{mk}\epsilon}{p^*}\right)^{1-\theta} - \left(\frac{p_{xf}\epsilon}{p^*}\right)^{1-\rho} F'(K) - \frac{\partial \widehat{H}}{\partial K} + r q \quad (8)$$

The transversality condition for the current-value problem can be writing as

$$\lim_{t \rightarrow \infty} [q K e^{-r t}] = 0$$

This condition is hold if  $q$  and  $K$  tend asymptotically towards constants and  $r^* > 0$ . If we substitute  $I$  from equation (2) into equation (7) we get

$$\dot{K} = -\frac{K(1 + \beta\delta - q)}{\beta} \quad (9)$$

From this equation, the equilibrium condition,  $\dot{K} = 0$ , for  $K$  gives the steady-state value of  $q$

$$q^* = 1 + \beta\delta \quad (10)$$

The graphical representation of this equation in a,  $(q, K)$ , space is a horizontal line (see figure 3). Equations (2) and (9) imply that equation (8) can be rewritten as

$$\dot{q} = -\frac{(q-1)^2}{2\beta} + q(r + \delta) + (r + \delta)^\theta \left(\frac{p_{mk}\epsilon}{p^*}\right)^{1-\theta} - \left(\frac{p_{xf}\epsilon}{p^*}\right)^{1-\rho} F'(K) \quad (11)$$

The equilibrium condition,  $\dot{q} = 0$ , for  $q$  gives

$$-\frac{(q-1)^2}{2\beta} + q(r+\delta) + (r+\delta)\theta \left(\frac{p_{mk}\epsilon}{p^*}\right)^{1-\theta} - \left(\frac{p_{xf}\epsilon}{p^*}\right)^{1-\rho} F'(K) = 0 \quad (12)$$

If we substitute,  $q = q^*$ , from equation (10) into equation (12) we get

$$F'(K^*) = \frac{2p_{mk}(r+\delta)^\theta \epsilon + p^*(2r(1+\beta\delta) + \delta(2+\beta\delta)) \left(\frac{p_{mk}\epsilon}{p^*}\right)^\theta}{2p^*} \frac{1}{\left(\frac{p_{mk}\epsilon}{p^*}\right)^\theta \left(\frac{p_{xf}\epsilon}{p^*}\right)^{1-\rho}} \quad (13)$$

In equation (12) by applying the implicit-function theorem, the slope of the implicit function,  $q(K)$ , is

$$\frac{dq}{dK} = \frac{\beta \left(\frac{p_{xf}\epsilon}{p^*}\right)^{1-\rho} F''(K)}{1 + \beta(r+\delta) - q} \quad (14)$$

By the properties of the neoclassical production function in appendix A, the numerator of this expression is negative. The denominator is positive if the parameters  $r$ ,  $\beta$  and  $\delta$  are reals, which we suppose, and  $q < 1 + \beta(r+\delta)$ . This last condition must hold at the steady-state value,  $q^*$ , because  $r^* > 0$ . Consequently the implicit function,  $q(K)$ , is downward sloping (see figure 3). The study of the phase diagram in appendix B indicates that the figure 3 exhibits saddle-path stability with a downward stable arm.

## 2.2 Exchange rate pass-through

To analyze the effects of exchange rate on investment we first, make assumptions on the values of  $\rho$  and  $\theta$  and second, study only the consequences of an exchange rate depreciation, considering that the role of an exchange rate appreciation would be symmetrical. In addition, we assume that  $p_{xf}$ ,  $p_{kf}$  and  $p^*$  are constants or equal to one.

**Situation 1:** The firm relies heavily on imported capital ( $\theta$  very near 0) and export less output ( $\rho$  very near 1). In that case, an exchange rate depreciation (an increase in  $\epsilon$ ) rises the price of imported capital goods expressed in real terms, this involves a reduction of profits, *ceteris-pribus*. We can distinguish two cases:

- The producers realize that the depreciation is permanent. The rise in capital costs pushes them to reduce the production permanently. In figure 3 (appendix D), the curve  $qe$  moves downward because the profits are lower (figure 4, appendix D). The shadow price of capital  $q$  come to the new point corresponding to the given stock of capital on the saddle-path. The two variables  $q$  and  $K$  rise along the saddle-path toward the new equilibrium  $S'$ . Given that  $\dot{K}$  and  $q$  are positively related, the investment shrinks suddenly and then gradually increase. It implies that, a permanent anticipated exchange rate depreciation leads to a temporary decrease in investment.
- The producers realize that the depreciation is temporary. As they know that the profits will come to their original value,  $q$  passes first to the point  $F$  (figure 5, appendix D), then the economy moves towards  $G$  on the old saddle-path. Finally, the economy goes down towards point  $S$  along the old saddle path. The temporary shock reduces investment but not as much as in the permanent case.

<sup>10</sup>See Chang (1992), pp. 161-239.



**Situation 2:** The firm relies less on imported capital ( $\theta$  very near 1) and export more output ( $\rho$  very near 0). Considering this setting, the effects of exchange rate on investment are symmetrical to those presented in situation 1.

The conclusion to draw from this analysis is that the effects of exchange rate on investment are non-linear.

## 2.3 The role of volatility

In their study Campa and Goldberg (1995) following Abel and Blanchard (1992) argued that in the presence of uncertainty, investment is a function of expected per-period profits and the cost of capital. For sake of simplicity, we consider that investment depends only on expected per-period profits.

$$I = \psi \left( E \left( \Pi \left( \epsilon, p_{xf}, p^*, p_{mk} \right) \right) \right) \quad (15)$$

where  $E$  is the expectation operator. To examine the impact of exchange rate volatility, we assume as in Campa and Goldberg (1995) that the exchange rate is log-normally distributed with mean  $\mu$  and variance  $\sigma^2$ , the distribution of the exchange rate is exogenous to the firm. Then investment is function of  $\mu$  and  $\sigma^2$ .

$$I = \psi \left( E \left( \Pi \left( \mu, \sigma^2 \right) \right) \right) = \psi \left( Z \left( \mu, \sigma^2 \right) \right) \quad (16)$$

where  $Z(\cdot) = E(\Pi(\cdot))$ . The differentiation of equation (16) gives

$$dI = \frac{d\psi}{dZ} \frac{\partial Z(\mu, \sigma^2)}{\partial \mu} d\mu + \frac{d\psi}{dZ} \frac{\partial Z(\mu, \sigma^2)}{\partial \sigma^2} d\sigma^2 \quad (17)$$

In equation (17) if we replace  $Z(\cdot)$  by  $E(\Pi(\cdot))$  we have

$$dI = \frac{\partial E(\Pi(\cdot))}{\partial \mu} \psi' d\mu + \frac{\partial E(\Pi(\cdot))}{\partial \sigma^2} \psi' d\sigma^2 \quad (18)$$

To simplify the presentation, we suppose that the production function is a Cobb-Douglas function

$$Q = F(K) = K^\alpha \quad (19)$$

In this case the cost function is

$$C(\cdot) = (r + \delta)^\theta \left( \epsilon \frac{p_{mk}}{p^*} \right)^{1-\theta} Q^{\frac{1}{\alpha}} \quad (20)$$

The per-period profits are then

$$\Pi = \left( \epsilon \frac{p_{xf}}{p^*} \right)^{1-\rho} Q - (r + \delta)^\theta \left( \epsilon \frac{p_{mk}}{p^*} \right)^{1-\theta} Q^{\frac{1}{\alpha}} \quad (21)$$

Taking expectations<sup>11</sup> of equation (21) we have

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<sup>11</sup>See appendix C for details

$$E(\Pi) = \left(\frac{p_{xf}}{p^*}\right)^{1-\rho} \exp\left\{(1-\rho)\mu + \frac{1}{2}(1-\rho)^2\sigma^2\right\} Q \\ - (r+\delta)^\theta \exp\left\{(1-\theta)\mu + \frac{1}{2}(1-\theta)^2\sigma^2\right\} \left(\frac{p_{mk}}{p^*}\right)^{1-\theta} Q^{\frac{1}{\alpha}} \quad (22)$$

By deriving equation (22) with respect to  $\mu$  and  $\sigma^2$  we get

$$\frac{\partial E(\Pi)}{\partial \mu} = (1-\rho) \exp\left\{(1-\rho)\mu + \frac{1}{2}(1-\rho)^2\sigma^2\right\} \left(\frac{p_{xf}}{p^*}\right)^{1-\rho} Q \\ - (1-\theta) \exp\left\{(1-\theta)\mu + \frac{1}{2}(1-\theta)^2\sigma^2\right\} (r+\delta)^\theta \left(\frac{p_{mk}}{p^*}\right)^{1-\theta} Q^{\frac{1}{\alpha}} \quad (23)$$

$$\frac{\partial E(\Pi)}{\partial \sigma^2} = \frac{1}{2}(1-\rho)^2 \exp\left\{(1-\rho)\mu + \frac{1}{2}(1-\rho)^2\sigma^2\right\} \left(\frac{p_{xf}}{p^*}\right)^{1-\rho} Q \\ - \frac{1}{2}(1-\theta)^2 \exp\left\{(1-\theta)\mu + \frac{1}{2}(1-\theta)^2\sigma^2\right\} (r+\delta)^\theta \left(\frac{p_{mk}}{p^*}\right)^{1-\theta} Q^{\frac{1}{\alpha}} \quad (24)$$

As for the effects of depreciation (appreciation) studied earlier, equation (24) shows that the effects of exchange rate volatility on investment are ambiguous. In the first place, exchange rate volatility affects positively profits through domestic and exports sales, in the second place, exchange rate volatility acts negatively on profits through imported capital goods. The effects of exchange rate volatility on investment depend then on which of these effects prevail and on the values of  $\theta$  and  $\rho$ .

### 3 Empirical investigation

This section presents estimation methods, the data and variables, and the results.

#### 3.1 Estimation Methods

Since our data base is composed of annually data going from 1975 to 2004, we run panel data unit root tests on all variables. Table 1 shows that among the five unit root tests, there exist at least one which tells us that each variable is non stationary.

This outcome led us to apply recent panel data cointegration techniques to estimate a model of the form

$$\frac{I_{it}}{K_{it-1}} = \gamma EV_{it} + \beta' X_{it} + \alpha_i + \delta_{it} + \epsilon_{it} \quad (25)$$

where  $\frac{I_{it}}{K_{it-1}}$  is investment  $I_{it}$  over lagged capital stock  $K_{it-1}$ ,  $EV_{it}$  the exchange rate volatility,  $X_{it}$  all other explanatory variables,  $\alpha_i$  country individual specific effects,  $\delta_i$  time specific effects and  $\epsilon_{it}$  the idiosyncratic error.  $i$  specify countries and  $t$  the time. To estimate equation (25), we use the FMOLS (*Fully Modified Ordinary Least Squares*) estimator developed in panel data context by Pedroni (1996) and Phillips and Moon (1999a). This

Variables	Levin, Lin and Chu t	Breitung t-stat	Im, Pesaran and Shin W-stat	Maddala Wu ADF -Fisher Chi-square	PP - Fisher Chi-square	Hadri Z-stat
Investment, t / Capital stock, t-1	1.2975 (0.9028)	0.3458 (0.6352)	-1.9590 (0.0251)	116.8340 (0.1496)	139.6890 (0.0079)	9.7625 (0.0000)
GDP, t / Capital stock, t-1	3.3161 (0.9995)	0.8132 (0.7919)	0.4463 (0.6723)	93.9174 (0.7035)	104.5540 (0.4114)	12.0348 (0.0000)
REER volatility 1, t	3.4882 (0.9998)	-1.2381 (0.1078)	-1.1465 (0.1258)	122.8660 (0.0781)	3021.0700 (0.0000)	6.6479 (0.0000)
Real interest rate, t	-1.5507 (0.0605)	-3.5656 (0.0002)	-2.9037 (0.0018)	94.2369 (0.3592)	658.1490 (0.0000)	13.4941 (0.0000)
Investment deflator, t / GDP deflator, t	-0.2080 (0.4176)	-0.6727 (0.2506)	-1.5745 (0.0577)	108.5020 (0.3112)	188.7280 (0.0000)	6.5644 (0.0000)
Long term debt, t / GDP, t	1.6168 (0.9470)	-3.0040 (0.0013)	2.2875 (0.9889)	69.1210 (0.9948)	59.2335 (0.9998)	9.8184 (0.0000)
ln(1+Inflation), t	1.8531 (0.9681)	-2.9731 (0.0015)	-2.4724 (0.0067)	134.8430 (0.0163)	782.8750 (0.0000)	8.6758 (0.0000)
REER volatility 1, t × Imports of GS, t	-0.6414 (0.2606)	-0.5348 (0.2964)	-0.9650 (0.1673)	103.9010 (0.4290)	1136.6900 (0.0000)	6.9685 (0.0000)
Terms of trade, t	2.02646 (0.9786)	1.2532 (0.8949)	-3.5582 (0.0002)	188.3260 (0.0000)	211.3420 (0.0000)	7.5547 (0.0000)
REER volatility 2, t	2.5109 (0.9940)	-0.5354 (0.2962)	-2.7373 (0.0031)	133.3530 (0.0202)	2501.2300 (0.0000)	7.6559 (0.0000)
REER volatility 1, t × Exports of GS, t	0.3174 (0.6245)	-1.0508 (0.1467)	-0.1375 (0.4453)	98.9928 (0.5659)	931.1110 (0.0000)	8.2079 (0.0000)

The p-values are in parenthesis. All tests include intercepts (fixed effects) and individual trends. For the autocorrelation correction methods, the specified lags are 3 or 4 and Newey-West bandwidth selection using either Barlett, Parzen or Quadratic Spectral kernel depending on the variable and the test type

Table 1: Panel unit root tests

estimator was initially introduced in time series context by Phillips and Hansen (1990). The advantage of the FMOLS estimator over the OLS estimator<sup>12</sup> is that it deals with possible autocorrelation and heteroskedasticity of the residuals, potential endogeneity of the regressors, takes into account the presence of nuisance parameters and is asymptotically unbiased<sup>13</sup>. Other estimators used for estimations and inferences in panel data cointegration are the DOLS (*Dynamic Ordinary Least Squares*), Kao and Chiang (2000), Mark and Sul (1999), Pedroni (2001), PMGE (*Pooled Mean Group Estimator*), Pesaran, Shin and Smith (1999), and the vector error-correction representation, Breitung (2005), Mark and Sul (2003). Pedroni (1996) and Phillips and Moon (1999a) showed that the FMOLS estimator is normally distributed. Analogous results were also obtained by Kao and Chiang (2000) for the methods FMOLS and DOLS.

The use of panel data cointegration techniques in estimating equation (25) has several advantages. Initially, annual data enable us not to lose information contrary to the method of averages over subperiods employed in some previous studies. Then, the add of the cross sectional dimension makes that statistical tests are normally distributed, more powerful and do not depend on the number of regressors as in individual time series.

<sup>12</sup>The OLS estimator is super-consistent but is asymptotically biased and is function of nuisance parameters, Kao and Chen (1995), Pedroni (1996) and Kao and Chiang (2000).

<sup>13</sup>The reader concerned with these problems is invited to look the cited papers. A good survey on recent panel data cointegration is provided by Baltagi and Kao (2000) and Hurlin and Mignon (2006)

To test the presence of cointegration in equation (25), we utilize Pedroni (1999) tests. To explain the tests procedure we rewrite equation (25) in the following manner

$$y_{it} = \alpha_i + \delta_i t + \beta_{1i}x_{1,it} + \beta_{2i}x_{2,it} + \dots + \beta_{Mi}x_{M,it} + \epsilon_{it} \quad (26)$$

where  $i = 1, \dots, N$ ,  $t = 1, \dots, T$  and  $m = 1, \dots, M$ . Pedroni (1999) compute four within tests and three between tests. If we write the residuals in equation (26) as an AR(1) process  $\hat{\epsilon}_{it} = \rho_i \hat{\epsilon}_{it-1} + u_{it}$ , the alternative hypothesis for the tests are formulated in the following manner

- For within tests, the alternative hypothesis is  $H_A : \rho_i = \rho < 1 \forall i$
- For between tests, the alternative hypothesis is  $H_A : \rho_i < 1 \forall i$

The seven tests are

1. Within tests (*Panel cointegration statistics*)

- Panel  $\nu$ -statistic: non parametric test, variance ratio type

$$T^2 N^{3/2} Z_{\nu N,T} \equiv T^2 N^{3/2} \left( \sum_{i=1}^N \sum_{t=1}^T \hat{L}_{11i}^{-2} \hat{\epsilon}_{it-1}^2 \right)^{-1} \quad (27)$$

- Panel  $\rho$ -statistic: non parametric test. Phillips-Perron  $\rho$  statistic type

$$TN^{1/2} Z_{\rho N,T-1} \equiv TN^{1/2} \left( \sum_{i=1}^N \sum_{t=1}^T \hat{L}_{11i}^{-2} \hat{\epsilon}_{it-1}^2 \right)^{-1} \sum_{i=1}^N \sum_{t=1}^T \hat{L}_{11i}^{-2} (\hat{\epsilon}_{it-1} \Delta \hat{\epsilon}_{it} - \hat{\lambda}_i) \quad (28)$$

- Panel  $t$ -statistic: non parametric test. Phillips-Perron  $t$  statistic type

$$Z_{tN,T} \equiv \left( \hat{\sigma}_{N,T}^2 \sum_{i=1}^N \sum_{t=1}^T \hat{L}_{11i}^{-2} \hat{\epsilon}_{it-1}^2 \right)^{-1/2} \sum_{i=1}^N \sum_{t=1}^T \hat{L}_{11i}^{-2} (\hat{\epsilon}_{it-1} \Delta \hat{\epsilon}_{it} - \hat{\lambda}_i) \quad (29)$$

- Panel  $t$ -statistic: parametric test. Augmented Dickey-Fuller  $t$  statistic type

$$Z_{tN,T}^* \equiv \left( \hat{s}_{N,T}^{*2} \sum_{i=1}^N \sum_{t=1}^T \hat{L}_{11i}^{-2} \hat{\epsilon}_{it-1}^{*2} \right)^{-1/2} \sum_{i=1}^N \sum_{t=1}^T \hat{L}_{11i}^{-2} \hat{\epsilon}_{it-1}^* \Delta \hat{\epsilon}_{it}^* \quad (30)$$

2. Between tests (*Group mean panel cointegration statistics*)

- Group  $\rho$ -statistic: non parametric test. Phillips-Perron  $\rho$  statistic type

$$TN^{-1/2} \tilde{Z}_{\rho N,T-1} \equiv TN^{-1/2} \sum_{i=1}^N \left( \sum_{t=1}^T \hat{\epsilon}_{it-1}^2 \right)^{-1} \sum_{t=1}^T (\hat{\epsilon}_{it-1} \Delta \hat{\epsilon}_{it} - \hat{\lambda}_i) \quad (31)$$

- Group  $t$ -statistic: non parametric test. Phillips-Perron  $t$  statistic type

$$N^{-1/2} \tilde{Z}_{tN,T} \equiv N^{-1/2} \sum_{i=1}^N \left( \hat{\sigma}_i^2 \sum_{t=1}^T \hat{\epsilon}_{it-1}^2 \right)^{-1/2} \sum_{t=1}^T (\hat{\epsilon}_{it-1} \Delta \hat{\epsilon}_{it} - \hat{\lambda}_i) \quad (32)$$

- Group  $t$ -statistic: parametric test. Augmented Dickey-Fuller  $t$  statistic type

$$N^{-1/2}\tilde{Z}_{tN,T}^* \equiv N^{-1/2} \sum_{i=1}^N \left( \sum_{t=1}^T \hat{s}_i^{*2} \hat{\epsilon}_{it-1}^{*2} \right)^{-1/2} \sum_{t=1}^T \hat{\epsilon}_{it-1}^* \Delta \hat{\epsilon}_{it}^* \quad (33)$$

where

$$\hat{\lambda}_i = T^{-1} \sum_{s=1}^{k_i} \left( 1 - \frac{s}{k_i + 1} \right) \sum_{t=s+1}^T \hat{\mu}_{it} \hat{\mu}_{it-s}, \quad \hat{s}_i^2 \equiv T^{-1} \sum_{t=1}^T \hat{\mu}_{it}^2$$

$$\hat{\sigma}_i^2 = \hat{s}_i^2 + 2\hat{\lambda}_i, \quad \hat{\sigma}_{N,T}^2 \equiv N^{-1} \sum_{i=1}^N \hat{L}_{11i}^{-2} \hat{\sigma}_i^2, \quad \hat{s}_i^{*2} \equiv T^{-1} \sum_{t=1}^T \hat{\mu}_{it}^{*2}$$

$$\hat{\tilde{s}}_{N,T}^2 \equiv N^{-1} \sum_{i=1}^N \hat{s}_i^{*2}, \quad \hat{L}_{11i}^2 = T^{-1} \sum_{t=1}^T \hat{\eta}_{it}^2 + 2T^{-1} \sum_{s=1}^{k_i} \left( 1 - \frac{s}{k_i + 1} \right) \sum_{t=s+1}^T \hat{\eta}_{it} \hat{\eta}_{it-s}$$

$$\hat{\mu}_{it} = \hat{\epsilon}_{it} - \hat{\rho}_i \hat{\epsilon}_{it-1}, \quad \hat{\mu}_{it}^* = \hat{\epsilon}_{it} - \hat{\rho}_i \hat{\epsilon}_{it-1} - \sum_{k=1}^{k_i} \hat{\rho}_{ik} \Delta \hat{\epsilon}_{it-k}, \quad \hat{\eta}_{it} = \Delta y_{it} - \sum_{m=1}^M \hat{b}_{mi} \Delta x_{mi,t}$$

### 3.2 Data and Variables

To study the effect of volatility on investment, we utilize annually data from 1975 to 2004 of 51 developing countries (23 low-income and 28 middle-income countries)<sup>14</sup>. The data are from World Development Indicators (WDI) 2006, International Financial Statistics (IFS), April, 2006 and CERDI 2006.

In what follows we expose first, the method of the real exchange rate volatility calculation and second, present the other variables used in the study.

Before calculating the exchange rate volatility, we calculate the real exchange rate (base 100 = 2000) using the following formula

$$REER_{i/j} = \prod_{j=1}^{10} \left( NBER_{j/i} \frac{CPI_i}{CPI_j} \right)^{w_j} \quad (34)$$

where:

$NBER_{j/i}$ : is the nominal bilateral exchange rate of trade partner  $j$  relative to country  $i$ ;  
 $CPI_i$ : represents the consumer price index of country  $i$  (IFS line 64 or GDP deflator for countries without  $CPI$ );

$CPI_j$ : corresponds to the consumer price index of trade partner  $j$  (IFS line 64 or GDP deflator for countries without  $CPI$ );

$w_j$ : stands for trade partner  $j$  weight (mean 1999-2003, PCTAS-SITC-Rev.3). Only the first ten partners are taking (CERDI method).

After calculating the exchange rate, we compute as Serven (1998), Serven (2002) and Bleaney and Greenaway (2001) the real exchange rate volatility using ARCH family

<sup>14</sup>the choice of the sample is based on the availability of data

methods. We proceed as such because many ARCH family methods can take account asymmetric chocks effects. We employ two ARCH-Family methods: GARCH (Generalized Autoregressive Conditional Heteroskedasticity), Bollerssev (1986), and GARCH-M (GARCH-in-Mean), Engle, Lilien and Robins (1987). The former specification implies symmetric effect of innovations while the second assumes asymmetric impact of good and bad news. The two estimated models, for each country of the sample, are

GARCH(1,1)

$$\begin{aligned}\ln(reer_t) - \ln(reer_{t-1}) &= \beta_0 + \epsilon_t \\ \sigma_t^2 &= \gamma_0 + \gamma_1 \epsilon_{t-1}^2 + \delta_1 \sigma_{t-1}^2\end{aligned}\quad (35)$$

GARCH-M(1,1)

$$\begin{aligned}\ln(reer_t) - \ln(reer_{t-1}) &= \beta_0 + \psi \sigma_t^2 + \epsilon_t \\ \sigma_t^2 &= \gamma_0 + \gamma_1 \epsilon_{t-1}^2 + \delta_1 \sigma_{t-1}^2\end{aligned}\quad (36)$$

where  $\epsilon_t \sim N(0, \sigma_t^2)$ ,  $\epsilon_t^2$  is the squared residuals,  $\sigma_t^2$  the variance of the regression model's disturbances,  $\gamma_i$  the ARCH parameters,  $\delta_1$  the GARCH parameter and  $\psi$  the GARCH-M parameter. We compute the exchange rate volatility as the square root of the variance of the regression model's disturbances. In the paper, the GARCH(1,1) measure of exchange rate volatility is referred to as *REER volatility 1, t* and the GARCH-M(1,1) measure as *REER volatility 2, t*<sup>15</sup>.

As dependent variable, we use the ratio of actual investment (WDI constant 2000 US dollars) over lagged capital stock (computed by the perpetual-inventory method using constant 2000 US dollars investment series). Formulating investment this way is known as capacity principle, Chenery (1952)<sup>16</sup>. Traditional determinants of investment are considered as control variables: GDP over lagged capital stock, real interest rate, user cost of capital (investment deflator over GDP deflator), inflation, long term debt and the terms of trade. See Table D1 in appendix D for further details on explanatory variables. Table 6 in appendix D gives summary statistics on all variables.

### 3.3 Estimation Results

In this section, we describe first the panel data cointegration tests and second present the estimation results.

Table 2 illustrates that among the seven tests of Pedroni (1999), there is at least one that shows that we reject the null hypothesis of no cointegration in all 5 equations<sup>17</sup>. This allows us to estimate the panel data cointegration relationships.

<sup>15</sup>The weights used to generate the REER, from which these two measurements come, are respectively: (Exports+Imports)/2 including oil countries, (Exports+Imports)/2 without oil countries.

<sup>16</sup>Other formulations close to this are the capital stock adjustment principle, Goodwin (1951) and the flexible accelerator, Koyck (1954).

<sup>17</sup>See table 3 for a list of these equations.

Pedroni Panel Cointegration Tests		(1)	(2)	(3)	(4)	(5)
Panel Cointegration tests	panel v-stat	-0.2949	-2.6656	-2.9809	-3.1164	-3.6536
	panel rho-stat	0.4283	4.1791	4.9366	4.8765	6.5996
	panel pp-stat	-3.1529	-2.1764	-3.9206	-3.0677	-2.9631
	panel adf-stat	-2.4911	2.0490	5.6660	-0.4804	0.3043
Group mean cointegration tests	group rho-stat	2.5166	7.3718	8.1990	8.2804	9.6908
	group pp-stat	-1.9672	-1.6667	-4.2611	-2.9673	-4.6715
	group adf-stat	-1.4405	0.3701	1.9417	0.5910	2.8247

All reported values are distributed  $N(0,1)$  under null of no cointegration

Table 2: Panel data cointegration tests

As mentioned earlier, panel data cointegration estimators, in particular the FMOLS, deal with possible autocorrelation and heteroskedasticity of the residuals, takes into account the presence of nuisance parameters, are asymptotically unbiased and, more importantly, deal with potential endogeneity of the regressors.

Table 3 present the results of Pedroni (1999) panel data cointegration estimation results.

Dependent Variable: Investment, t / Capital stock, t-1					
Regressors	(1)	(2)	(3)	(4)	(5)
GDP, t / Capital stock, t-1	0.2361*** (0.0000)	0.1391*** (0.0000)	0.2217*** (0.0000)	0.2194*** (0.0000)	0.3585*** (0.0000)
Real interest rate, t		-0.0121* (0.0778)	-0.1675 (0.1575)	-0.0170*** (0.0006)	-0.5345*** (0.0000)
Investment deflator, t / GDP deflator, t		-0.0506*** (0.0000)	-0.0663*** (0.0000)	-0.0257*** (0.0000)	-0.0611*** (0.0000)
REER volatility 1, t	-0.0213* (0.0595)	-0.9431*** (0.0000)	-0.7822*** (0.0000)	-0.3318*** (0.0000)	-1.0195*** (0.0000)
ln(1+Inflation), t			-0.1615 (0.1989)		-0.6314*** (0.0000)
Long term debt, t / GDP, t				-0.0987*** (0.0000)	
Terms of trade, t					0.0695*** (0.0000)

\*\*\*, \*\* and \* significant at 1%, 5% and 10% respectively. P-values in brackets.

Table 3: Panel data cointegration estimation results

All five equations illustrates that the real exchange rate volatility is statistically significant and has the expected sign. Regression 1 represents the *capacity principle* model in which we add the real exchange rate volatility. In this model, the Reer volatility is negative and marginally significant. The coefficient increases in magnitude and statistical significance when we control for traditional investment determinants, beginning from regression 2. These regressions show that the impact of Reer volatility is high. Referring to regression 2, an increase in Reer volatility by one standard deviation reduces the ratio of investment to lagged capital stock by an amount approximately equivalent to eight standard deviations. If we take regression 5, the impact become higher because an increase of Reer volatility equal to the its interquartile range make the ratio of investment to

lagged capital pass from the ninetieth percentile to approximately the tenth percentile, a drop higher than the interquartile range. The absolute value of Reer volatility coefficient diminish by more than a half when we introduce long term debt in regression 4, suggesting that the effect of volatility on investment may pass through long term debt. The coefficient of actual GDP over lagged capital stock is positive and highly significant in all regressions. This is in line with Chenery (1952) capacity principle which state that an augmentation in capacity usage rise investment. The real interest rate and the user cost of capital have the expected signs and are, generally, statistically significant. Meaning that large costs of capital reduce investment. The other remaining variables have the expected signs and are, generally, statistically significant.

Table 4 presents the results of the interaction of the the real exchange rate volatility with the variable imports, in the first place, and with the variable exports, in the second place.

Dependent Variable: Investment, t / Capital stock, t-1				
Regressors	(1)	(2)	(3)	(4)
GDP, t / Capital stock, t-1	0.2459*** (0.0000)	0.2929*** (0.0000)	0.2933*** (0.0000)	0.3043*** (0.0000)
REER volatility 1, t	-1.4319*** (0.0016)	-0.9161*** (0.0042)	-1.3506*** (0.0045)	-0.5971*** (0.0049)
Imports of GS, t	0.3553 (0.1328)	0.3565*** (0.0013)	0.3242*** (0.0005)	
REER volatility 1, t × Imports of GS, t	-0.1067*** (0.0033)	-0.4744*** (0.0044)	-0.1905*** (0.0023)	
Terms of trade, t	0.0254*** (0.0000)		0.0128*** (0.0000)	
Investment deflator, t / GDP deflator, t		-0.0525*** (0.0000)	-0.0498*** (0.0000)	-0.0421*** (0.0000)
ln(1+Inflation), t		0.0073 (0.4298)	0.0066 (0.3045)	0.0118 (0.1891)
Exports of GS, t				0.0115** (0.0220)
REER volatility 1, t × Exports of GS, t				0.2349** (0.0117)

\*\*\*, \*\* and \* significant at 1%, 5% and 10% respectively. P-values in brackets.

Table 4: Exchange rate volatility pass-through

In all four regressions, the Reer volatility coefficient is negative and significant at 1 percent level. The interaction of Reer volatility with imports of goods and services is negative, statistically significant with a high coefficient in absolute value in all first three equations. This suggests that the effect of Reer volatility is higher in countries which rely heavily on imports. This outcome corroborates the theoretical prediction of the paper. In regression 4, the interaction of Reer Volatility with exports of goods and services has the expected sign. This result imply that, the more an economy exports, the less exchange rate volatility has negative impact on investment. The export threshold for which the marginal impact of Reer volatility on investment is nil is 2.54. This value is out of range of exports of goods and services in the sample<sup>18</sup>. Then in our sample, we could consider that the effect of Reer volatility on investment is negative in regression 4.

<sup>18</sup>The minimum of export of goods and services over GDP is 0.0290 and the maximum 1.2441.



Table 5 gives an estimation using an alternative measurement of Reer volatility. It also provides regressions on subsamples of low-income and middle-income countries.

Dependent Variable: Investment, t / Capital stock, t-1			
	Full sample	Middle-Income Countries	Low-Income Countries
Regressors	(2)	(2)	(5)
GDP, t / Capital stock, t-1	0.4308*** (0.0000)	0.3096*** (0.0000)	0.4067*** (0.0000)
Real interest rate, t	-0.0119*** (0.0000)	-0.0411*** (0.0000)	-1.2375*** (0.0000)
Investment deflator, t / GDP deflator, t	-0.0827*** (0.0000)	-0.0463*** (0.0000)	-0.1172*** (0.0000)
REER volatility 1, t		-0.0489*** (0.0040)	-1.8454*** (0.0000)
REER volatility 2, t	-7.7435*** (0.0000)		
ln(1+Inflation), t			-1.3942*** (0.0000)
Terms of trade, t			0.0578*** (0.0000)

\*\*\*, \*\* and \* significant at 1%, 5% and 10% respectively. P-values in brackets.

Table 5: Estimation results using an alternative measurement of Reer volatility and on subsamples of countries

As mentioned, the alternative measurement of Reer volatility, the GARCH-M(1,1), takes into account asymmetric effects of innovations. Regression 1 in table 5 shows that the impact of the GARCH-M(1,1) measurement is significant and very high. This demonstrates that if we take account asymmetric effects, volatility can have a strong negative impact on investment. The coefficients of the Reer volatility for regressions on the subsamples of countries are significant and have the expected signs. The absolute value of the coefficient of the Reer volatility for low-income countries is larger than that of middle-income countries. Thus the effect of exchange rate volatility on investment is higher in low-income countries than in middle-income countries. This because low-income countries are more vulnerable to shocks.

## 4 Conclusion

This paper examines the relation between the exchange rate, its volatility and investment both theoretically and empirically. The theoretical part of the paper indicates that exchange rate and exchange rate volatility have nonlinear effects on investment. Using new developments on panel data cointegration techniques, we find that real exchange rate volatility has a strong negative impact of investment. An increase in Reer volatility by one standard deviation reduces the ratio of investment to lagged capital stock by an amount approximately equivalent to eight standard deviations. The robustness checks illustrates that this negative impact of Reer volatility on investment is stable to the use of an alternative measurement of Reer volatility and on subsamples of countries (low-income and high-income countries).

Though the results found were informative, some caveats remain. If data on both public and private investment are available, some regressions on these two variables would allow us to compare the effects of Reer between these two variables and domestic investment. Some studies on structural change in the context of panel cointegration could also provide helpful information on the impact of Reer volatility on investment.

From political economy perspectives, the results illustrate that macroeconomic instability, in particular exchange rate volatility could have negative impacts on investment and that efforts made to reduce them might relaunch investment and productivity.

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## A Properties of the neoclassical production function

1. Constant return to scale  
 $F(\lambda K) = \lambda F(K)$  for all  $\lambda > 0$
2. Positive and diminishing returns to private inputs  
 $\partial F/\partial K > 0$ ,  $\partial^2 F/\partial K^2 < 0$
3. Inada conditions  
 $\lim_{K \rightarrow 0}(\partial F/\partial K) = \infty$ ,  $\lim_{K \rightarrow \infty}(\partial F/\partial K) = 0$
4. Essentiality  
 $F(0) = 0$

## B Phase diagram study

To study de phase diagram, we consider points either side of the equilibrium lines.

For the  $K$ -line

- $\dot{K} > 0$  if  $q > 1 + \beta\delta$ . In figure 3 this is shown by horizontal arrows pointing to the right.
- $\dot{K} < 0$  if  $q < 1 + \beta\delta$ . In figure 3 this is shown by horizontal arrows pointing to the left.

For the  $q$ -line

- If we start at a point on the  $\dot{q} = 0$  schedule and increase  $K$  a bit, the right-hand side of the expression for  $\dot{q}$  in equation (11) increases. Hence  $\dot{q}$  is increasing in that region and the arrows point to the north in figure 3.
- An asymmetric description shows that the arrows point south, in figure 3, for points to the left of the  $\dot{q} = 0$  schedule.

## C Derivation of equation (22)

The lognormal distribution is

$$f(x) = \begin{cases} \frac{1}{\sigma x \sqrt{2\pi}} \exp\left\{-\frac{1}{2}\left(\frac{\ln x - \mu}{\sigma}\right)^2\right\}, & \text{for } x > 0 \\ 0, & \text{for } x \leq 0 \end{cases}$$

The expectations apply only to the real exchange as it is the only source of uncertainty

$$\begin{aligned} E(\Pi) &= E[(\epsilon)^{1-\rho}] \left(\frac{p_{xf}}{p^*}\right)^{1-\rho} Q - (r + \delta)^\theta E[(\epsilon)^{1-\theta}] \left(\frac{p_{mk}}{p^*}\right)^{1-\theta} Q^{\frac{1}{\alpha}} \\ E(\Pi) &= \exp\left\{(1-\rho)\mu + \frac{1}{2}(1-\rho)^2\sigma^2\right\} \left(\frac{p_{xf}}{p^*}\right)^{1-\rho} Q \\ &\quad - (r + \delta)^\theta \exp\left\{(1-\theta)\mu + \frac{1}{2}(1-\theta)^2\sigma^2\right\} \left(\frac{p_{mk}}{p^*}\right)^{1-\theta} Q^{\frac{1}{\alpha}} \end{aligned}$$

## D Explanatory Variables: definitions, expected sign and source

Table D1

Variables	Definitions, Expected Sign and References	Data Source
GDP, t / Capital stock, t-1	Actual GDP over lagged capital stock, capacity principle, Chenery (1952). Based on this theory and the related ones (capital stock adjustment principle, Goodwin (1951) and flexible accelerator, Koyck (1954)), we expect this variable to have a positive sign. This variable is included to take account inertia problems since we cannot include the lagged dependent variable	WDI 2006
Real interest rate, t	We expect real interest rates to have a negative effect	WDI 2006
Investment deflator, t / GDP deflator, t	It is a proxy for the user cost of capital. It should exert a negative impact on investment, Serven (2002)	WDI 2006
REER volatility 1, t × Imports of GS, t	Real Effective Exchange Rate times Import of goods and services over GDP. The theoretical part of the paper suggests that exchange rate volatility can affects investment through imported capital stock. We introduce imports of goods and services as a proxy for imported capital stock. We expect the variable Real effective exchange rate volatility × Imports of goods and services over GDP to have a negative effect	WDI 2006
REER volatility 1, t × Exports of GS, t	Real Effective Exchange Rate times Exports of goods and services over GDP. The theoretical part of the paper suggests that exchange rate can affects investment through export sales. We expect the variable Real effective exchange rate volatility × Export of goods and services over GDP to have a positive impact	WDI 2006
Long term debt, t / GDP, t	Long term debt over GDP. It should have a negative effect	WDI 2006
Terms of trade, t	Prices of exports over prices of imports. This variable should exert a positive effect	WDI 2006
ln(1+Inflation), t	Natural logarithm of 1 plus annual inflation rate. This variable is expected to have a negative sign	WDI 2006

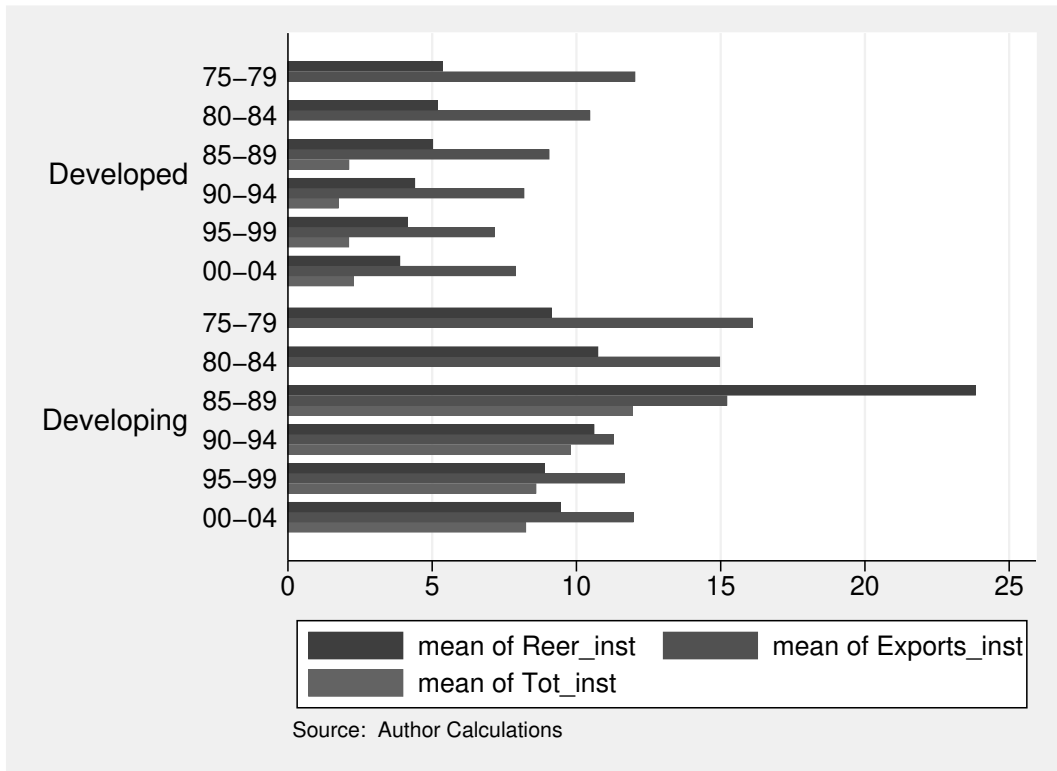


Figure 1: Instabilities in Developing and Developed countries (Reer, Exports and Tot)

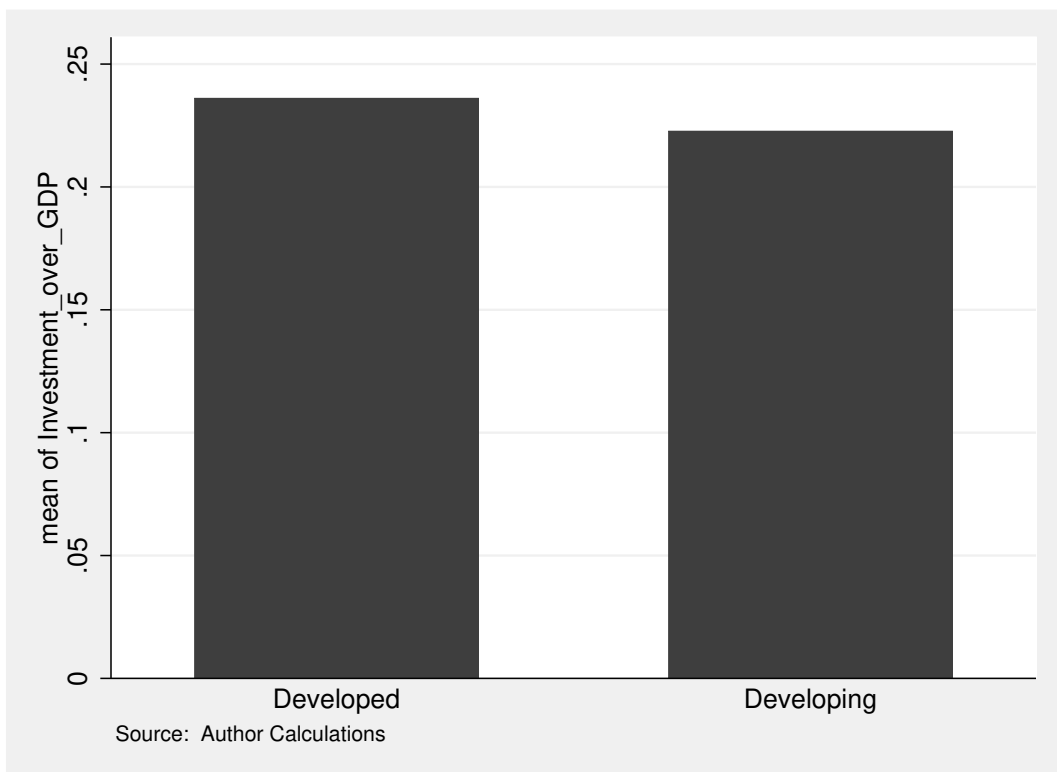


Figure 2: Investment/GDP in Developing and Developed countries (1975-2004)

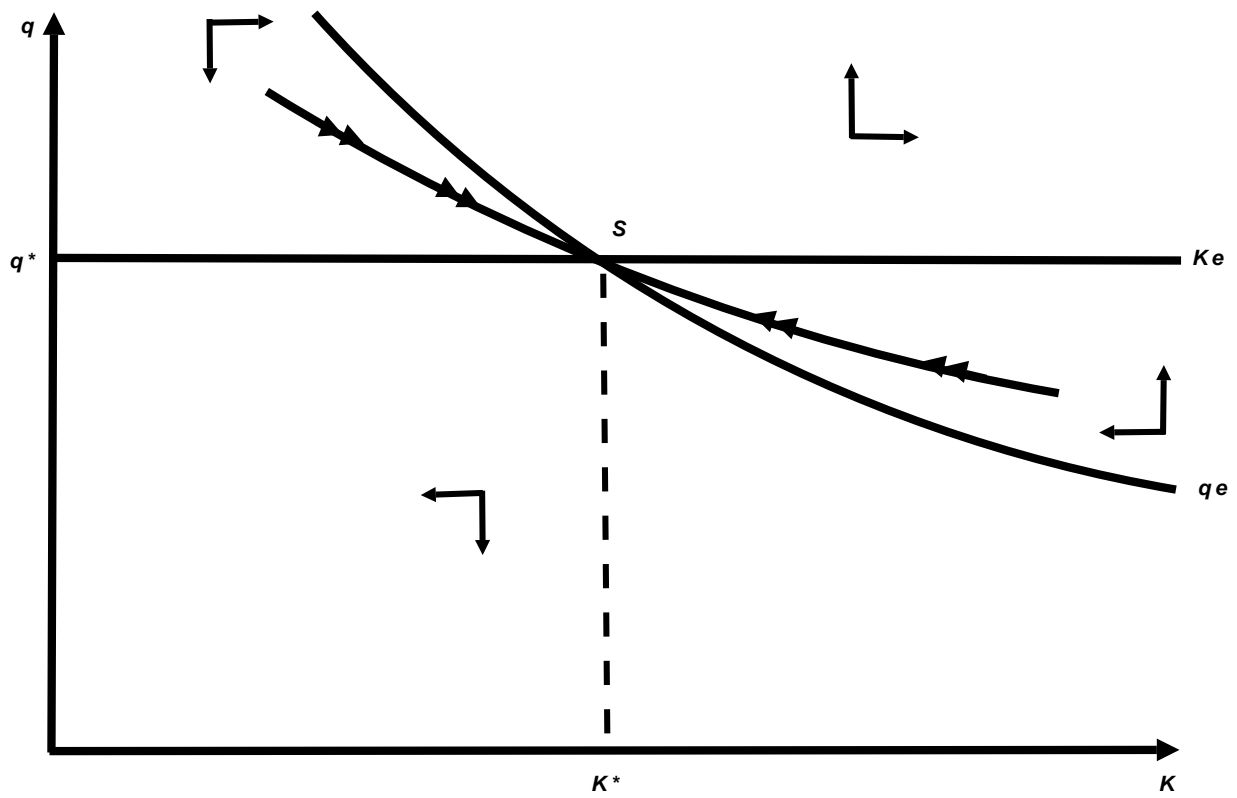


Figure 3: Phase diagram

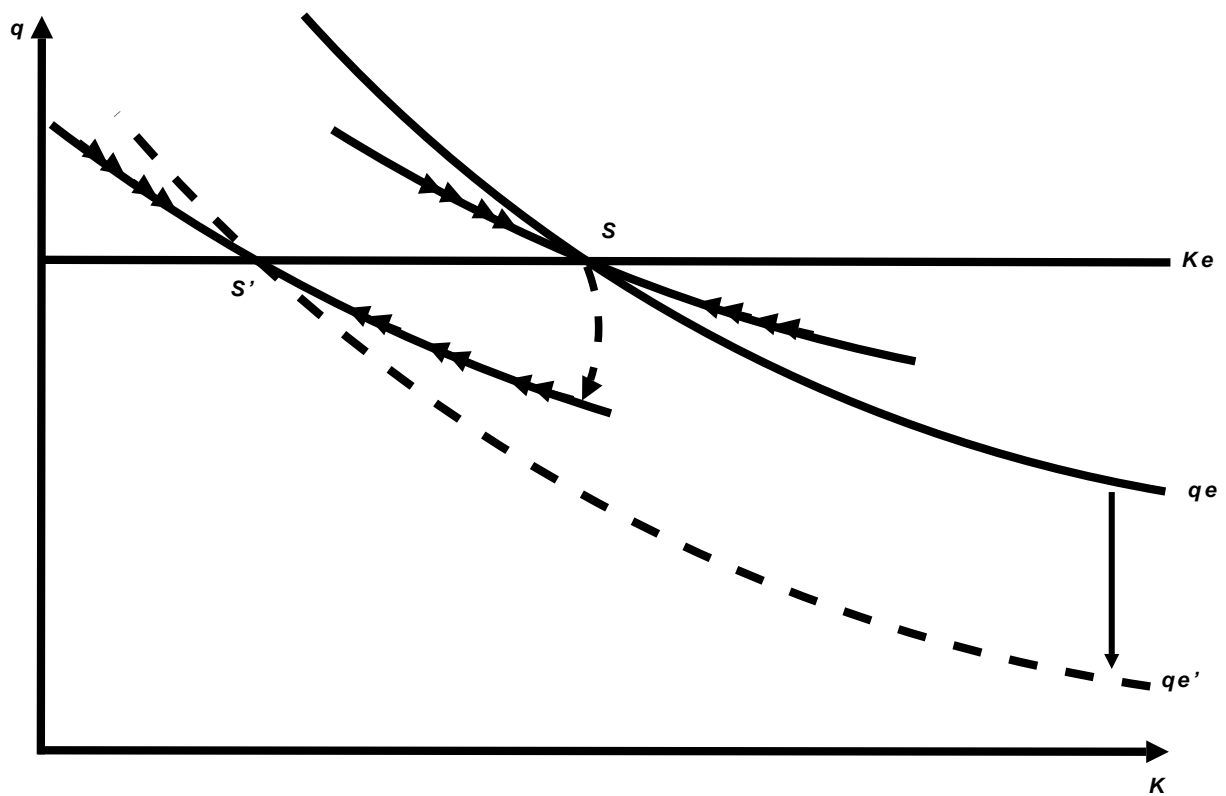


Figure 4: Permanent exchange rate depreciation



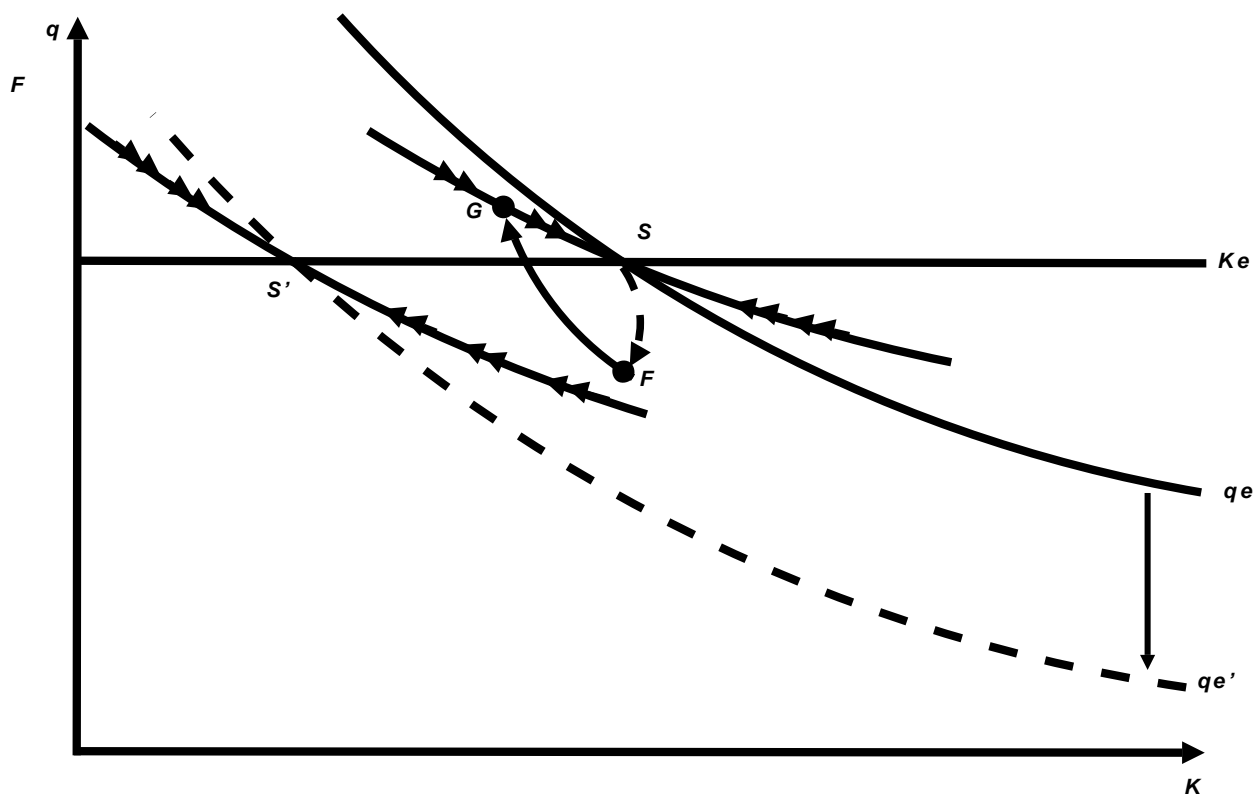


Figure 5: Temporary exchange rate depreciation

Variables	Observations	Mean	Std. Dev.	Min	Max
Investment, t / Capital stock, t-1	1472	0.0725	0.0296	-0.0050	0.1994
GDP, t / Capital stock, t-1	1475	0.3599	0.1928	0.0584	1.6920
Real interest rate, t	1087	0.0767	0.2799	-0.9781	7.8980
Investment deflator, t / GDP deflator, t	1523	1.0586	0.3474	0.1198	3.4958
REER volatility 1, t	1499	0.1323	0.2534	0.0000	6.8452
REER volatility 1, t × Imports of GS, t	1498	0.0437	0.1409	0.0000	4.4626
ln(1+Inflation), t	1530	0.1733	0.3717	-0.2763	4.7749
Long term debt, t / GDP, t	1517	0.6140	0.6023	0.0233	8.2349
Terms of trade, t	1518	1.0853	0.3759	0.3213	6.0800
REER volatility 2, t	1499	0.1213	0.1364	0.0000	2.2887
REER volatility 1, t × Exports of GS, t	1498	0.0338	0.0698	0.0000	2.2272

Table 6: Summary statistics on variables

Low-Income countries		
N°	Word Banque Code	Countries
1	BDI	Burundi
2	BEN	Benin
3	BFA	Burkina Faso
4	BGD	Bangladesh
5	CIV	Cote d'Ivoire
6	CMR	Cameroon
7	COG	Congo, Rep.
8	GHA	Ghana
9	GMB	Gambia, The
10	GNB	Guinea-Bissau
11	IND	India
12	KEN	Kenya
13	LSO	Lesotho
14	MDG	Madagascar
15	MLI	Mali
16	MRT	Mauritania
17	MWI	Malawi
18	NIC	Nicaragua
19	RWA	Rwanda
20	SEN	Senegal
21	TGO	Togo
22	ZMB	Zambia
23	ZWE	Zimbabwe

Middle-Income countries		
N°	Word Banque Code	Countries
1	ARG	Argentina
2	BOL	Bolivia
3	CHL	Chile
4	CHN	China
5	COL	Colombia
6	CRI	Costa Rica
7	DOM	Dominican Republic
8	DZA	Algeria
9	ECU	Ecuador
10	EGY	Egypt, Arab Rep.
11	GAB	Gabon
12	GTM	Guatemala
13	HND	Honduras
14	HUN	Hungary
15	IDN	Indonesia
16	LKA	Sri Lanka
17	MAR	Morocco
18	MEX	Mexico
19	MYS	Malaysia
20	PER	Peru
21	PHL	Philippines
22	PRY	Paraguay
23	SWZ	Swaziland
24	THA	Thailand
25	TTO	Trinidad and Tobago
26	TUN	Tunisia
27	URY	Uruguay
28	VEN	Venezuela, RB

This subdivision is from the World Development Indicators 2006 classification based on countries 2004 GNI per capita: Low Income Countries (GNI/per capita  $\leq$  US \$825); Middle Income Countries (US \$826  $\leq$  GNI per capita  $\leq$  US \$10065).

Table 7: List of 51 countries