ESSAYS ON REAL EXCHANGE RATE AND COMPETITIVENESS

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ABSTRACT

In the planning of a country's economic policy, exchange rate policy has a major role, especially in less developed countries where industrial policies and foreign trade are mainly based on the exchange rate competitiveness. Therefore, it is not surprising that the exchange rate policy is used by governments and policy makers to assess the country's competitive position in the world trade.

In practice, the real exchange rate (RER) is associated with the evaluation of the external position of countries through the price elasticity analysis between exports and imports. However, the assessment of countries competitive position on the basis of price elasticity is a simplified overview for understanding reality. Despite the research efforts made to cast light on the field of concern, a causal relationship between the behavior of the RER and highest competitiveness indicators remain unclear. In fact, this relationship disregards the effects of non-price competitiveness, such as competitive advantages based on the value added like high

technologies applied to new products developments and new processes designs.

To round up, some authors and policy makers support the assumption that the overvaluation of a currency deteriorates the competitive position of a country and that competitive devaluations facilitate growth through its positive impact on the share of the tradable goods in the economy, especially in the industry. Nevertheless, there is vast empirical evidence supporting that an appreciation of the RER will not always result in a loss of competitiveness and, conversely, RER depreciation will not always imply a higher competitiveness performance. Thus, competitiveness policies strongly based on the RER evolution through time can lead to misleading conclusions.

This thesis is focused on the effects of the real exchange rate as an instrument of macroeconomic policy aimed at achieving higher indicators of competitiveness in the business sector. Theoretical and empirical evidence is offered to business decision-makers as useful information.

Chapter one analyzes the effect of two opposed monetary policies to achieve the same goal, namely, to improve competitiveness indicators by increasing the indicator of exports over imports by the use of competitive devaluations. We examine the effects of exchange rate depreciations (appreciations) during long periods of time on the external performance in less developed countries. Findings motivated the study of the impact of an exchange rate policy and the inflation variable on microeconomic factors that contribute with higher competitiveness indicators of a country, specifically, the relationship of these variables with the investment in technological breakthrough and innovation.

For instance, let us consider what many authors have pointed out: devaluation may have contractionary effects on the national economy and an increasing inflation rate would deteriorate external indicators, such as the trade balance and the change in net international reserves. If the economic policy of a country and an industrial strategy of development are highly sensitive to movements of the exchange rates, we might come up with the following questions: how would the investment is affected in the short and long term facing a fluctuation in the foreign exchange rate? How would exchange rate uncertainty affect the cost and price structure in private sectors? In addition, increasing inflation rates generate the appreciation of the real exchange rate and, therefore, further devaluation should be expected in order to keep competitive export-prices. Again, how would it affect the cost and price structure of the industry? How could the decision-making process be affected under costs and price uncertainty? Finally, consider the case of a national strategic-partner practicing depreciations (appreciations) of the currency. Does it imply new devaluations to takes place?

In a sense, all these questions lead us to explore how to promote competitiveness based on factors that eventually would '*protect*' firms from macroeconomic imbalances. Recent literature suggests that the factors influencing differences in international competitiveness across countries are technological competitiveness and innovativeness.

Chapter two introduces the uncertainty in the exchange rate behavior (appreciation and / or depreciation) as a "*risk-factor*" in decision making related to private contracts on international technology transfer. In this regard, we have studied the effects of an uncertain exchange rate on the firm's behavior on technology and innovation, more precisely, the effects in the international technology transfer investments. Krugman (1979) suggests that technology transfer brings the benefit of improved terms of trade in less developed countries. Also, Mendi (2007) suggests that the productivity factor may increase simply because firms using a superior technology raise average productivity.

Finally, the third chapter examines the effect of the inflation variable as a "*risk- factor*" when making investment decisions in R&D activities in the private sector.

In general terms, business decisions are subject to the economic policy established by a government. In other words, despite business decisions designed to meet their expectations in the market, governments generally set the standards and rules by applying economic policies that provide the framework for decision-making in the public and private sectors. We explore the effects of the real exchange rate and inflation in the decision making process of the business sector, more precisely, in the field of investment in technological breakthrough.

In order to clarify some aspects of these dilemmas, this dissertation focused on the role of exchange rate policies on the investment behavior in the business sector. In addition, we studied the effects of inflation on the behavior in a specific type of investment in the private sector.

In light of the inconclusive debate regarding the uses of competitive devaluations in the long run as a path to improve the competitive position of less developed countries, chapter one empirically examined the effects of fixed (flexible) and depreciated (appreciated) exchange rate policies on the trade balance (TB) in less developed countries. In this paper, we estimate the effects of appreciated and depreciated real exchange rates (RER) in the TB of Argentina and Brazil using multivariate co-integration tests and vector error correction models. The empirical evidence in the study supports that flexible and depreciated RER improves the TB of goods in the short-run for the countries' sample; thus, a strong appreciation of the RER should worsens the TB in the long-run. Besides, trade balance suffered a strong deterioration during periods of higher inflation rates. Hence, conclusions send a message of caution on the consequences to keep competitiveness policies based on exchange rate policies.

Having analyzed the impact of competitive devaluations in the long run, it was considered appropriate to inquire about how it would affect innovation or technology transfer between companies during periods of depreciated exchange rate. Chapter two proposes a simple model to study the impact of exchange rate fluctuations on a firm's decision to import a cost-reducing technology. It is showed how exchange rate fluctuations, and more precisely the possibility of a devaluation of the domestic currency, reduce the value of the locally-generated revenues in terms of the foreign currency. This may make the set of feasible contracts empty, meaning that there is no fixed fee and/or royalty rate that both parties may find acceptable in order to transfer the technology. Finally, we show that exchange rate uncertainty introduces a distortion in the parties' specific investment decisions and could even prevent the transfer from taking place.

Chapter three explores the relationship between inflation and research and development expenditure in a sample of OECD countries and, using a variety of fixed-effects panel specifications, it was shown that inflation has a negative and highly significant impact on R&D expenditures. Estimations on the G-7 economies, periods of lower inflation rates and the countries that invested in R&D over the sample mean, reveal that inflation adversely affects investment in R&D in low-and middle-income countries. Also, the findings in this paper suggest that only the most advanced economies are less affected by the behavior of inflation and, in particular, the public sectors with respect to the business sectors. These results have important implications for economic policy targeting inflation and promoting sustainable economic growth.

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1. Competitive Devaluations and the Trade Balance in LDC's: An Empirical Study in Latin American Countries.

Abstract

Policy makers in LDC's use to support competitive devaluations to improve the trade balance (TB). In this paper, we estimate the effects of appreciated and depreciated real exchange rates (RER) in the TB of Argentina and Brazil using cointegration tests for non-stationary data and vector error correction models (VECM). The estimations confirm the existence of long-run relationship among the TB and the RER and foreign and domestic incomes for the countries during opposite RER policies. Based on our estimations, the Marshall-Lerner condition held during periods of more flexible and depreciated RER and, the estimation of the general impulse response functions shows that devaluations in both countries do not follow a J-curve pattern in the short-run.

1.1 Introduction

In this paper we attempt to provide new empirical contribution on the relationship between the exchange rate behaviour and the trade balance (TB) in LDC's, more precisely, Latin American countries. Since the beginning of the *floating era*, conventional wisdom support devaluations (competitive devaluations) as a path to improve the TB by allowing country's exports cheaper in terms of foreign currency, leading to an increase in exports; and, the other channel is allowing country's imports expensive in terms of domestic currency leading to a decline in imports.

It is usual in LDC's to find economic growth programs to be centered in exports-led activities and imports substitution based on competitive devaluations. However, vast empirical evidence on devaluations causing significant and sustained improvement in the TB is mixed and ambiguous. In this sense, the countries' sample under analysis in this paper provides an opportunity for a better understanding on the dynamic relationship between TB and competitive devaluation. During the period under analysis, the countries' exchange rate policies have been changed over time as a response to economic crisis but performing ambiguous external performance. Figure 1 shows that the variables' behaviour of interest does not follow an expected theoretical behaviour through time. For instance, while the Brazilian RER appreciates overtime achieving the lower rates than previous period, the TB performance was the highest in the last twenty years, contrary as it is expected.

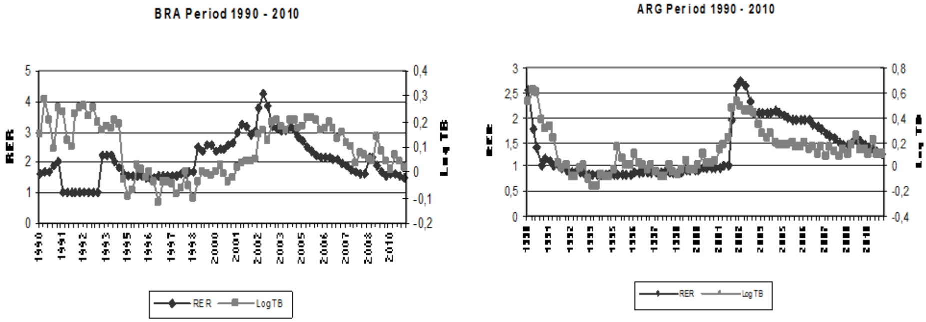
International economic literature supports that the responses of a country's TB to movements in its RER follows a J-curve. The J-curve effect indicates that currency depreciation improves the TB in the long-run but worsen it in the short-run. The initial deterioration occurs because of the effect of depreciation is to rise spending on imports, measured in local currency, by more than any initial increase in export revenues. In other words, the TB is likely to decline subsequent to depreciation episode because it is expected that exports and imports volumes (quantities) adjust slowly to movements in relative prices, but import prices respond quickly to exchange rate changes. Implicit in this discussion is the assumption that in the short-run elasticities is sufficiently low and in the long-run elasticities are sufficiently high, or in the long-run the Marshall-Lerner (ML) condition holds. According to the ML condition, currency devaluation improves the trade balance in the long-run only if the sum of the absolute values of imports and exports demand price elasticities exceeds unit.

In this paper, it is used non-structural techniques that directly model the TB as a function of the RER, and domestic and foreign expenditure. Furthermore, we will verify the ML condition and the J-curve phenomenon for Argentina and Brazil. The econometric techniques are based on the estimation of the ‘partial reduced form’ equation for the TB of goods. Tests for unit-roots to examine the stationary properties of the data reveal non-stationary in the series. Next, we apply Johansen and Juselius (1991) procedure to search for cointegrating relationships from a stable vector autoregressive (VAR) modeling specification. Based on the vector error-correction model (VECM) formulation and generalized impulse response function (GIR), we analyze the long and short-run trade balance dynamic for a sample of Latin American countries.

Results in the estimations suggest that the TB improves in the long-run with flexible and depreciated RER for both countries under analysis. Also, the GIR function reveals that the TB does not follow a J-curve pattern for both countries during the periods.

In Section 2 the literature review is developed. Section 3 contains the theoretical framework and suggested econometric methodology. In Section 4 it is described data set and empirical test are applied. Finally, in Section 5 Conclusions and Policy Implications are presented.

Figure 1.



Source: International Financial Statistics

1.2 Literature Review

In the theoretical field, the standard analysis of the effects of devaluations in the TB is based on the *elasticity approach* (e.g., see Robinson, 1947; Metzler, 1948), which describes the sufficient conditions for the improvement in the TB in terms of elasticties of demand and supply. If demand elasticity is sufficiently large and the supply sufficient small, devaluations should improve the TB. Khan (1974), Rittermberg (1986) among others, argue that for LDC's relative prices play an important role in the determination of trade flows, thus, devaluations as a path to improve the TB is expected.

Early studies bring mixed empirical evidence from developing and developed countries; Rose (1990 and 1991) and Ostry and Rose (1992) among others, found empirical evidences that relative prices do not provide significant and predictable impact in the TB, supporting that devaluations are likely to be ineffective in reducing trade imbalances and stimulating export growth. Also, Reinhart (1995) finds evidence that trade flows are significantly responsive to relative prices in developing countries, supporting that a nominal devaluation will improve the TB if it is transferred into a real devaluation. For instance, in the presence of an inflationary processes, the more indexed an economy is, the less likely devaluations will produce a real effect (Cooper, 1971). Regarding to the effectiveness of devaluations as a tool to improve the external accounts, Edwards (1989), studying devaluation episodes of Latin American countries finds that after the third year of devaluations, currencies appreciated by the effects of inflation, however, the current account was improved through time in almost all cases contrary what it is expected.

Recent empirical studies are focused in the examination in the long and short-run effects of devaluations in the TB. Magee's (1973) pioneer contribution supports that while exchange rates adjust instantaneously, exist a lag in the time by which consumers and producers take to changes in relative prices[1]. Thus, a favourable effect of the exchange rate depreciation in the long run is argued. The long run effect of devaluation in the TB is captured analyzing the ML condition and, the J-curve effects in the short run. According to the latter, devaluations improve the TB in the long run, but worsen it in the short-run. The initial deterioration occurs if the immediate effect of depreciation is to rise spending on imports, measured in local currency, by more than any initial increase in export revenues.

Regarding this paper, early studies conducting a wide diverse of econometric models and estimation techniques find evidence of the J-curve and verify the ML condition in developing countries (see Krugman and Baldwin, 1987; Bahmani-Oskooee and Malixi, 1992;

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[1] Two possible reasons of deterioration of the trade balance by devaluation effect are argued. On one hand, a short run deterioration in the trade balance by contract rigidities that take time to wear off; and second, there is a pass-through effect of currency depreciation on domestic prices which may not take place until some time has passed after devaluation. Thus, a favorable effect of the exchange rate depreciation in the long- run is argued.

Wilson 1993; Bahmani-Oskooee and Alse, 1994; Demirden and Pastine, 1994; Bahmani-Oskooee and Niroomand 1998; Boyd, Caporale and Smith; 2001). However, some authors find mixed results relating to the ML condition validity and the J-curve behavior of the TB (Hayne and Stone, 1982; Bahmani-Oskooee, 1985; Nolan, 1986; Marwah and Klein, 1996; Bahmani-Oskooee and Ratha, 2004).

Finally, Rose and Yellen (1989), Rose (1991), Upadhyaya and Dhakal (1996), Shirvani and Wibratte (1997) among others, have not found empirical evidence of the j-curve employing cointegration techniques.

In relationship with this paper, Kalyoncu, Ozturk and Artan (2009), found mixed evidence of the effects of devaluations in the short and long-run using Johanen-Juselius (1991) cointegration test and impulse response in a group of Latin American countries. For instance, only Argentina and Peru's cases present evidence of the J-curve behavior in the TB and the ML condition. In counterpart, Bustamante and Morales (2007) employing the cointegrated VAR model in Peru during the period 1991-2008 found no evidence of J-curve pattern, but the ML condition was held. Matesanz and Fugarolas (2009) find controversial results using VAR-based cointegration tests and impulse response functions to assess the long and short run effects of RER in the TB of Argentina during the period 1962-2005. After devaluation episodes, the TB has not followed the J-curve pattern and, paradoxically the ML condition held in the period of fixed and over valuated exchange rate. Mahmud (2004) finds that the ML condition holds when fixed exchange rate policies are implemented in developed countries.

From previous literature review, the findings reported for Latin American countries respect the short and long-run effects, named J-curve phenomenon and ML condition are inconclusive. The aim of this paper is to complement the existent literature.

1.3 Theoretical Framework

The interest in this paper relates to the dynamic response of the TB to devaluation episodes in a sample of Latin American countries. Some influential works are based on the use of structural demand and supply equations for exports and imports to estimate the effects of RER on the TB (see, e.g., Bahmani-Oskooee, 1985; Krugman and Baldwin, 1987). In this paper we follow the straightforward modelling introduced by Rose and Yellen (1989) and Rose (1990), named the partial 'reduced form equation' for the TB examination. This analysis does not distinguish between the price and volume effects. As Rose and Yellen pointed out, to determine the nature of the effects of RER in the TB in the short term, named the J-Curve phenomenon, the 'partial reduced form' equation is preferable than the detailed structural approach; thus, the TB dynamic is testable directly avoiding the identification and estimation of structural parameters.

Following Rose and Yellen (1989), the 'partial reduced form' equation for the TB takes the following form

$TB = B\,(E, Y, Y^*)$

Then, we begin defining the standard model specification for long-run demand function for exports (*X*) and imports (*M*):

$$X_t = \left(P/P^* \cdot E\right)_t^{\omega} \cdot \left(Y^*{}_t\right)^{\mu} \tag{2}$$

$$M_t = \left(P^* \cdot E/P\right)_t^{\varphi} \cdot \left(Y_t\right)^{\delta} \tag{3}$$

where *X* and *M* are the volume of exports and imports, respectively. *E* is the nominal exchange rate; *p, p** denote the domestic and foreign price levels and, *Y*, *Y** domestic and foreign incomes. ω and φ are the RER elasticities for exports and imports and μ and δ are the income elasticities for imports and exports.

Then, computing equations (1) and (2) in logarithms form, take the following form:

$$\ln Xt = \omega\left[\ln P_t - \ln P_t^* + \ln E_t\right] + \mu \ln Y_t^* \quad (4)$$

$$\ln Xt = \varphi\left[\ln P_t - \ln P_t^* + \ln E_t\right] + \delta \ln Y_t \quad (5)$$

where, $\ln e_t = \left[\ln P_t - \ln P_t^* + \ln E_t\right]$ is the natural logarithms of the RER and, the TB is defined as the ratio between exports and imports:

$$\ln TB_t = \mu \ln Y_t + \delta \ln Y_i^* + \psi \ln e_t \quad (6)$$

where, $\psi = -(\omega + \varphi)$. In the model, the coefficient on $\ln e_t$ indicates the long-run effects. For instance, if μ and δ are positive and, ω and φ negative, the ML condition holds whenever ψ is positive indicating that a higher RER (real depreciation) or negative, indicating lower RER (appreciation) appears to improve the TB in the long run.

Finally, it was considered the Rose and Yellen (1989) approach in this study due to restrictions imposed by data availability. The major concern of this paper relates to the dynamic performance of the TB of goods in periods of opposite monetary regimes.

1.3.1 Econometric Procedure

The methodological approach introduced in this paper entails the direct estimation of the non-structural equation in 6. We introduce the estimation techniques for the dynamics between the TB and the RER for the cases of Argentina and Brazil. The dynamic specification of the TB assumes to be related to the lagged values of RER and, additionally, the domestic and foreign income variables. Furthermore, due to the aim in this paper on the short and long-run effects of RER behaviour in the TB, error correction model is estimated.

The TB (*TB*) is defined as the ratio between exports of goods (*X*) to imports of goods (*M*), depending of the RER (*RER*) and the real domestic and foreign incomes (*Y, Y**). The RER is computed as the ratio of US consumer price index (*CPIusa*) to domestic consumer price index (*CPIn*) multiplied by the nominal exchange rate of the domestic currency with US Dollars. The national income (*Y*) and foreign income (*Y**) is defined as gross domestic product (*GDP*) volume in national currency and, the US GDP is taken as proxy of foreign output. The world income variable is included in the model in order to take account of the potential effects. All the variables are analyzed in its logarithmic form.

In order to find out a long-run equilibrium relationship among the variables under analysis, cointegration analysis is performed. Taking into account the 'partial reduced equation' form in (6) to model the TB dynamic, the long-run cointegrating relationship can be written in the following log-linear form:

$$\ln TB_t = \beta_0 + \beta_1 \ln Y_t + \beta_2 \ln Y*_t + \beta_3 \ln RER_t + u_t \qquad (7)$$

where u_t is the random error term and β_0 is a constant. Any positive value in the estimator β_3 ($\beta_3 > 0$) verifies the ML condition. In the estimation of β_1, it is expected to be positive ($\beta_1 > 0$) if an increase in the countries' incomes induces higher demand for imports and, a rise in foreign incomes induces an increase in countries' exports demand; thus, a negative estimate of β_2 is expected ($\beta_2 < 0$). The RER will improve or deteriorates the TB if the coefficient of β_3 will be positive or negative. It is assumed that a higher RER should improve the TB and, in counterpart, a lower RER will deteriorate it as it is commonly expected.

The variables are expected to be integrated in order 1 and, in order to determine a stable long-run relationship in the series and, the linear combination should be stationary in order 0. In other words, the linear combination of non-stationary data series in equation 7 is stationary.

With this purpose, we first test the stability of the VAR model running the univariate Augmented Dickey-Fuller (ADF) unit root test to examine the behaviour of each variable over time, determining whether the linear combination of non-stationary data series in equation (7) is stationary, thus, describing a non-spurious regression. Following the methodology, a necessary condition for the examination of the long-term relationship between the variables is to assess the order of integration of the time-series. In this regard, the next stage is to implement cointegration test in Johansen and Juselius (1989) to apply the maximum likelihood procedure to a VAR model. A cointegration test looks for stable long-run equilibrium relationships.

In testing the existence of long-run relationship require a *p*th-order structural and dynamic VAR model on the variables that, related to the Granger representation theorem, can be written as an unrestricted VECM up to *p* lags (Granger representation theorem):

$$\Delta x_t = \mu + \alpha z_{t-1} + \sum_{i=1}^{p} \Gamma_i \Delta x^*_{t-i} + \mu_t$$

in our case,

$$\ln TB_t = \alpha_0 + \sum_{j=1}^{p} \varpi_j \Delta \ln TB_{t-j} + \sum_{j=1}^{p} \lambda_j \Delta \ln Y_{t-j} + \sum_{j=1}^{p} \vartheta_j \Delta \ln Y^*_{t-j} + \sum_{j=1}^{p} \nu_j \Delta \ln RER_{t-j} + \eta \left[\ln TB_{t-1} - \hat{\beta}_0 - \hat{\beta}_1 \ln RER_{t-1} - \hat{\beta}_2 \ln Y_{t-1} - \hat{\beta}_3 \ln Y^*_{t-1} \right] + \varepsilon_t \quad (8)$$

where Δ is the first difference operator, and η provides information on the speed-of-adjustment coefficient to long-run equilibrium and, ε_t is a disturbance assumed to be white noise; *j* is the lag order and *p* is the maximum number of the lag length.

The error correction modelling denoted in equation (7) gives the short-run dynamic behaviour model of the TB using the estimate of past disequilibrium. In this equation it is looking for the pattern of dynamic adjustment that occur in the short-run to establish these long-run relationship in response to shocks in the system.

In this fashion, it is required the determination of the appropriate lag length of each variable by which it is used the Akaike Information Criterion (AIC) tests.

Next, regarding to the outcome of the unit root test, we test for cointegration by using Johansen and Juselius (1990) and Johansen (1991) maximum likelihood procedure that derives in two statistics tests in order to determine the number and estimation of cointegration vectors:

i) Trace statistic

$$\lambda_{trace}(r_0|k) = -T\sum_{i=r_0+1}^{n}\ln(1-\hat{\lambda}_i) \quad (9)$$

ii) Maximal-Eigenvalue statistic

$$\lambda_{\max}(n-1) = -T\ln(1-\hat{\lambda}_i) \quad (10)$$

Once the existence of cointegration between the variables is determined, we proceed to identify co-integration coefficients.

In the final step of the empirical analysis in this paper, we estimate the VECM to capture the transitional dynamics of the system to the long-run equilibrium. Then, it is applied the generalized impulse response function (GIR) in order to examine if shocks to RER induce the TB to follows a J-curve for each country. Following the J-curve theoretical assumptions, under competitive devaluations an initial deterioration in the TB is expected followed by an improvement in the long-run.

1.4 Data and Empirical Results

Quarterly data from the International Financial Statistics database by the International Monetary Found (IMF) is used for the analysis in this paper and covering the period 1990-2010 for four Latin American countries: Argentina, Brazil. For the case of Argentina, the RER was calculated based on additional data from the FIEL Foundation, more precisely, the domestic CPI*arg*. TB is constructed using Goods Exports and Imports: F.O.B end of period, in nominal USD terms. The National CPI indices are based on base year text 2005. The national and foreign income is real gross domestic product (*GDP*) in national currency in line (99.b.r).

1.4.1 Test for unit-roots

A necessary condition to test the long-run relationship with time series variables is first, to test the unit-roots in the variables included in reduced equation form. In this paper, we use Dickey-Fuller test in equation 6. We first test the augmented ADF test that involves the estimation of the following regression for each individual variable:

$$\Delta X_t = \alpha + \beta_t + \rho X_{t-1} + \sum_{i=t}^{m} \phi i \Delta X_{t-1} + \varepsilon_t \qquad (11)$$

where ε_t is the error term and *m* is (i.e., the number of lagged first-differenced term) is determined such that ε_t is approximately white noise. The null hypothesis that ΔX_t is a non-stationary time series translates into Ho: β_0 = 0. The null is rejected if β_0 is significantly negative. The sample periods for Argentina are 1990:1 through 2001:4 and 2002:1 through 2010:4; In the case of Brazil periods are 1990:1 through 1999:4 and 2000:1 through 2010:4. Critical values of rejection are also reported for all tests.

In table 1 are summarized the results in both periods under analysis and indicate the presence of unit roots of each variables in the periods for Brazil and Argentina. The ADF test is consistent with the hypothesis that unit root non-stationary characterizes each of the variables. For instance, *ln Y*, *ln Y** and *ln* RER contain unit-root I(1) in their levels form but not in their first differences form. The null hypothesis of a unit roots in the univariate representation cannot be rejected for any of the variables at reasonable significance level.

Once it is establish that series are I(1), we proceed to test for a long-run co-integrating relationship between ln *TB*, ln *RER*, ln *Y* and ln *Y** using Johansen (1998) co-integration test procedures.

1.4.2 Cointegrating VAR Analysis

Before undertaking cointegration tests, it is specified the relevant order of lags (ρ) of the vector autoregression model (VAR). To define the appropriated number of lags of the VAR model, it was selected on the basis of the Akaike (AIC) criteria in all samples. The results obtained from the Johansen and Juselius method are showed in table 2.

Results show that the best lag order in Argentina during the first period (1990 – 2001) is three years and one year for the second period (2002 – 2010). In the case of Brazil, the best lag order is one year for the first period (1990 – 1999) and two years for the second period (2000 – 2010).

Next, we apply Johansen and Juselius procedure to test the number and estimation of co-integrating relationship. Let *r* be the number of co-integration equations from zero to *k*-1, where *k*=4 is the number of endogenous variables in the model. The *trace statistic* tests the hypothesis of existence of *r* co-integrating vector (H0: r = a against the alternative HA: $r \geq$ a+1) while the *eigenvalue* tests the hypothesis of existence of *r* cointegrating vector against the alternative that r+1 exists (H0: r = a against the alternative HA: $r \geq$ a+1). In table 3, results suggest that the null hypothesis of none cointegration (r = 0) for the variables in equation 6 is rejected by the trace statistic test that confirms one cointegrated vector at 5% level of significance among the variables for the case of Argentina and Brazil in all periods.

Long-run elasticity estimates from the VECM and their standard error are reported in table 4 for *Y*, *Y** and *RER*. Setting the estimated coefficient ln*TB* at -1 we normalize the income variables and RER coefficients and, thus, the estimates of $\beta_1 - \beta_3$ indicate the long-run TB elasticities. Each cointegrating parameter (β_1, β_2 and β_3) measures the TB elasticity respect to the Argentina and Brazil's income, US income and RER, therefore, percentage change in the TB for one percentage point change in the explanatory variable.

During periods of appreciated RER in Argentina (1990 – 2001) the TB is negatively associated with domestic output and, during periods of flexible and depreciated exchange rate (2002 – 2010) the TB is positively associated with both, domestic and international output. In the case of Brazil, results are controversial; during periods before devaluation with more fixed appreciated exchange rate (1990 – 1999) than the preceding period, the TB is negatively associated with international output and, during periods of more depreciated and flexible exchange rate (2000 – 2010) the TB is negatively associated with domestic output and positively associated with international output. This performance could be interpreted in two ways, first, in figure 1 it can be notice that the RER has been highly appreciated while the TB become to deteriorate overtime. Second, while USA is one of the main Brazilian commercial partners, Argentina represent an important market for their exports and imports during the last decade, thus, would be suggested to test the Argentinean foreign income variable (Y^*) in the analysis.

Respect the relation between TB and RER the variables are positively co-integrated and, the elasticity coefficient in β_3 is positive and statistically significant at the 95% coefficient level during periods of more depreciated RER in both countries.

The results let us conclude that the ML condition is verified under depreciated exchange rate periods for Argentina (2002-2010) and Brazil (2000-2010). Regarding to the Brazilian TB's behaviour, our findings are opposite with Gomes and Paz (2005), by which the ML condition does not hold during the period of more appreciated exchange rate policy (1990 – 1999) suggesting that the TB does not improve under fixed exchange rate regime.

Concluding, the long-run approach to verify the ML condition in this paper, suggest that a flexible and depreciated RER policy improves the TB in the long-run for those countries.

1.4.3 Generalized Impulse Response Analysis (GIR)

To examine the J-curve pattern, the generalized impulse response function (GIR) of ln TB is calculated for a one standard-deviation RER innovation. For this purpose the information from Johansen's correction model and a one-time shock to the RER is traced. The results are reported in figures 2 and 3 for Argentina, and figures 4 to 5 for Brazil. With a competitive real depreciation an initial worsening in the TB by an improvement would give rise to J-curve effects. The effect arises because in the short-run price effects prevail and quantities adjustments dominate in the long-run.

In figure 2 the Argentinean GIR function for the period 1990-2001 shows no evidence of the J-curve pattern. The result shows an initial strong positive response to the exchange rate shock (improvement of the TB in the short-run). However, an improvement in the long-run prevails. This result proves that the ML condition is not verified during this period.

Surprisingly, in figure 3 for the period 2002-2010 it is showed a strong positive response to the exchange rate shock (improvement of the TB in the short-run) until the second quarter with a deterioration of the TB in the long-run. Again, this response proves that the ML condition is not verified in this period.

While the empirical evidence in this study suggests that depreciations improve the TB for Argentina in the short term, it must be notice that the RER suffered a strong real appreciation during the second period, achieving almost the same levels that previous period characterized by a currency board system (convertibility plan[2]). Thus, at any appreciation rate of the RER, a deterioration of the TB is expected.

In figure 4, evidence of the J-curve pattern was not found in Brazil during the period 1990-1999. With a competitive depreciation of the currency, an initial strong positive response to the exchange rate shock (improvement of the TB in the short-run) is showed and, a deterioration of the TB prevails in the long-run. Also, notice that during this period the ML condition was not verified, confirming the results in the GIR function. Figure 5 shows that evidence of J-curve pattern was not found in Brazil during the period 2000-2010, followed by a continuous improvement in the long-run.

Empirical evidence on the effects of devaluation on the TB in the short-run found no evidence of the J-curve pattern for Argentina and Brazil in all the periods under analysis using quarterly data. Also, the

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[2] The Convertibility Plan, introduced in April 1991, was designed to stabilize the economy centered on the use of a currency board-like arrangement, in which the peso was fixed at par with the U.S. dollar and autonomous money creation by the central bank was severely constrained.

generalized impulse response function (GIR) analysis shows mixed results in the long-run. Once verified the ML condition in Argentina and Brazil during periods of more flexible and depreciated exchange rate policies, the GIR analysis shows that the Argentinean TB deteriorates in the long-run.

Response of LnTB

One S.D. LnRER Innovation

Figure 2. ARG 1990-2001

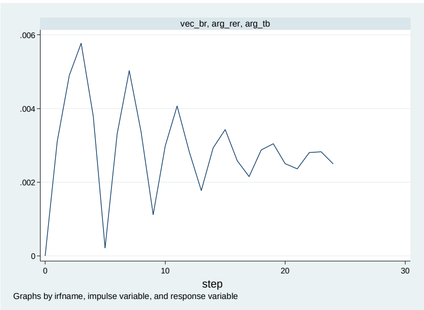


Figure 3. ARG 2002-2010

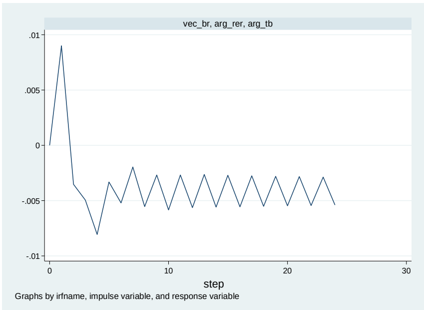


Figure 4. BRA 1990-1999

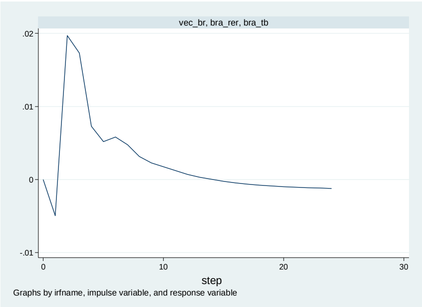
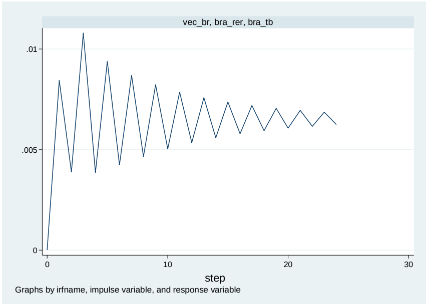


Figure 5. BRA 2000-2010



1.5 Conclusions and Policy Implications

In this paper was empirically examined the effects of fixed (flexible) and depreciated (appreciated) exchange rate policies on the trade balance in Argentina and Brazil. In light of the recurrent debate relating to the uses of competitive devaluations as a path to improve the competitive position of LDC’s, the opposite exchange rate policies practiced in Argentina and Brazil during the last two decades provide an opportunity to present new empirical insights.

To explore empirically this relationship, in the international trade literature the effects of devaluations on the trade balance has been traditionally examined in the Marshall Lerner condition and the J-curve framework. The ML condition holds if an improvement of the TB in the long-run takes place by the effects of devaluations. The J-curve pattern indicates deterioration of the TB in short-run and the improvement in the long-run. Applying VAR-based cointegration test and generalized impulse response function, it was verified that the ML condition held only in periods of more depreciated and flexible exchange rate policies for Argentina (2002-2010) and Brazil (2000-2010). By using the generalized impulse response function to find evidence of the J-curve pattern, we found that the TB of Argentina and Brazil has not followed the J-curve pattern of adjustment in none of the periods (1990-2010) and, evidence related to the long-run effects after an initial improvement on the TB is ambiguous. During the period of depreciated and flexible exchange rate policy in Argentina, the TB deteriorates in the long-run and, paradoxically, improves during periods of fixed and appreciated RER.

During periods of appreciated and fixed RER in Brazil (1990-1999) the TB of goods deteriorates in the long-run as it was expected, and improves in the long-run during the period of flexible and more depreciated exchange rate policy.

Concluding, the empirical evidence in this paper supports that flexible and depreciated RER improves the TB of goods in the short-run for this countries; thus, a strong appreciation of the RER should worsens the TB in the long-run.

As Reinhardt (1995) and Dornbusch (1996) pointed out, a nominal devaluation can improve in the trade balance only if it is transferred into a real devaluation. In the case of Argentina, the RER was highly appreciate during the period 2002-2010 by the effects of inflationary process[3] which would support the deterioration of the TB in the long-run based on the generalized impulse response function. The same effects would be expected in Brazil during the period 1990-1999, where the inflation rate achieves 1300% in 1993.

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[3] Annual inflation rate since year 2006 at date was calculated on 25% per year.

Based on our findings, we contribute with policy-makers sending a message of caution on the consequences to keep competitiveness policies based on exchange rate policies during long periods of time.

1.6 Appendix

Table 1. ADF-Testing for Unit Roots

Argentina		Brazil	
RER		RER	
1990-2001	-1,565 (lag=3)	1990-1999	0,131 (lag3)
2002-2010	-2,175 (lag=5)	2000-2010	0,141 (lag5)
TB		TB	
1990-2001	-1,998 (lag=1)	1990-1999	0,107 (lag4)
2002-2010	-1,953 lag(2)	2000-2010	0,204 (lag 5)
GDP		GDP	
1990-2001	-1,892 (lags=2)	1990-1999	0,196 (lag5)
2002-2010	1,213 (lags=4)	2000-2010	0,075 (lag 4)
GDP		GDP	
1990-2001	0,073 (lag=4)	1990-1999	0,169 (lag 5)
2002-2010	-1,680 (lag=3)	2000-2010	0,0628 (lag 5)

ADF: critical value at 5% = -2,904

Table 2. Selection Order Criteria

Argentina Period 1990-2001

	LL	*LR*	*df*	*ρ*	*EPE*	*AIC*	*HQIC*	*SBIC*
0	124,3				2,5	-6,2	-6,1	-5,99
1	190,5	132,3	16	0.000	1,9	-8,7*	-8,43*	-7,89*
2	214,5	47,93	16	0.000	1,3*	-9,2	-8,6	-7,61
3	227,5	26,1	16	0,05	1,6	-9	8,2	-6,78
4	242,5	30,02*	16	0,02	2	-8,9	7,9	-6,04

Argentina Period 2002-2010

	LL	*LR*	*df*	*ρ*	*EPE*	*AIC*	*HQIC*	*SBIC*
0	297,35				7.2	-14,3	-14,24	-14,14
1	418,44	242,19	16	0.000	4.3	-19,43	-19,13	-18,60
2	448,77	60,65	16	0.000	2.2	-20,13	-19,58	-18,63
3	508,01	118,48	16	0.000	2.8*	-22,24*	-21,43*	-20,07*
4	523,66	31,31*	16	0.012	3.2	-22,22	-21,19	-19,38

Endogenous variables: TB, GDParg, GDPusa, RER.

Brazil Period 1990-1999

	LL	*LR*	*df*	*ρ*	*EPE*	*AIC*	*HQIC*	*SBIC*
0	147,94				1,7	-6,54	-6,48	-6,38
1	289,77	283,6	16	0,000	5,6	-12,26*	-11,96*	-11,45*
2	310,73	41,9	16	0,000	4,5	-12,48	-11,94	-11,02
3	343,06	64,6	16	0,000	2,3	-13,23	-12,44	-11,12
4	362,99	39,8*	16	0,001	2,1	-13,40	-12,38	-10,65

Endogenous variables: TB, GDPbra, GDPusa, RER.

Brazil Period 2000-2010

	LL	*LR*	*df*	*ρ*	*EPE*	*AIC*	*HQIC*	*SBIC*
0	110,99				3,1	-5,94	-5,88	-5,76
1	278,16	334,3	16	0,000	7,0	-14,34	-14,03	-13,46
2	306,06	55,7	16	0,002	3,7*	-15,00*	-14,45*	-13,42*
3	317,82	23,5	16	0,101	5,2	-14,76	-13,96	-12,48
4	331,83	28,0*	16	0,031	7,0	-14,65	-13,61	-11,66

Endogenous variables: TB, GDPbra, GDPusa, RER.

Table 3.Johansen test for cointegration

Argentina Period 1990-2001

Rank	Parms	LL	Eigenvalue	Trace Stat	5% Critical Value
0	36	450,57	.	106,54	47,21
1	43	493,62	0,85	106,54	29,68
2	48	500,93	0,27	20,44*	15,41
3	51	503,21	0,09	5,81	3,76
4	52	503,84	0,02	1,26	

Brazil Period 1990-1999

Rank	Parms	LL	Eigenvalue	Trace Stat	5% Critical Value
0	20	274	.	73,13	47,21
1	27	296,6	0,69	27,84*	29,68
2	32	304,5	0,34	11,96	15,41
3	35	310,2	0,25	0,56	3,76
4	36	310,5	0,01	0	

Table 4. Johansen cointegration test results. Cointegration equation.

Argentina Period 1990-2001

beta	Coef	Std. Error	z	P> I z I	[95% conf. interval]	
TB	1	-	-	-	-	-
GDP*arg*	-2,19	0,60	-3,62	0,000	-3,38	-1,005
GDP*usa*	4,86	0,55	8,75	0,000	3,77	5,95
RER	-8,22	0,50	-16,1	0,000	-9,22	-7,2
Cons	-53,0	-	-	-	-	-

Brazil Period 1990-1999

beta	Coef	Std. Error	z	P> I z I	[95% conf.	Interval]
TB	1	-	-	-	-	-
GDP*bra*	0,042	0,009	4,68	0,000	-3,38	-1,005
GDP*usa*	-0,289	0,457	-0,6	0,527	3,77	5,95
RER	-0,275	0,154	-1,8	0,076	-9,22	-7,2
Cons	4,24	-	-	-	-	-

Table 5. Johansen and Juselius test for cointegration

Argentina Period 2002- 2010

Rank	Parms	LL	Eigenvalue	Trace Stat	5% CriticalValue
0	20	176,7	.	114,3	47,21
1	27	221,8	0,91	24,07*	29,68
2	32	230,4	0,38	6,85	15,41
3	35	232,6	0,11	2,45	3,76
4	36	233,8	0,06	1.26	

Brazil Period 2000-2010

Rank	Parms	LL	Eigenvalue	Trace Stat	5% Critical Value
0	4	255,37	.	68,78	47,21
1	11	277,73	0,63	24,08*	29,68
2	16	285,44	0,29	8,65	15,41
3	19	288,64	0,13	2,25	3,76
4	20	289,77	0,05		

Table 6. Johansen cointegration test results. Cointegration equation

Argentina Period 2002-2010

beta	Coef	Std. Error	Z	P> I z I	[95% conf. interval]	
TB	1	-	-	-	-	-
GDP*arg*	5,86	0,35	16,7	0.000	5,17	7
GDP*usa*	0,091	0,17	0,53	0,595	-0,24	0,43
RER	4,63	0,27	16,6	0.000	4,09	5,18
Cons	-70,3	-	-	-	-	-

Notes: The vectors are normalized for TB: *b*1, *b*2 and *b* 3 denote the argentine GDP, USA GDP and TCR elasticities of trade balance, respectively. Results carried out by STATA.

Brazil Period 2000-2010

beta	Coef	Std. Error	z	P> I z I	[95% conf. interval]	
TB	1	-	-	-	-	-
GDP*bra*	-0,89	0,28	-3,1	0,002	-1,46	0
GDP*usa*	2,01	0,31	6,34	0	1,39	2,63
RER	0,23	0,4	0,59	0,557	-0,55	1,02
Cons	-22,2	-	-	-	-	-

Notes: The vectors are normalized for TB: *b*1, *b*2 and *b* 3 denote the argentine GDP, USA GDP and TCR elasticities of trade balance, respectively. Results carried out by STATA.

2. Exchange Rate Uncertainty and International Technology Transfer*

(The chapter was carried out in co-authorship with Pedro Mendi)

Abstract

We propose an incomplete contract model of licensing of a cost-reducing technology. We incorporate exchange rate uncertainty and analyze its impact on the parties' investment and licensing decisions. Exchange rate fluctuations introduce a distortion between the licensor and the licensee's value for the technology. We show that exchange rate uncertainty introduces a distortion in the parties' specific investment decisions and could even prevent the transfer from taking place.

2.1 Introduction

The access to superior technology increases firm efficiency and is a source of growth in total factor productivity (see Mendi, 2007),

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which ultimately has a positive effect on growth. Furthermore, the use of a superior technology may bring about positive external effects, usually known in the literature as spillover effects. The existence of positive diffusion effects implies that the social benefits of technological imports exceed the private benefits to the importing firm. Thus analyzing factors that facilitate or hinder the acquisition of foreign technology is of relevance in the study of the determinants of a country's development.

This paper analyzes the role of a potential obstacle to the acquisition of foreign technology, namely exchange rate uncertainty. We propose a licensing model to study the impact of changes in the exchange rate as well as exchange rate uncertainty on a domestic firm's decision to purchase the right to use a cost-reducing technology. We assume that he effective implementation of the superior technology requires the undertaking of non-contractible investments by the licensor as well as by the licensee.

While the first-best contract involves the use of a fixed fee (no distortion in output decisions), variable payments must be included to provide the parties to the transaction and especially the licensor with incentives to make the non-contractible investments. Exogenous changes in the exchange rate, as well as exchange rate uncertainty may prevent the parties from undertaking the investments required for the correct transfer of the technology, which might prevent the transfer altogether.

Intuitively, exchange rate fluctuations introduce a wedge between the buyer and the seller's valuation for the technological transfer. For instance, the possibility of a devaluation of the domestic currency, reduce the value of the locally-generated revenues in terms of the foreign currency. If this problem is serious enough, the set of feasible contracts might be empty, in the sense that there is no fixed fee and/or royalty rate that both parties may find acceptable in order to transfer the technology.

Our model is based on that in Choi (2001), who analyzes technology transfer under moral hazard. In his model, licensor and licensee had to make non-contractible investments that increase the value of the technology to be transferred. Contract terms are thus chosen to provide the parties with the right incentives to undertake such costly investments. We adapt Choi's model to allow for fluctuations in the exchange rate. In our model, changes in the exchange rate occur in the interim between the licensor and the licensee's specific investment decisions. This fits the case of a transfer of technology where there is a relationship between the parties that extends for several years. Our results are also driven by the interdependence of the licensor and the licensee's decisions to undertake relationship-specific investments. In order for the licensee to enjoy a cost reduction, both the licensor and the licensee must choose strictly positive levels of investment. This contrasts with the assumption in Choi (2001) of additive effects of the licensor and the licensee's investment levels on the licensee's marginal cost if using the licensor's technology. Finally, notice that we do not assume risk aversion on either the licensor or the licensee's side, in contrast to Bousquet et al (1998), and yet increasing exchange rate uncertainty decreases the likelihood of technology transfer.

To the best of our knowledge, no papers have analyzed the effect of Exchange rate uncertainty on the international technology transfer process. There are some papers that study the impact of exchange rate fluctuations on investment and growth. For instance, Cottani et al. (1990) find a strong negative correlation across countries between real exchange rate instability and per capita income growth, using a sample of developing countries. Darby *et al* (1999) propose a theoretical model based on Dixit and Pindyck (1994) to find that there are situations where increasing volatility in the exchange rate negatively affects investment. Bleaney and Greenaway (2001) find that, for a panel of 14 sub-Saharan countries, investment is negatively affected by exchange rate instability. Servén (2003) also finds a negative effect of real exchange rate uncertainty on private investment, using a sample of developing countries.

Our paper thus stresses the importance of exchange rate stability to foster technology transfer. This conclusion could be potentially useful when designing policies, especially in developing countries. In fact, if a country has to rely on foreign technology to enhance its productivity, and exchange rate fluctuations hamper this process, then the government should seriously consider policies that produce exchange rate stability. The conclusions from the model that we present are against the case of a competitive devaluation. While such devaluation might bring about a temporary cost advantage that could boost exports in the short run, it would make the acquisition of technology harder, which has a negative effect on productivity and growth in the long run. It also introduces an additional factor to be taken into account when evaluating the benefits of a monetary union, or the potential costs of leaving an existing one.

The structure of the paper is as follows. We present the model in Section 2. In Section 3, we consider the case of a deterministic exchange rate. We introduce exchange rate uncertainty in Section 4. Finally, Section 5 discusses the implications of the model and introduces some concluding comments.

2.2 The model

Consider a domestic monopolist in the production of a given product. The monopolist faces a linear demand function $p = a - bq$, and has access to a technology that allows production to be carried out at constant marginal cost $c > 0$. There is also a foreign patentee, who owns a cost-reducing process technology. The use of the superior technology allows the licensee to produce at a cost $c(e,i) = c_F(1 - e \cdot i)$, where $e, i \in [0,1]$ are the licensor and licensee's normalized investment levels. Notice that the licensee cost function is such that $c(0,i) = c(e,0) = c_F, c(1,1) = 0,$ and $\frac{\partial c}{\partial e} \leq 0, \frac{\partial c}{\partial i} \leq 0.$ Hence, the licensee's production cost is zero if and only if the technology is transferred and both the licensor and licensee choose the maximum investment levels. Furthermore, we assume $c_F \geq c$. This cost function is intended to represent a situation where the technology is new to the licensee and an effective implementation of the technology requires costly actions on both sides. For example, technologies with an important tacit component are well represented by this cost structure: the licensee must increase its absorptive capacity, and the licensor must exert effort to make sure the licensee receives the right level of tacit knowledge.

The licensee's outside option is to use the existing technology, that is, to produce at cost c. We assume that the licensee must opt for one of the two technologies, which means that if it accepts the licensor's offer, the licensee can not switch back to the existing technology. Finally, let $\alpha(e) = \alpha \cdot e$ and $\beta(i) = \beta \cdot i$ be the licensor and licensee's costs per unit of investment.

Our model focuses on arm's-length transfers of the technology from the licensor to the licensee. Consider contracts defined by F and r, where F is a fixed payment, independent of output produced, and r is the royalty rate, which determine variable payments. We consider royalty rates as a fixed payment per unit sold, denominated in the domestic currency. We could extend our analysis by considering the case of variable payments as a percentage of the licensee's sales, or fixed payment per unit sold denominated in the foreign currency. All these payment schedules are widely used in actual contracts, see for instance Mendi (2005), or Vishwasrao (2007).

The exchange rate ρ is denominated in units of the foreign currency per unit of the domestic currency. Both the fixed and the variable payments are denominated in the domestic currency. We assume that there is parity between the domestic and the foreign currencies at time of contracting, and that this exchange rate is subject to variation prior to the licensor's choice of its relationship-specific investment e, but after the licensee chooses its investment level i. We assume away the possibility of the licensee borrowing in the first periods an amount equal to all future payments, converting them into foreign currency at parity, and making future payments as scheduled. Notice that this would eliminate the effect of exchange rate uncertainty. We assume that this is not feasible for the licensee either because of lack of credit market development in the licensee's country, or because the time span between the signing of the contract and the licensor's choice is long enough. Of course, relaxing these constraints would increase the likelihood of an efficient transfer of technology.

We assume that the licensor makes the licensee a take-it-or-leave-it offer, specifying contract terms F, r, where r is a fixed payment, denominated in domestic currency, per unit sold.

The timing of the game is as follows:

1. The licensor makes the licensee a TIOLI licensing contract offer F, r.

2. The licensee accepts or rejects the contract offer. If accept, the licensee pays the fixed fee F upfront. The licensee also chooses its investment in absorptive capacity i.

3. The exchange rate ρ is determined.

4. The licensor chooses its investment level e. The licensee's production costs $c(e, i)$ are thus determined.

5. Production takes place, and variable payments (if any) are realized as specified in the contract.

Notice that, the licensor makes its choice of specific investment $e \in [0,1]$ after observing the realization of the exchange rate ρ. As we will see below, this implies that the licensor might choose a zero level of investment if the realization of the exchange rate fails to reach some threshold level.

This assumption on timing is crucial in our results. If both parties could commit to choosing their investment levels before the exchange rate is observed, uncertainty would not have any effect, since both parties would make their decisions based on expected exchange rates. However, in our model an increase in variance increases the probability of the licensor not undertaking the required investment. We now proceed to analyze the licensor and the licensee's problems at the different stages, with and without exchange rate uncertainty.

2.3 Deterministic exchange rate

We begin our analysis by considering the simple case of a deterministic exchange rate. This is the particular case, which assumes that both parties know ex-ante what the relevant exchange rate will be.

The contract terms (F, r) must be such that both the licensor and the licensee have the incentive to undertake the level of investment required for the successful transfer of the technology.

Of course, in order for the licensor to choose a positive investment level, variable payments must be introduced. If all payments were fixed, the licensor's optimal effort level would be zero.

Given our assumptions on demand and cost functions, at stage 4, given r and i, the licensor's problem reads

$$\max_{e \leq 1} F \quad \rho \cdot r \frac{a - c_F(1 - ei) - r}{2b} - \alpha \cdot e$$

The solution to the licensor's problem at stage 4 defines an optimal investment function $e*(i, r)$. Notice that, given the functional form of the licensee's cost function, the licensor's revenues are linear in e, and so are its costs. Hence, the solution will be either $e=0$ or $e=1$.

Specifically,

$$e^*(i,r)=\begin{cases}0\ if\ \ i<\frac{2b\alpha}{prc_F}\\ 0\ if\ \ i\geq\frac{2b\alpha}{prc_F}\end{cases}$$

At the previous stage, the licensee chooses i anticipating the licensor's investment choice in the following stage. Thus, the licensee's relevant constraint is its acceptance constraint, i.e. that its profits if using the licensor's technology exceed those if using the existing one.

The licensee solves

$$\max_{i\leq 1} \quad \frac{(a-c_F(1-e*(i,r)\cdot i)-r)^2}{4b}-F-\beta\cdot i$$
$$s.t. \quad \frac{(a-c_F(1-e*(i,r)\cdot i)-r)^2}{4b}-F-\beta\cdot i\geq\frac{(a-c)^2}{4b}$$

The solution to the licensee's problem defines a function $i*(r)$ that the licensor takes into account when optimally choosing the royalty rate r. Notice that $\frac{\partial e}{\partial i}=0$ for $i\neq\frac{2b\alpha}{\rho rc_F}$. Furthermore, if $i<\frac{2b\alpha}{\rho rc_F}$, then $e*=0$, which also implies that $\frac{\partial c}{\partial i}=0$. Now, for $i\geq\frac{2b\alpha}{\rho rc_F}$, the licensee's gross profits are convex in i, which implies that the licensee will choose $i=1$ as long as its acceptance constraint is satisfied.

But notice that if $i*=e*=1$, the licensee's acceptance constraint becomes

$$\frac{(a-r)^2}{4b} - \beta \geq \frac{(a-r)^2}{4b}$$

which implies that a necessary condition for the licensee's acceptance constraint being satisfied is $r \leq a - \sqrt{(a-c)^2 + 4b\beta}$. This imposes an upper bound on the royalty rate that is acceptable to the licensee. Thus, the licensee's optimal investment function $i^*(r)$ (provided that the licensor adjusts the fixed fee F so as to satisfy the licensee's acceptance constraint) is

$$i^*(r) = \begin{cases} 0 \; if \;\; i < a - \sqrt{(a-c)^2 + 4b\beta} \\ 0 \; if \;\; i \geq a - \sqrt{(a-c)^2 + 4b\beta} \end{cases}$$

Finally, at stage one, the licensor's problem is

$$\max_{F,r\geq 0} F+\rho\cdot r\cdot \quad \frac{(a-c_F(1-e*(i*(r),r)\cdot i*)-r)^2}{4b}-\alpha-e*(i*(r),r)$$
$$s.t. \quad \frac{(a-c_F(1-e*(i,r)\cdot i)-r)^2}{4b}-F-\beta\cdot i\geq\frac{(a-c)^2}{4b}$$

Of course, the licensor will always make the licensee's acceptance constraint binding, provided that $e=i=1.$ Recall that, since $c_F>c,$ the new technology generates a lower value than the old one if either $e\neq 1$ or $i\neq 1.$ We can then express the fixed fee as a function of the royalty rate.

The licensor's problem then reads:

$$\max_{r\geq 0}\frac{(a-r)^2}{4b}-\beta\cdot i-\frac{(a-r)^2}{4b}+\rho\cdot r\cdot\frac{a-r}{2b}-\alpha$$
$$s.t. r\geq\frac{2b\alpha}{\rho r c_F}, r\leq a-\sqrt{(a-c)^2+4b\beta}$$

whose first-order condition reads

$$\frac{a-r^2}{2b}+\frac{\rho}{2b}\left[a-2r\right]\leq 0$$

which implies that an interior solution (ignoring the constraints imposed by the licensor and the licensee) is given by

$$r=a\frac{1-\rho}{1-2\rho}$$

Notice that if $\rho<\frac{1}{2}$, then the optimal (interior) royalty would exceed a.

On the other hand, if $\rho\in\left(\frac{1}{2},1\right]$, then the royalty would be negative. Furthermore, if $\rho<\frac{1}{2}$, the licensor's profits increase with r, whereas if $\rho>\frac{1}{2}$, its profits are decreasing with r. Notice that the licensor's constraint imposes a lower bound on the royalty rate, whereas the licensee imposes an upper bound on the royalty rate. Intuitively, the licensee must be high enough so that the licensor has the incentive to make the non-contractible investment, although it has to be low enough so that the licensee accepts the contract. Also notice that the licensor's constraint depends on the realization of the exchange rate, specifically introducing a negative relationship between the exchange rate and the royalty rate. Thus, the lower the exchange rate (expressed in terms of units of the foreign currency per unit of the domestic currency), the higher the royalty rate that the licensor will demand in order to make the relationship-specific investment.

Furthermore, $\lim_{\rho \to 0} \frac{2b\alpha}{\rho c_F} = \infty$, which means that the lower bound on the royalty rate goes to infinity as the exchange rate approaches zero. Since the licensee's constraint does not depend on the realization of the exchange rate, there will be a threshold value of the exchange rate, $\tilde{\rho}(r)$ such that for $\rho < \tilde{\rho}(r)$ there exist no value of r that implements the transfer of the technology. This leads to the formulation of the following proposition.

Proposition 1 *Absent exchange rate uncertainty, the transfer of technology will take place only if the realization of the exchange rate exceeds some threshold value.*

Proof. *From the licensor's incentive constraint, we have that, in order for it to choose* $e=1$, *it is necessary that* $r \geq \frac{2b\alpha}{\rho c_F}$. *On the other hand, in order for the licensee to accept the licensor's offer and choose* $i=1$, *it is necessary that* $r \leq a-\sqrt{(a-c)^2+4b\beta}$. *Since* $\lim_{\rho \to 0} \frac{2b\alpha}{\rho c_F} = \infty$, *there is always a value of* ρ *such that* $a-\sqrt{(a-c)^2+4b\beta} = \frac{2b\alpha}{\rho c_F}$ *and if* ρ *is below that level, there is no value of* r *that satisfies both constraints.*

For $\rho \geq \tilde{\rho}$, the licensor will choose r depending on whether its effect on its own profits is positive or negative. As we pointed out above, if $\rho > \frac{1}{2}$, the licensor's will choose the lowest r that satisfies the licensor and the licensee's constraints. If $\rho > \frac{1}{2}$, the licensor's choice will depend on whether the solution $r = a\frac{1-\rho}{a-2\rho}$ satisfies the two constraints. Specifically, if $a\frac{1-\rho}{a-2\rho} < \frac{2b\alpha}{\rho c_F}$, the licensee will choose $r = a\frac{1-\rho}{a-2\rho}$. If $\frac{2b\alpha}{\rho c_F} \leq a\frac{1-\rho}{a-2\rho} \leq a-\sqrt{(a-c)^2+4b\beta}$, then

$r = a\frac{1-\rho}{a-2\rho}$. Finally, if $a\frac{1-\rho}{a-2\rho} > a - \sqrt{(a-c)^2 + 4b\beta}$, then $r = a - \sqrt{(a-c)^2 + 4b\beta}$ and there will be no fixed fee.

2.4 Exchange rate uncertainty

We now take one step forward in our analysis and study the case of a stochastic exchange rate. Assume that the exchange rate is a random variable distributed according to a distribution function $G(\rho)$ on the interval $[\underline{\rho}, \overline{\rho}]$. Both the licensor and the licensee know this distribution function, although the licensor chooses its non-contractible investment levels after observing the realization of the exchange rate. This will allow it to make its choice conditional on the realization of the exchange rate. In contrast, the licensee must make its choice before the realization of the exchange rate is known. However, the licensee foresees the licensor's optimal behavior in the following stage and estimates the probability that the licensor chooses $e = 1$. The licensee incorporates this information in its computation of its own expected profits. We will see below that, holding constant the expected exchange rate, if the expand the range of variation of the exchange rate, the probability of efficient transfer might decrease, and it might even be the case that the contract is not signed, in the sense that there are no contract terms (F, r) that jointly satisfy the licensor and the licensee's constraints.

Relative to the case of no exchange rate uncertainty, the licensor's problem at stage four does not change, since it is able to observe the realization of the exchange rate, as well as the licensee's choice of i prior to making its choice of e. Thus, the optimal investment rule is the same as in the previous case. Notice that this implies that the licensee will choose $e = 1$ (provided that the licensee chooses $i = 1$) only if $\rho \geq \tilde{\rho} = \frac{2b\alpha}{rc_F}$.

Given the licensor's optimal investment rule, the licensee is able to identify two intervals of ρ, specifically $\rho < \tilde{\rho}$ and $\rho \geq \tilde{\rho}$. In the former interval, the licensor chooses $e = 0$ whereas in the latter, it chooses $e = 1$. Recall that the licensee chooses $i = 1$ if it chooses a positive investment level. This is the case if its acceptance constraint is satisfied when $i=1$, i.e. the licensee chooses $i=1$ if its expected profits exceed those if rejecting the licensor's offer:

$$\int_{\underline{\rho}}^{\tilde{\rho}} \frac{(a-c_F-r)^2}{4b} dG(\rho) + \int_{\tilde{\rho}}^{\bar{\rho}} \frac{(a-r)^2}{4b} dG(\rho) - F - \beta \geq \frac{(a-r)^2}{4b}$$

$$\frac{(a-c_F-r)^2}{4b} G(\tilde{\rho}) + \frac{(a-r)^2}{4b} (1-G(\tilde{\rho})) - F - \beta \geq \frac{(a-r)^2}{4b}$$

At the initial stage, the licensor chooses the royalty rate to maximize its own profits, subject to the licensee's acceptance constraint and to its own incentive constraint, which defines the threshold value $\tilde{\rho}(r)$. The licensor will always adjust the value of the fixed fee to make the licensee's constraint binding.

Then,

$$F = \frac{(a-c_F-r)^2}{4b} F(\tilde{\rho}) + \frac{(a-r)^2}{4b}(1-F(\tilde{\rho})) - \beta - \frac{(a-r)^2}{4b}$$

This way, we may write the licensor's expected profits as

$$E\pi^{lsor} = \frac{(a-c_F-r)^2}{4b} G(\tilde{\rho}) + \frac{(a-r)^2}{4b}(1-G(\tilde{\rho})) - \beta - \frac{(a-r)^2}{4b} +$$

$$+\int_{\underline{\rho}}^{\tilde{\rho}} \rho \cdot r \cdot \frac{(a-c_F-r)^2}{4b} dG(\rho) + \int_{\tilde{\rho}}^{\bar{\rho}} \frac{a-r}{4b} dG(\rho) - \alpha =$$

$$= \left[\frac{(a-c_F-r)^2}{4b} + r \cdot \frac{a-c_F-r}{2b} \cdot E[\rho | \rho < \tilde{\rho}] \right] G(\tilde{\rho}) +$$

$$+ \left[\frac{(a-r)^2}{4b} + r \cdot \frac{a-r}{2b} \cdot E[\rho | \rho < \tilde{\rho}] \right] (1-G(\tilde{\rho})) - \beta - \frac{(a-c)^2}{4b} - \alpha$$

Whether or not the licensor's technology is transferred depends on the existence of a royalty rate that satisfies the licensee's acceptance constraint and at the same time induces the licensor to choose $e=1$. In particular, the licensee's acceptance constraint is crucial. We observe that the licensee's expected profits if $i=1$ are a weighted average of its profits if the licensor chooses $e=0$ and its profits if the licensor chooses $e=1$, the weights being $G(\tilde{\rho})$ and $(1-G(\tilde{\rho}))$, respectively.

Therefore, the shape of the distribution $G(\cdot)$ matters when determining the licensee's expected gross profits if using the licensor's technology and undertaking $i=1$.

In particular, if under an alternative distribution $H(\cdot)$ it is the case that $H(\tilde{\rho})>G(\tilde{\rho})$, then the licensee's expected gross profits, holding r constant, decrease. Of course, the licensor will adjust the contract terms (F,r). If $F>0$, then the licensor will have to lower F. However, if the constraint $F\geq 0$ becomes binding, the licensor will be forced to reduce r. But notice that when the licensor reduces the value of r, it also lowers the threshold value $\tilde{\rho}$, thus reducing the probability of the licensor choosing $e=1$ at stage four. If the new distribution $H(\cdot)$ assigns a high enough probability to low realizations of the exchange rate, then it may be the case that there is no value of r that allows for the realization of the transfer. This is because, since the licensee's profits as a function of r decrease when the distribution changes in this way and since the licensee's expected gross profits are concave in $r,$ these gross profits may fall short of the reservation profits as the distribution changes.

We may summarize the previous discussion by means of the following proposition:

Proposition 2 *Given a distribution $G(\cdot),$ there is always an alternative distribution $H(\cdot),$ second-order stochastically dominated by $G(\cdot),$ with $E(\rho)$ being the same for both distributions. But such that there is no transfer of the technology if the distribution is $H(\cdot).$*

What the proposition implies is that, holding constant the expected value of the exchange rate, increasing variance reduces the probability of transfer. This is because the modification in the shape of the distribution assigns a greater probability to the extreme values of the discount factor, which reduces the licensee's expected profits and therefore makes it harder for its acceptance constraint to hold.

Recall that one of the assumptions in our model is that payments are made in domestic currency. An obvious extension in the analysis is to consider payments being made in the currency of the licensor’s country. If this is the case, exchange rate uncertainty would work in a slightly different way, but also introducing an impediment to technology transfer. Specially, increasing the variance of the distribution would increase the probability of the licensee not being to make the required payments, thus reducing the likelihood of the parties reaching the agreement. Again, lacking access to credit and hedging is crucial in the argument, and this situation most likely applies to developing countries. A similar argument would apply if considering other payment mechanism by which the licensor provides the licensee with some, although no full, insurance.

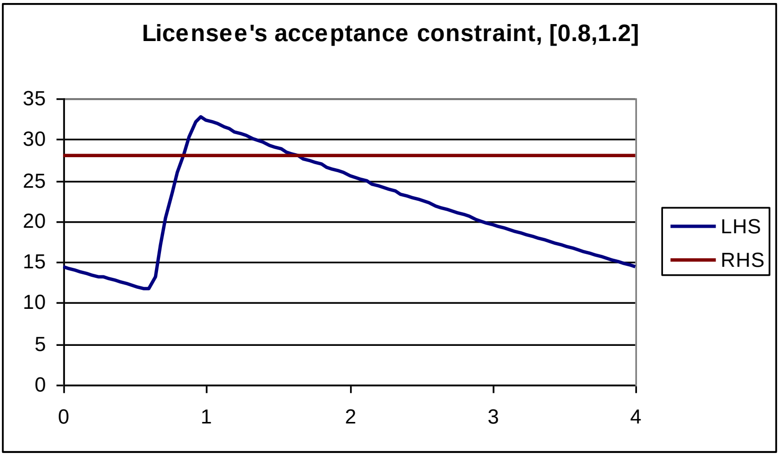
2.4.1 Numerical examples

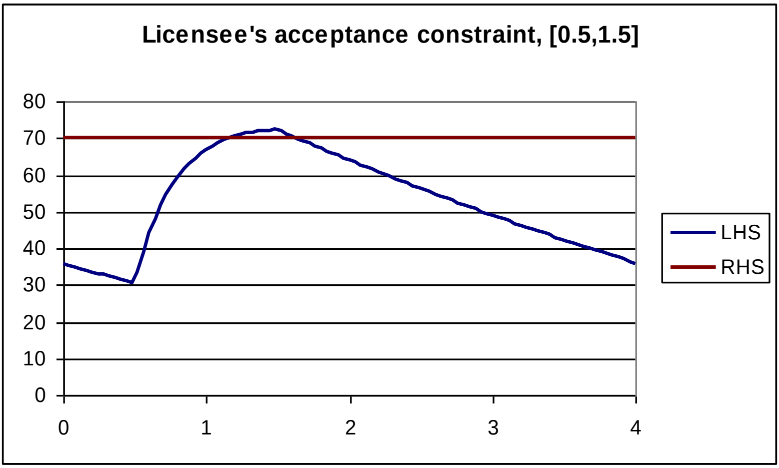
We will illustrate this analysis by means of some numerical examples. The purpose of this exercise is to show that an increase in exchange rate uncertainty may prevent the technology from being transferred, even if the expected exchange rate remains the same.

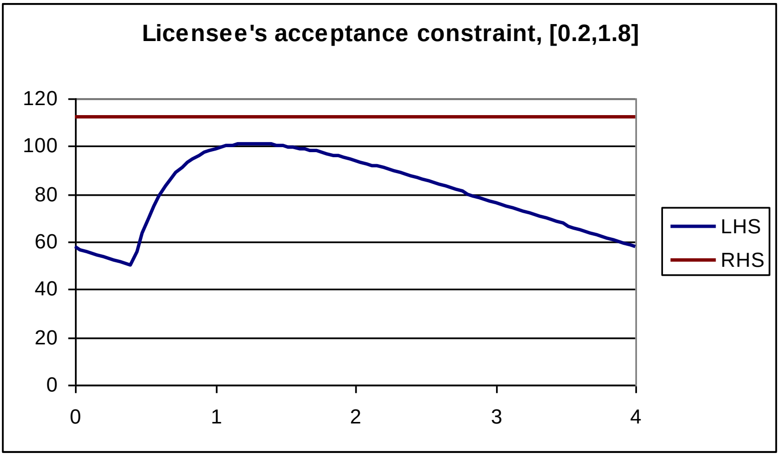
Assume that the demand function is $p = 10 - q.$ Costs are $c = 2$ and $c_F = 4.$ Recall that $c(e,i) = c_F(1 - e \cdot i),$ with $e,i \in [0,1].$ Further assume that $\alpha = \beta = \frac{3}{2}.$ With this parameters, and assuming no exchange rate uncertainty, the technology will be transferred as long as $\rho \geq \frac{1}{2}.$ For these realizations of the exchange rate, the licensor chooses a royalty rate $r = 1.633,$ which is the maximum consistent with acceptance by the licensee. If, holding everything else constant, we now set $\beta = 2,$ the royalty is $r = 1.515.$ If $\alpha = 2$ and $\beta \frac{3}{2},$ the technology is transferred only if $\rho \geq 0.65,$ and the optimal royalty is $r = 1.633.$ Notice that in all three cases, the technology is transferred if there is parity between the two currencies, i.e. if $\rho = 1.$

Let us now consider the case of exchange rate uncertainty, and consider the original levels of the investment costs, i.e. $\alpha = \beta = \frac{3}{2}.$ What we will do is to consider values of $\overline{\rho}$ and $\underline{\rho}$ such that

$E\rho = 1,$ given that ρ follows a uniform distribution on $[\underline{\rho}, \overline{\rho}]$. We will see that increasing the amplitude of the interval --and therefore the variance of the distribution-- will eventually make the transfer of the technology impossible. For instance, if $[\underline{\rho}, \overline{\rho}] = [0.8, 1.2],$ then royalties in the interval $[0.841,\ 1.601]$ will permit the transfer of the technology. Notice that the licensor's profits are increasing in the royalty rate, which implies that it will choose the highest royalty in the interval. If $[\underline{\rho}, \overline{\rho}] = [0.5, 1.5],$ the interval of feasible royalties is reduced to $[1.161,\ 1.601].$ Finally, if $[\underline{\rho}, \overline{\rho}] = [0.2, 1.8],$ there is no royalty rate that implements the technology transfer. This is because the licensee's acceptance constraint is not satisfied for any value of r. The evolution of the right-hand side and the left-hand side of the licensee's incentive constraint as a function of the length of the interval is displayed in Figures 1, 2, and 3.


Licensee's acceptance constraint, [0.8,1.2]
35
30
25
20
15
10
5
0
0
1
2
3
4
LHS
RHS


Licensee's acceptance constraint, [0.5,1.5]
80
70
60
50
40
30
20
10
0
0
1
2
3
4
LHS
RHS



2.5 Conclusions

We have presented a model to analyze the effects of exchange rate fluctuations on a firm's technological imports activities. The model assumes that it is necessary that both the licensor and the licensee exert some costly effort, so that the technology is efficiently transferred. The payment mechanism, which we have assumed to include an upfront fee, F, plus a constant per-unit royalty payment, r, must provide the parties with the incentives to undertake such investments. In particular, the royalty rate must be high enough so that the licensor has the incentive to make the relationship-specific investment, but it can not be too high to make the upfront payment negative.

The exchange rate plays the role of introducing a wedge between the licensor and the licensee's valuation for the technology. Initially, the exchange rate is known to both parties, and normalized to one. However, after the parties sign the contract, but before they make their relationship-specific investments, there is some variation in the exchange rate. Given this variation, and given the payment schedule stipulated in the contract, the parties might decide not to undertake the required investment.

We analyze first the case of deterministic exchange rates. By making use of the model, we find that the parties' incentive and acceptance constraints impose an upper and a lower bound on the realization of the exchange rate that would permit the transfer of the technology. In the case of stochastic exchange rates, we argue that there is always a degree of exchange rate variability that prevents the transfer of technology from taking place.

We believe that our model could be used as an argument in favor of exchange rate stability in countries that depend on foreign technology. The uncertainty introduced by exchange rate fluctuations may even keep profitable technological transfers from happening, which has negative consequences on domestic productivity and ultimately on growth. Furthermore, the lack of access to superior technology prevents the country from taking advantage of potential diffusion effects that the use of a superior technology might bring about.

There are a number of testable hypotheses that could be derived from our theoretical model. First, the transfer of know-how is associated with royalty payments, a result also suggested in Macho-Stadler et al (1996). Also, the transfer of know-how is most affected by exchange rate fluctuations, since it requires costly actions on the seller's side, as well as a minimum degree of absorptive capacity. Thus, within a country, know-how is most likely to be transferred between domestic firms rather than internationally. Additionally, the likelihood of international transfers of know-how increases with exchange rate stability. To see this, one could compare the ratio codified knowledge to know-how across different countries. The transfer of know-how also increases with financial development, access to credit, and the existence of instruments to hedge against exchange rate fluctuations.

3. Inflation and R&D Investment

Abstract

This paper explores the relationship between inflation, research and development (R&D) expenditures for a sample of Organization for Economic Co-operation and Development (OECD) countries. Data from 15 countries collected from 1981 to 2008 shows that inflation has a negative and highly significant impact on R&D expenditures. Moreover, the estimates made on the G-7 economies regarding periods of lower inflation rates as well as the countries that invested in R&D over the sample mean, revealed that inflation adversely affects R&D investment in low-and middle-income countries. Likewise, the findings in this paper suggest that only the most advanced economies are less affected by the behavior of inflation and, in particular, the public sectors when compared with the business sectors. These results have important implications for economic policy targeting inflation and promoting a sustainable economic growth.

Keywords: R&D investment; Inflation; Panel data evidence

3.1 Introduction

Since the Schumpeter's fundamental contribution (1942), economists in the field of industrial organization have been concerned about the determinants of technological progress at industry level. However, little attention it has received concerning the efforts devoted to explore the effects of size and market structure (Cohen and Levin, 1989).

Considering the above mentioned, this paper aims to complement the literature on research and development investment (R&D) by adding a macroeconomic variable that could affect the firm's ability to invest in R&D activities. Specifically, in this work we study the inflation effects on R&D investment behavior, a relationship that, up to the moment this paper was finished, has received little attention.

For instance, if wages are indexed at any current inflation rate, it is expected that firm’s optimal investment decision rule is affected by changes on future payoffs and operating costs. Hence, if in a country the inflation rate grows above the normal range, or shows evidence of an inflationary process, it will be reasonable to expect firms to take less risky options in the resource allocation strategies. As a consequence it may abandon an in-process-project, postpone R&D investment decisions, invest in more liquid projects or invest in other assets so as to maximize its profits and/or to ‘*protect*’ the value of the money.

In this sense, and considering the bibliography consulted up to this moment, although in the literature the inflation effects on investment have been widely discussed, positions about the effects remain mixed. Yet, this paper’s hypothesis is that inflation has adverse effects on R&D because of its special features. For instance, since R&D projects usually take long periods of time to be completed, uncertain returns on investment caused by unexpected inflation rates should encourage investors to postpone or to abandon these investments.

Empirical evidence has been obtained from the OECD Analytical BERD (ANBERD) database where the gross R&D expenditures in the business enterprise sector of a country, plus own loan assistance and overseas financing, as well as excluding government's investment. It is expected that the private sector be sensitive to the inflation variable behavior and, the inflation rate effect in public sectors is also analyzed in order to lie out a contrast between different types of investors. Indeed, it is expected a less sensitive behavior of the public sector over the inflation variable. Therefore, to study the public investments in R&D conducted by a country, the gross domestic expenditure on R&D (GERD) database has been included in the analysis. GERD data comprises all the costs incurred by various sectors, whether they were in business enterprise sectors, higher education programs, government policies, and non-profit entities projects. Both databases were used to compare the R&D investment made by both, the business sector and the government one. Fifteen OECD countries were studied during the period 1981-2008.

Results in the estimates on the selected countries, confirm that inflation variable adversely affected R&D investment in all specifications with a statistical significance in BERD and GERD databases. However, contrary to what it was expected, public sectors showed further deterioration in R&D investments indicators than the business sectors in all the specifications, and with strong statistical significance.

In addition, a new set of specific estimates was performed to verify the robustness of the initial findings. The results suggest that the G7 economies have a non-negative relationship between inflation and investment in R&D during the period 1981-2008. When the results were compared between BERD and GERD data, the empirical findings supported that GERD is higher than BERD. Furthermore, when there is an interaction between the lowest inflation rate period and the R&D investment the findings also suggest a non-negative relationship. Interestingly, results in GERD estimations had suggested a greater commitment in R&D investment than it was found in BERD.

Finally, and considering the studied sample, the inflation effect among those countries with higher investment rate is higher in the business sector than in GERD yet negative for both sectors. In sum, the results obtained could be interpreted as only the most advanced economies are less affected by the inflation behavior and, in particular, the public sectors respect to the business one.

Contribution to the field is given, precisely, because of this original approach that attempts to fill the gap found in the related literature because both the theoretical and empirical evidence for the relationship between inflation and R&D remain absent.

According to our rationale, inflation is expected to affect firm's incentives to engage resources in R&D projects. Mansfield (1969) defines a successful R&D project as the one that attains its technical objectives in the budgeted time and within the budgeted cost; otherwise it is considered to be a technical failure. Therefore, at any inflation rate, prices and resource costs movements committed to the investments become stochastic with implications on both, future payoffs and completion costs of a project.

Increased R&D investment may lead to technological breakthroughs, thereby furthering economic growth and prosperity (Sylwester, 2001). Likewise, a greater allocation of resources to R&D would increase future productivity, making the creation of new product process and new production techniques more efficient. Amendola *et al.* (1993); and Park (1995), among others researchers have found evidence that R&D has an important effect on productivity growth. Fagerberg (1995), in a sample of ten OECD countries empirically found that R&D had a higher impact on competitiveness and exports than investments on physical capital. Lichtenberg (1993), Goel and Ram (1994), and Gittleman and Wolff (1995), found that R&D expenditures were associated with growth for a larger group of countries. Likewise, Grossman and Helpman (1995), support the importance of R&D in the GDP growth and exports. Mendi (2007), explained a strong and significant effect of domestic R&D on local productivity in a sample of sixteen OECD countries during the period 1971-1995.

Finally, conclusions and discussions presented in this article could be used as guidelines for governments and policy-makers in order to design suitable economic policies needed to forecast and create an appropriate environment to boost investment in R&D, as it becomes a key element for any sustainable economic development agenda.

This work is organized as follows: Section 2) the literature that has explored different aspects of the relationship between inflation and investment is discussed; in Section 3) Data and summary statistics are presented. Following, in Section 4) the outlines of applied econometric specifications are explained. In Section 5) the corresponding results and robustness findings are discussed. Finally, in Section 6) a summary of the study conclusions, and their implications are presented pointing out the areas that call for further research.

3.2 Literature review

Relevant literature related to the effects of inflation on investment-decision behavior in order to shed some light on the likely impact of inflation on R&D investment is presented in this Section. Furthermore, previous contributions are discussed as they are related to main factors in R&D investment projects that would be directly affected by increasing inflation rates and, consequently, they could discourage economic agents to develop R&D investment.

In spite of the large theoretical and empirical contributions on the inflation effects on investment, little is known about the inflation effect over R&D investment behavior. Mansfield's (1980) pioneering contribution described how R&D projects would be affected by inflation. Mansfield suggested that inflation had a large impact on firms' R&D expenditure when it was combined with plants/factories, equipment, manufacturing, marketing and financial capabilities as it tended to discourage ambitious R&D projects, especially during price instability periods. Therefore, firms should invest in shorter-term programs with adequate projected returns. In this sense, Baldwin and Ruback (1982) modeled the effect of inflation on firms' investment decisions in fixed assets with different live spans. They concluded that given the uncertainty about future relative prices caused by inflation effects, the choice between different lived assets would be non-monotonic and, it would increase the value of shorter-live assets.

Based on the pioneer theoretical contributions by Arrow (1968); Arrow and Fischer (1974); Nickel (1978) as well as Henry (1974), among others, more recent theoretical and empirical research effort has been focusing on the investor behavior analysis when investments are irreversible; that is to say, firms incurring in sunk costs that could not be fully recovered if market conditions turn out to be worse than it was expected. Indeed, it is expected that an investor facing an irreversible investment has the option to delay an investment decision, waiting for the arrival of new information that might affect the expenditure timing —for more details, see McDonald and Seigel (1986), Dixit (1992), Pindyck (1991), and Dixit and Pindyck (1994). The real options approach improves upon traditional NPV-based investment appraisal method by allowing the delay value and the importance of flexibility to be quantified and incorporated into the analysis.

The influential work by Dixit and Pindyck (1994), examined theoretically the investment behavior under future price and return uncertainty when investments are irreversible by using the option-pricing method. In the model, there is an option to delay the investment decision under uncertainty until new and favorable information from market conditions arrives. For instance, the value of an investment opportunity today is compared to the value of investing in a future period, which is a random variable subjected to price fluctuation. Abel *et al.* (1996) developed a more general option model of irreversibility, embodying the ‘call’ and the ‘put’ option. Carruth *et al.* (2000), explained the symmetric treatment of this two options could lead to ambiguous predictions due to the uncertain effect over irreversible investment.

Following this approach, R&D investment is irreversible given the number of its unique features. Therefore, firms' profit functions are to take into account the form of uncertainty, namely, economic uncertainty over the project future profitability and the technological uncertainty over the success of R&D investment itself (Weeds, 2002). Eventually, depending on R&D projects, firm's R&D investments are predominantly the payment to highly trained scientists, engineers and other specialists, whose salaries could constitute a sizable percentage of total expenditure (Himmelberg, Petersen, 1994; Hall, 2002). These projects involve specific physical capital, personnel and, as Pindyck (1991) pointed out, R&D investments are firm specific. Thus, we could expect uncertainty over future payoff as well as cost uncertainty due to the effects of inflation that should increase the option value probability to delay R&D investment decisions. In this regard, Pindyck (1992), examined irreversible investment decisions when projects take time to be completed and are subject to two stochastic types of cost uncertainty: technological and input cost uncertainty. In his model, it is showed that cost uncertainty has the strongest effects over the investment rule and in the value of the investment opportunity.

Friedman (1977) argued that increased inflation volatility makes market prices to be a less efficient system for coordinating economic activity and whose fundamental function is to transmit the information needed to decide how resources are to be employed at a lower cost. In contrast, Tobin (1965), Hartmann (1972) and Abel (1983) supported that increased uncertainty could raise the marginal profitability of capital and, thus, increase investment. Serven and Solimano (1993), examined investment behavior after inflation crisis and found a slow investment response to changes in inflation rates as a consequence of uncertainty in the economic climate; therefore, investor's behavior was to wait for stabilization to invest. Likewise, Fischer (1993) found inflation negative effects on investment with strong statistical significance arguing that uncertain inflation distorted price signals, real wages and the return rate on physical investment. Pindyck and Solimano (1993) explored both the irreversibility and uncertainty empirical relevance for aggregate investment behavior and found that inflation was the only economic risk *indicia* that strongly explained investment. Greene and Villanueva (1991) found similar results examining private investment in less developed countries (LDC's), supporting the idea that inflation increases the risk in longer-term investment projects by distorting the information content of relative prices. Huizinga (1993) examined inflation uncertainty effects in the U.S. resource allocation in manufacturing sectors. He supported empirical evidence to hold the conclusion that higher inflation uncertainty raises uncertainty over an investment project net present value (NPV); therefore, firms delay a project investment until the uncertainty decreases or until the expected payoff from the project increases above the perceived higher uncertainty. Bruno and Easterly (1998) found empirically that capital growth declines during periods of inflation crisis but investment on GDP ratio does not recover afterwards, arguing that the slow response is due to uncertainty and the lack of credibility created by inflation. As a result, investors wait to observe the temporal inflation behavior.

As Pindyck (1991) pointed out, the irreversibility condition makes investments sensitive to diverse forms of risk, not only uncertainty on product prices and operating costs that determine a project return , but also those forms related to macroeconomic variables affecting the investor's behavior. Thus, if uncertainty over the economic environment is high, economic instability depresses investment. Ingersoll and Ross (1992) examined irreversible investment decisions when the interest rate evolves stochastically and they showed that in an uncertain economy, most investments projects have option rights values, even in the case of projects with little or no uncertainty about their cash flows.

Goel and Ram (2000) conducted an empirical study over the irreversibility uncertainty effect on R&D, non-R&D and aggregate investments following Pindyck and Solimano (1993) model and they gave evidence to support macroeconomic variables as uncertainty measures having major effects on R&D investment.

It is evident the study field of the specific relationship between inflation and R&D has been neglected. Such situation has provoked the present analysis, looking forward to fill the gap in the related literature. Precisely, this paper presents evidence about the inflation effects on R&D and, in addition, it complements the empirical literature on R&D investment determinants, involving public and/or private sectors.

The before mentioned literature provides mixed results regarding the proposed relationship; however, the conclusions were obtained from the investment behavior on private businesses. Finally, because of the character of this study as well as the availability of data, the panel data technique was suggested in the econometric analysis within a range of OECD countries.

The next section provides further details on the data used to run the suggested analysis.

3.3 Data and summary statistics

3.3.1 Data

Data explored in this study are based on annual R&D expenditures ratio to GDP and inflation rates —measured as the annual percentage change in consumer price index— on country-level data for the period 1981-2008. The sample includes fifteen OECD countries: Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Ireland, Italy, Japan, the Netherlands, Portugal, Spain, the United Kingdom and the United States. It is important to point out that the database used does not include any low-income countries because there is no available data of R&D investment for less developed countries.

For the estimations, the OECD Statistical Compendium database was selected since it enables to retrieve the most complete information on the variables under analysis during the selected time frame. The data on R&D investment on GDP was retrieved from the OECD's Science, Technology and Industry Outlook, which is included in the Main Science and Technology Indicators database showing the overall spending on R&D calculated as a percentage of the country GDP. Estimations in this paper were computed using the BERD and GERD databases in order to include all the public and private investment in R&D carried out on national territory in the year concerned. In this regard, the GERD's data analysis was included in the regressions so as to obtain a wider appreciation of the R&D investment behavior. In fact, governments are one of the sources of R&D funding for private sectors, such as military expenditure.

On one hand, the gross domestic expenditure on research and development (GERD database), covers all the R&D expenditure performed in a country. GERD data includes the amount of the costs incurred by various sectors such as the European Bank for Reconstruction and Development (EBRD), Higher Education Research and Development (HERD), Government Expenditure on

Intramural R&D (GOVERD), and Non-Profit Organizations (PNRD). On the other hand, the business enterprise sector was analyzed by the Business Enterprise Research and Development Database (BERD). In BERD, it is presented the annual data on gross R&D expenditures, data which was broken down in 60 manufacturing and services sectors excluding government, financed R&D and including, own development and overseas financed one.

We expect to find evidence of a negative relationship between both variables, that is to say, a decreasing level of R&D investment during periods of increasing inflation rates for both databases. If this hypothesis were confirmed, it would highlight the influence and importance of inflation variable on this specific form of investment. However, the R&D inflation negative impact is expected to be greater for less developed countries rather than for high-income nations. Developing countries generally experienced higher inflation rates compared to the rates in developed countries. Thus, if an adverse effect of inflation on R&D investment is expected, it is assumed a higher sensitiveness effect in developing countries and, if the study actually finds evidence to support its main hypothesis, these results may be extrapolated to other middle and low-income regions.

The inflation rate data are the annual percentage changes in the Consumer Price Index (CPI), and it was obtained from the OECD Economic Outlook database.

One of the main advantages of the use of these databases is that it allows the R&D disaggregates the public and private investment and the R&D investment nature. Likewise, its corresponding behavior during periods of high inflation could be known. Certainly, it is assumed that incentives to invest will differ between public and private economic agents facing uncertainty or higher inflation rates. For instance, Griliches (1995) suggested that the differential over the returns on tangible capital investments observed at the private level could reflect individual firms' perceptions of especially high private risk in the R&D case. However, government's expenditure on R&D activities involved in this ratio would not be affected by changes in inflation. For example, governments used to sponsor some R&D projects and programs related to public aerospace and national defense. In a sample of 74 high and low-income countries proposed by Lichtenberg (1993), private R&D expenditure contribute to economic growth, while government R&D expenditure had not a positive impact in economic growth, even a negative one according to his estimations. Also, Park's (1995) findings supported the idea that public R&D expenditure had a negative association with domestic productivity growth.

Unfortunately, the OECD data on R&D investment used in this research has some limitations that should be taken into account when interpreting the estimation output. For instance, the information on R&D investment is not disaggregated into different types of R&D projects. R&D projects usually involve both, tangible and intangible capital investment and a wide array of mix expenditures. Thus, it is assumed that some projects are less affected by inflation changes than others. Therefore, in this study it could be spelled out the impact of inflation rates on the different specific types of R&D investment. More precisely, if an economy indexes wages according to its inflation rate, R&D projects that are intensive in labor should be more affected than those other projects that are more intensive in machinery expenditure.

However, given the available information, the database used for this study is an appropriate proxy of the general R&D investment behavior and a suitable sample for the purpose of this research.

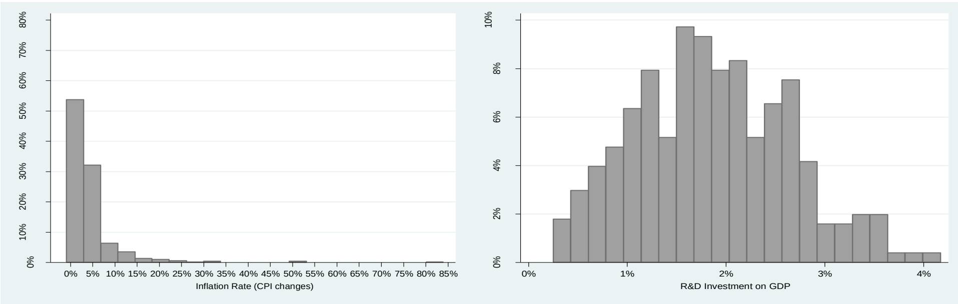
3.4 Summary statistics

Based on 15 countries panel data from 1981 through 2008, Table 1 (see appendix) displays the descriptive statistics for the variables at stake. First of all, it is important to highlight that inflation rates present a higher fluctuation than the share of R&D investment over GDP. Only 3 countries exhibit periods of high inflations rates, as it is the case of Iceland —with 85% annual change in the CPI in 1983—, Portugal —with 28,88% in 1984— and Ireland —with 20,37% in 1981. For these countries, only Iceland reached an inflation mean of 15% during the entire period, the rest of the countries have experienced an inflation mean below the two-digit threshold, which is considered to be low inflation. Furthermore, as it is shown in Figure 1, the average annual inflation rates were high for almost all the countries in the sample at the beginning of the 1980s, and they declined to a one single-digit rate from 1985 to 2008. It is interesting to see that R&D investment as a share of GDP increased overtime while, overall, the inflation rate decreased.

Figure 1 shows that 85% of the observations of inflation rates ranged under the value of 5%, while less than 8% of the observations exceeds double-digit inflation rate.

Therefore, at such level of inflation rates in the countries sample, it should be expected a growing level of R&D investment over time.

Figure 1.



3.5 Econometric procedure

The relationship between R&D investment behavior and inflation changes, for a sample of fifteen OECD's countries during the period 1981-2008 has been explored in this work. Since, we also have observations for the same 28 time periods for all the cross sections, we have a balanced panel.

The econometric procedure used in this paper, is as follows. First the baseline OLS model was estimated. Then, the same sample was used to implement the FGLS (Feasible Generalized Least Squares) estimator, which would be a suitable econometric procedure in the presence of dissent. Furthermore a panel data country fixed effect (FE) estimation method was implemented, enabling to account for the specific heterogeneity of the countries under study.

The FE methodology is appropriated for this study because it accounts for unobservable factors that could influence R&D investment decisions. For example, market conditions influencing R&D investment decisions such as technological opportunity and appropriability. Also, governments' incentives such as fiscal treatments and R&D subsidies have a strong influence on the dynamics and determinants of R&D investment from business firms, and, in general, any country-specific factor that is time-invariant.

Furthermore, in order to mitigate any potential endogenous problem between R&D and inflation, the inflation variable is lagged one period in the estimates. Finally, we perform several interactions of the inflation variable were performed in order to check the result robustness.

3.5.1 The model

The panel data within estimation econometric specification takes the following form:

$$R\&D/GDP_{it} = \alpha + \beta \cdot INF_{it} + \eta_i + u_{it} \qquad (1)$$

where, $R\&D/GDP_{it}$ is the annual R&D expenditure as a share of GDP for country i at time t and INF_{it} is the corresponding annual inflation rate expressed as the percentage change of the CPI. η_i is the country-i fixed effect and u_{it} is an idiosyncratic error.

Given the rationale detailed in previous sections, we expect a negative relationship between INF_{it} and $R\&D/GDP_{it}$ —i.e. $(\beta < 0)$— since a country with increasing inflation rates is expected to deteriorate its R&D investment ratio.

To ensure that the FE model is efficient, we tested if the idiosyncratic errors term u_{it} had a constant variance across t and no serial correlation. In this study we applied Wooldridge's test (2002) developed by Drukker (2003), based on the residuals from OLS estimation of the first difference of equation (1).

$$y_{it} - y_{it-1} = (X_{it} - X_{it-1})\beta_1 + \varepsilon_{it} - \varepsilon_{it-1} \tag{2}$$

$$\Delta y_{it} = \Delta X_{it}\beta_1 + \Delta\varepsilon_{it}$$

where Δ is the first-difference operator.

We also ran the Wald-test for heteroskedasticity robust standard error to potential unknown variance and covariance properties of the errors and data.

We tested the null for heteroskedasticity

(H_o = heteroskedasticity) that $\sigma_i^2 = \sigma^2 \quad i = 1, \ldots, N_g$,

where N_g is the number of cross-sectional units.

The Wald-test statistic can be computed as follows:

$$W = \sum_{i=1}^{N_g} \frac{(\hat{\sigma}_i^2 - \hat{\sigma}^2)^2}{V_i} \tag{3}$$

If heteroskedasticity problem is found, in order to obtain consistent estimator it will apply FGLS estimator that is widely used in the literature for solving the autocorrelation and heteroskedasticity problems that arise in panel data studies (Beck and Katz, 1995). Then, the FGLS estimator is defined by

$$\hat{\beta}_{FEGLS} = \left(\sum_{i=1}^{N} \ddot{X}_i' \hat{\Omega}^{-1} \ddot{X}_i \right)^{-1} \left(\sum_{i=1}^{N} \ddot{X}_i' \hat{\Omega}^{-1} \ddot{y}_i \right) \tag{4}$$

3.6 Empirical results and discussion

Table 2 shows the estimative results for the econometric specifications detailed in the previous section for BERD and GERD database.

According to the serial correlation test, the null hypothesis of no serial correlation is strongly rejected by the Fisher statistic (Prob > F = 0,000). We also confirmed the existence of heteroskedasticity problem in the data. Thus, the serial correlation and heteroskedasticity must be accounted to obtain efficient and robust estimators. In order to obtain consistent estimator, we applied FGLS estimator.

Column (i) exhibits the results of an OLS estimation, column (ii) includes one period lagged regressors for the inflation variables. The estimated coefficients are of the expected sign across all the econometric specifications. Hence, our results are strongly robust even after controlling for heteroskedasticity and serial correlation problems (column iv), any omitted variable bias (column iii) or accounting for potential problems of endogeneity (column ii).

Table 1 shows that there exist a negative and highly significant relationship between inflation and the share of R&D in the GDP of a country. According to the OLS and FGLS estimations from business enterprise sectors, a five percent point increase in inflation would drop the share of R&D to GDP by 0,19%. In economic terms, and considering the current 2011- USA’s GDP level, this would imply a loss of 28,86 billons of US dollars in R&D.

It is important to highlight that, in comparison to the OLS, the magnitude of the estimated inflation coefficient shrinks as we run a country fixed effects estimation and we correct for any potential problem of endogeneity, even though the level of significance remains at 1% level. In this setting, a five percent point increase in inflation will drop the share of R&D to GDP by 0,10% - 0,11% depending on the specification. Considering the previous USA's example this would entail an average loss in between 15,08 – 16,58 billons of US dollars in R&D.

Furthermore, as we move from OLS estimation to country fixed effects estimation including the mentioned instruments, the R^2 increased considerably, from 16,45% to 71,10%. This means that for the econometric specification in column (ii) a fairly large percentage of the within-country variation for R&D expenditure is explained between countries variation in inflation changes and, relatively little is explained within-countries.

Also, applying the same exercise performed above and based on all R&D carried out on national territory (GERD), that is to say, public and private R&D investment, a five percent point increase in inflation will drop the share of R&D to GDP by 0,23% according to the OLS and FGLS estimations. Again, considering the current 2011-

USA´s GDP level, this would imply a loss of 35,27 billons of US dollars in R&D. The country fixed effects estimation and the specification that correct for any potential problem of endogeneity suggests that a five percent point increase in inflation would drop the share of R&D to GDP by 0,12% - 0,16% depending on the specification. Considering the previous example of USA in 2011, it could be expected an average loss between 18,09 – 24,12 billons of US dollars in R&D.

As in the business enterprise sector analyzed in this study, while we move through OLS estimation toward country fixed-effects estimation including the mentioned instruments, the R^2 also increases from 14,87% to 74,33%. This results support the fact that for the econometric specification in column (ii) most of the variation for R&D expenditure is between countries and, again, relatively little is explained within-countries.

FGLS estimator in column (iv) serves to account for problems of heteroskedasticity and serial correlation, as it was detected using Wooldridge and Wald tests respectively for both databases. The resulting estimators were efficient and allowed for conditional heteroskedasticity in the errors and serial correlation. As it was expected, we found a negative association between increasing inflation and the ratio of R&D investment on GDP even after controlling for heteroskedasticity and serial correlation. Thus, we can confirm the negative effects of inflation on R&D investment behavior in the sample of selected countries. However, in spite of the negative sign in the coefficients showed in the estimative, they are relatively low in absolute values. For instance, the annual mean of inflation for the period is 4,66 percent point with a standard deviation of 6,81 percent point (see Appendix 1) where, one single-digit inflation rate could be interpreted as a relatively low-inflation rate. Therefore, it makes sense that during periods of lower inflation rates, a minor impact on R&D investment is expected.

Also, the applied methodology does not allow us to explore if R&D investment was retarded after periods of higher inflation rates. In this regard, Rodrik (1991) pointed out simplest models of investment with irreversibilities are difficult to implement empirically. Consistent with our assumption, cross-sectional analysis would be hampered by the absence of data on private investment levels in developing countries.

Interestingly, even though the estimated coefficients on BERD database (Business to business sectors) showed the expected behavior with respect to the initial hypothesis, the estimated coefficients computed on the GERD database have presented the greater negative impact of inflation on investment in R&D. In other words, at any increasing percentage point in inflation rate in a country, the government's commitment to invest in technological breakthrough is affected negatively.

Table 1. Regression output

	BERD				GERD			
Variables	(i) OLS	(ii) FE	(iii) FE	(iv) FGLS	(i) OLS	(ii) FE	(iii) FE	(iv) FGLS
Inflation	-0,0383***	-0,0186**	-0,02063***	-0,0383***	-0,0468***	-0,0243**	-0,0319***	-0,0468***
	(-4,31)	(-3,75)	(-5,09)	(-9,80)	(8,55)	(-3,5)	(-6,94)	(-9,51)
Inflation_L1		0,0077**				0,0090**		
		(2,18)				(1,85)		
Constant	1,2957***	0,3590**	1,2132***	1,2957***		1,9711***	1,9479***	2,0175***
	(27,91)	(3)	(73,59)	(52,49)		(83,31)	(90,66)	(49,56)
Observations	420	419	420	420	420	419	420	420
Number of Countries	15	15	15	15	15	15	15	15
Country FE		Yes	Yes			Yes	Yes	
R^2	0,1862	0,7110	0,1645		0,1487	0,7433	0,2489	
Serial Correlation Test								
Wooldridge Test			Prob > F= 0.000				Prob > F=0.000	
Wald Test Prob > chi2			0				0	

Country fixed effects have been included in all specifications. Dependent variable is Inflation rate.
*** Significant at 1%; ** significant at 5% level; * significant at 10% level

The results in this paper open up new questions concerning the development agendas of the countries and their link to investment in R&D. However, those questions lie beyond the scope of the analysis at stake, and they should be tackled in future research studies.

In short, our estimation output suggests that inflation has a negative and significant impact on R&D investment in both, public and private investors. However, verified the relationship between variables using country fixed effects, the following section will attempt to determine if the results are consistent by using new interactions. For instance, databases allow estimating the effects of inflation on R&D investment between G7 and non-G7 countries. Also, the relationship can be estimated during periods of high and low inflation and, finally the effect of inflation on those countries with the highest rates of R & D respect to the sample mean.

In the next section we perform several robustness checks to guarantee the validity of the results in this section.

3.6.1 Robustness check

In the previous section, the initial hypothesis of negative effect of inflation variable on R&D investment was proved in our sample across the different econometric. In this subsection, we run several checks in order to verify the robustness of these results. In particular, three cross product variables are added to equation (1): i) the interaction of a dummy for countries with higher R&D/GDP with the inflation variable; ii) the interaction of a dummy for the G7 countries[§] with the inflation variable as in Coe and Helpman (1994) and Mendi (2007) to check if the effect of inflation on R&D investment is stronger than in non-G7 countries and; iii) the interaction of a time dummy for the second half of the sampling period with the inflation variable. These additional cross product regressors will enable to account for different sources of heterogeneity that may have influenced the observed negative impact of inflation on R&D, which is outlined in the estimation output shown in Table 2.

The corresponding econometric specifications take the following forms:

[§] G7 countries are: Canada, France, Germany, Japan, Italy, UK and US.

$$R\&D/GDP_{it} = \alpha + INF_{it}\beta + High\_R\&D * INF_{it} + \eta_i + u_{it} \qquad (5)$$

$$R\&D/GDP_{it} = \alpha + INF_{it}\beta + G7 * INF_{it} + \eta_i + u_{it} \qquad (6)$$

$$R\&D/GDP_{it} = \alpha + INF_{it}\beta + Time\_Period * INF_{it} + \eta_i + u_{it} \qquad (7)$$

where *High_R&D* is a dummy variable that takes the value 1 if the country exhibits high levels of R&D investment, and 0 otherwise, *G7* is a dummy that is equal to 1 for countries included in the G7 group, and 0 otherwise, and *Time_Period* is a time dummy that takes the value 1 for years in the second half of the period sampling, and 0 otherwise.

The results of the estimation of equations (5) through (7) are shown in table 3. As expected, inflation has proved to exhibit a negative and highly significant negative impact on R&D even after controlling for heterogeneity caused by high investment levels in R&D, the fact of being high-income countries and the time effects of the period considered. Also, in columns (i) and (iv), coefficients show with statistical significance that the negative effect of inflation is higher in the business enterprise sector as expected and, although negative, the results in (iv) suggest a greater effort in R&D investment when all sectors are included in the estimations.

It is interesting to point out that our hypothesis has stronger impact for low and middle-income countries (as it does not hold for the G7 countries), and for those countries that commit fewer resources on R&D relative to their GDP. Furthermore, columns (ii) and (iv), illustrate that the gross domestic expenditure in R&D coefficient in G7 economies is higher than the business enterprise sectors with statistical significance. Nevertheless, this result makes sense since most of the G7 governments devote strong effort in R&D, for example, national defense (military). Similarly, governments also invest in business R&D designated to defense, contributing to high indices of business R&D.

Also, as we could expect, our hypothesis does not satisfy the second half of the sample period because the corresponding inflation is low (a single-digit average inflation rate for the period) and, therefore, it makes sense to observe a positive relationship between both variables.

Columns (iii) and (vi) reveal that the enterprise business sector, while positive, has a lower performance in R&D investment respect to all the sectors involved in R&D activities.

The elasticity estimated in the robustness check exercises confirm the proposed initial hypothesis in this study and, again, as it has been checked in the previous section, the inflation impact on R&D is greater on gross domestic expenditure in R&D variable in all the estimations with a strong statistical significance. This finding is, perhaps, one of the most revealing facts for the study. On the one hand, the fact that GERD presents the larger impact of inflation than in BERD analysis suggests a large relevance of governments, non-profit organizations and education in the technological breakthrough of a country.

On the other hand, the results in this paper suggest that the technological capacities differ between developed and less developed countries. For instance, when inter acting the coefficient in columns (i) and (ii) for both, BERD and GERD analysis it is observed a positive coefficient in the G7 countries, while negative when interacting with the rest of the countries in the sample.

Table 2. Robustness checks regression output

	BERD			GERD		
Variables	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Inflation	-0,0170* (-7,27)	-0,0212* (-8,73)	-0,0135* (-6,01)	-0,0284* (-9,99)	-0,0335* (-11,57)	-0,0234* (-8,58)
High R&D/GDP dummy x Inflation	-0,0425* (-5,30)			-0,038* (-4,07)		
G7 dummy x inflation		0,0064* (0,82)			0,0164*** (1,75)	
Time Period dummy x Inflation			0,0832* (8,56)			0,0950* (8,56)
Constant	1,2711* (63,14)	1,2062* (61,94)	1,0851* (50,65)	1,9964* (84,30)	1,9300* (83,27)	1,7913* (65,75)
Observations	420	420	420	420	420	420
Number of Countries	15	15	15	15	15	15
Country Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0,2189	0,1659	0,3036	0,2785	0,2545	0,3645

Coutry fixed effects have been included in all specifications. Dependent variable is Inflation rate. *** Significant at 1%; ** significant at 5% level; * significant at 10% level.

Therefore, the results suggest that only advanced economies are less sensitive to the inflation behavior during the period under analysis. However, the interpretation of the interactions must be taken with caution because the obtained results do not imply a causal direction in the proposal relationship.

As many authors have pointed out, the economic prosperity leads the business enterprise sectors to intensify higher efforts in R&D activities. Of course, a lower and stable in the middle and long-run inflation rates allows firms to plan with some certainty the returns on investment.

In brief, the additional specifications in this section confirm the robustness our findings; the validity of our hypothesis that inflation has a significant and negative impact on the investment behavior in R&D.

3.7 Conclusions

The purpose of this study is to complement the existent literature on determinants of R&D investment decisions by estimating empirically the role played by inflation on R&D. In particular, after the review of the literature concerning the effects of inflation on investment-decision behavior, we have seen that the particular question of whether high inflation rates discourage investment on

R&D remains largely unexplored. Hence, this study fills this gap in the literature by using a sample of 18 countries, from 1981 to 2008.

The different econometric specifications and robustness checks confirmed our initial hypothesis that inflation has a strong and significant detrimental effect on R&D investment for the countries of our sample. The impact seems to be greater during the first half of the period at stake, it is more important for non-high income countries and for those nations that exhibit a lower proportion R&D investment over their GDP.

These results have important economic implications that are worth mentioning. First, in the light of the detrimental effects of inflation on R&D expenditure showed in the estimations, it is advisable to send a message of caution to governments and policy makers respect to inflation policies. For instance, based on the outputs in this formal analysis, we strongly recommend the commitment for the achievement of stable and low inflation rates.

Inflation variable is an important measure of economic stability of countries and, its control becomes a necessary condition to create certain economic scenarios for investment decisions. Thus, as it was showed in the results, in the presence of high inflation rates R&D investments decreases and, thereby, it has a negative contribution to economic growth, which will be deteriorated in the long run. For instance, not only an impact on GDP is expected, but also in new technological breakthroughs, productivity, wages and, thus, the standard of living. Furthermore, it was empirically shown that the economic impact of the detrimental influence of inflation on R&D expenditure.

However, it is important to highlight that due to recording problems associated with data on R&D and the lack of information for less developed countries, the relationship between inflation and investment on R&D needs further exploring by future research.

3.8 Appendix

Country	Variable	Mean	Std.Dev.	Min	Max
BELGIUM	R&D	1,7270	0,1710	1,4900	2,0700
	Inflation	3,0370	2,1350	0,9480	8,7260
CANADA	R&D	1,6790	0,2610	1,2200	2,0900
	Inflation	3,4910	2,7160	0,1650	12,4700
DENMARK	R&D	1,8440	0,5380	1,0400	2,7200
	Inflation	3,4870	2,5490	1,1600	11,1760
FINLAND	R&D	2,4350	0,8280	1,1600	3,4900
	Inflation	3,5390	2,9320	0,1870	11,3000
FRANCE	R&D	2,1730	0,1130	1,9000	2,3800
	Inflation	3,4370	3,2560	0,5410	13,3140
GERMANY	R&D	2,4540	0,1580	2,1800	2,7400
	Inflation	2,3080	1,5380	-0,1290	6,3440
IRELAND	R&D	1,0350	0,2410	0,6400	1,4300
	Inflation	4,7990	4,4560	1,4170	20,3730
ITALY	R&D	1,0800	0,0980	0,8600	1,2500
	Inflation	5,5160	4,4510	1,6630	17,9600
JAPAN	R&D	2,9450	0,2820	2,3300	3,4810
	Inflation	1,0140	1,4190	-0,8990	4,9130
NETHERLAND	R&D	1,8980	0,1320	1,6410	2,1800
	Inflation	2,3800	1,5100	-0,6910	6,7380
NORWAY	R&D	1,5730	0,1420	1,1700	1,7100
	Inflation	4,1290	3,2660	0,4650	13,6570
PORTUGAL	R&D	0,6160	0,2860	0,2500	1,5100
	Inflation	8,8120	7,8250	2,2930	28,8810
SPAIN	R&D	0,8210	0,2490	0,4000	1,3500

	Inflation	5,6790	3,6000	1,8340	14,5490
GREAT BRITAIN	R&D	1,9630	0,1920	1,6900	2,3500
	Inflation	3,6560	2,6240	0,8000	11,8760
USA	R&D	2,6100	0,0990	2,3400	27700
	Inflation	3,5000	1,7110	1,5520	10,3340

BIBLIOGRAPHY

Abel, A. B. (1983). “Optimal Investment Under Uncertainty,” *American Economic Review*, 73(1), 228-233.

Abel, A., Dixit, A., Eberly, J.C., Pindyck, R.S. (1996). “Options, the value of capital and investment,” Quarterly Journal of Economics 111, 753-777.

Akaike, H. (1970) “Statistical predictor identification,” *Annals of the Institute of Statistical Mathematics*, 22, 201–7.

Amendola, G., Dosi, G., & Papagni, E. (1993). “The dynamics of international competitiveness,” *Weltwirtschaftliches Archiv*, 129(3), 451-471.

Arrow, K. J. and A. C. Fisher (1974). “Environmental Preservation, Uncertainty and Irreversibility,” *Quarterly Journal of Economics*, 89, 312-319.

Arrow, K.J. (1968). “Optimal Capital Policy and Irreversible Investment,” *in J.N. Wolfe, ed., Value, Capital, and Growth, Chicago*: Aldine, 1-20

Bahmani-Oskooee, M. (1985) “Devaluation and the J-curve: some evidence from LDCs,” *The Review of Economics and Statistics,* 67, 500–504.

Bahmani-Oskooee, M. and A. Ratha (2004) “The J-Curve: a literature review,” *Applied Economics*, 36, 1377-1398.

Bahmani-Oskooee, M. and Alse, J. (1994). “Short-run versus long-run effects of devaluation: Error correction modeling and cointegration,” *Eastern Economic Journal* Vol. 20, No. 4 (Fall, 1994), pp. 453-464.

Bahmani-Oskooee, M. and F. Niroomand (1998). “Long-run price elasticities and the Marshall-Lerner condition revisited,” *Economics Letters*, 61, 101-109

Bahmani-Oskooee, M. and Malixi, M. (1992). “More evidence on the J-curve from LDCs,” *Journal of Policy Modeling*, 14, 641–53.

Barro, R. (1996). “Inflation and growth,” *Federal Reserve Bank of St. Louis Review*, 78, 153-169.

Beck, N. and Katz, J. N. (1995). “What to do (and not to do) with Time-Series Cross-Section Data,” *The American Political Science Review*, 89 (3), pp.634-647.

Bleaney, M. and D. Greenaway (2001). “The Impact of Terms of Trade and Real Exchange Rate Volatility on Investment and Growth in Sub-Saharan Africa,” *Journal of Development Economics*, 65: 491-500.

Bousquet, A., H. Cremer, M. Ivaldi, and M. Wolkowicz (1998). “Risk Sharing in Licensing,” *International Journal of Industrial Organization,* 16(5): 535—554.

Boyd, D., Caporale, G. M. and Smith, R. (2001) “Real exchange rate effects on the balance of trade: cointegration and the Marshall–Lerner condition,” *International Journal of Finance and Economics*, 6, 187–200.

Briault, C. (1995). “The Costs of Inflation,” *Bank of England Quarterly Bulletin,* 33–45.

Bruno M., and Easterly W. (1998). “Inflation crises and long-run growth,” *Journal of Monetary Economics* 41, 3-26.

Bustamante, R. and Morales, F. (2009) “Probando la condición de Marshall-Lerner y el efecto Curva-J: Evidencia empírica para el caso peruano,” *Banco Central de Reserva del Perú, Estudios Económicos* N° 16, 103-126.

Carruth A., Dickerson A., Henley, A. (2000b). “What do we know about investment under uncertainty?,” *Journal of Economic Surveys* 14, 119-153.

Choi, J.P. (2001). “Technology Transfer with Moral Hazard,” *International Journal of Industrial Organization,* 19: 249-266.

Cohen, W. M., and Levin, R. C. (1989). "Empirical studies of innovation and market structure," *In R. C. Schmalensee and R. Willig (eds.), Handbook of Industrial Organization*: 1059-1 107. Amsterdam: El Sevier.

Cooper, R. N. (1971). “Currency devaluation in developing countries,” *Essays in International Finance*, no. 86, Princeton University, International Finance Section, Princeton, NJ.

Cottani, J.A., D.F. Cavallo and M.S. Khan (1990). “Real Exchange Rate Behavior and Economic Performance in LDCs,” *Economic Development and Cultural Change*, 39(1): 61-76.

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

Demirden, T. and Pastine, I. (1995) “Flexible exchange rates and the J-curve: an alternative approach,” *Economics Letters*, 48, 373–7.

Dickey, D.A. and Fuller, W.A. (1981). “Likelihood ratio statistics for autoregressive time series with a unit root,” *Econometrica*, 49, 1057–72.

Dickey, D.A. and W.A. Fuller (1979) “Distribution of the estimates for the autorregresive Time series with a Unit Root,” *Journal of the American Statistical Association*, 74, 427-431.

Dixit A., K. (1992). “Investment and Hysteresis,” *Journal of Economic Perspective*, 6(1), 107-132.

Dixit, A. and R. Pindyck (1994). “Investment under Uncertainty,” *Princeton University Press, Princeton, NJ.*

Dixit, A. and R. Pindyck (1994). “Investment under Uncertainty,” *Princeton University Press*. Princeton, NJ.

Dornbusch, R. (1996) “The effectiveness of exchange-rate changes,” *Oxford Review of Economic Policy*, 12, 26-38.

Dornbusch, R., Fischer, S., (1993). “Moderate inflation,” *World Bank Economic Review*, 7, 1-44.

Edwards, S. (1989) “Exchange Controls, Devaluations, and Real Exchange Rates: The Latin American Experience,” *Economic Development and Cultural Change*, 37, 3, 457-494

Edwards, S. and Montiel, P. J. (1989). "Devaluation Crises and the Macroeconomic Consequences of Postponed Adjustment in Developing Countries," *IMF Staff Papers, Palgrave Macmillan,* 36(4), 875-903.

Fisher, Stanley (1983). “Inflation and Growth,” *NBER Working Paper, No. 1235, Cambridge, Massachusetts: National Bureau of Economic Research.*

Friedman, M. (1977). “Nobel Lecture: Infation and Unemployment,” *Journal of Political Economy*, 85(3), 451-472.

Furman, J.L., Porter, M. E and Stern, S. (2002). “The determinants of national innovative capacity,” *Research Policy* 31, 899–933.

Gittleman, M. B. and Wolff, E. (1995): “R&D activity and cross-country growth comparisons,” *Cambridge Journal of Economics*, vol. 19, 1, 189-207.

Goel R. K., Rati Ram, R. (2001). “Irreversibility of R&D investment and the adverse effect of uncertainty: Evidence from the OECD countries,” *Economics Letters* 71, 287–291.

Goel, R. K., & Ram, R. (1994). “Research and development expenditures and economic growth: A cross-country study,” *Economic Development and Cultural Change*, 42, 403-411.

Gomes, F. A. R. and L. S. Paz (2005) “Can real exchange rate devaluation improve trade balance? The 1990-1998 Brazilian case,” *Applied Economics Letters*, 12, 525-528.

Greene, J., Villanueva, D. (1991). “Private investment in developing countries,” *IMF Staff Papers* 38, 33-38.

Greene, W. (2000). “Econometric Analysis,” *Upper Saddle River, NJ: Prentice–Hall.*

Hall, B. H. (2002). “The financing of research and development,” *Oxford Review of Economic Policy*, 18(1), 35-51.

Hartman, R. (1972). “The effect of price and cost uncertainty on investment,” *Journal of Economic Theory* 5, 258-266.

Haynes, Stephen E., and Stone, Joe A. (1982) “Impact of the Terms of Trade the U.S. Trade Balance: A Reexamination,” The *Review of Economics and Statistic*s 64: 702-706.

Henry, C. (1974). “Investment Decisions under Uncertainty: The ‘Irreversibility Effect,”, *American Economic Review*, 64, 1006-1012.

Himmelberg, C. P. and Petersen, B. C. (1994). “R&D and Internal Finance: A Panel Study of Small Firms in High-Tech Industries,” *Review of Economics and Statistics*, 76, 38-51.

Huizinga, H. (1993). “Inflation uncertainty, relative price uncertainty and investment in US manufacturing,” *Journal of Money, Credit and Banking* 25, 521-554.

Huseyin Kalyoncu, H., Ozturk, I., Artan, S. and Kalyoncu, K. (2009). “Devaluation and trade balance in Latin American countries,” 128 *Zb. rad. Ekon. fak. Rij*. 27, 1, 115-128.

IFS (2010). *International Financial Statistics, August, IMF, Washington, DC.*

Ingersoll, J., and Ross., S. (1992). ”Waiting to Invest: Investment and Uncertainty,” *Journal of Business* 65, nº. 1: 1-29.

Johansen, S. (1989) “Estimation and Hypothesis testing of Cointegration Vectors in Gaussian Vector Autorregresive Models,” *Econometrica*, 59, 1551-1580.

Johansen, S. and K. Juselius (1990) “Maximum Likelihood Estimation and Inferences on Cointegration with applications to the demand for money,” *Oxford Bulletin of Economics and Statistics*, 52, 169-210.

Kamien M. (1989). “Market Structured and Innovation Revisited,” *Japan and World Economy*, 331-339.

Khan, M. (1974) “Import and Export Demand in Developing Countries,” *Staff Papers, IMF*, 21, 678-693.

Krugman, P. (1979) “A Model of Innovation, Technology Transfer, and the World Distribution of Income,” *Journal of Political Economy* 87, pp. 253-266.

Krugman, P. Richard E. Baldwin, R. (1987) “The Persistence of the U.S. Trade Deficit,“ *Brookings Papers on Economic Activity*, 1, pp. 1-55.

Kwiatkowski, D., Phillips, P.C.B., Schmidt, P., Shin, Y., (1992). “Testing the null of stationarity against the alternative of a unit root:

How sure are we that economic time series have a unit root?," *Journal of Econometrics* 54, 159–178.

Levin, R., Cohen, W., and Mowery, D. (1985). "R&D Appropriability, Opportunity and Market Structure: New Evidence on Some Schumpeterian Hypothesis," *American Economic Review*, 75, 2, 20–24.

Lichtenberg, F. R. (1992). "R&D Investment and International Productivity Differences," Working Paper No. 4161, *National Bureau of Economic Research, Cambridge.*

Macho-Stadler, I., X. Martinez-Giralt and D. Perez-Castrillo (1996). "The Role of Information in Licensing Contract Design," *Research Policy*, 25: 43-57.

Magee, S. P. (1973) "Currency contracts, pass through and devaluation," *Brooking Papers on Economic Activity*, 1, 303–25.

Mahdavi, S. and Sohrabian, A. (1993) "The exchange value of the dollar and the US trade balance: an empirical investigation based on cointegration and Granger causality tests," *Quarterly Review of Economics and Finance*, 33(4), 343–58.

Mahmud, S. F. et al. (2004) "Testing Marshall-Lerner condition: a non-parametric approach," *Applied Economics Letters*, 11, 231-236.

Mansfield, E. (1969). “The Economics of Technological Change,” *Longmans, London.*

Mansfield, E. (1980). “Research and Development, Productivity and Inflation,” *Science*, vol. 209, 1091-1093.

Mansfield, E. (1982). “Technology Transfer, Innovation and Public Policy,” *The Transfer of Innovation and Public Policy, D.C. Heath, Lexington.*

Marwah, K. and Klein, L. R. (1996) “Estimation of J-curve: United States and Canada,” *Canadian Journal of Economics*, 29, 523–39.

Matesanz and Fugerolas (2009) “Exchange rate policy and trade balance: a cointegration analysis of the Argentine experience since 1962,” *Applied Economics*, 41, 2571-2582.

McDonald, R.L. and D. Siegel (1986). “The Value of Waiting to Invest,” *Quarterly Journal of Economics* Vol. 101, No. 4, 707-728.

Mendi, P. (2005). “The Structure of Payments in Technology Transfer Contracts: Evidence from Spain,” *Journal of Economics and Management Strategy*, 14(2): 403-429.

Mendi, P. (2007). “Trade in Disembodied Technology and Total Factor Productivity in OECD Countries,” *Research Policy*, 36: 121-136.

Metzler, L. (1948) "The Theory of International Trade," *In A Survey of Contemporary Economics, edited by Howard S. Ellis. Vol. 1. Philadelphia: Blakiston, 1948.*

Ostry, J. and Rose, A. (1992) “An empirical evaluation of the macroeconomics effects of tariff,” *Journal of International Money and Finance*, 11, 63-79.

Park, W. (1995). “International R&D Spillovers and OECD Economic Growth,” *Economic Inquiry*, 33, 571-591.

Phillips, P. C. B, Perron, P. (1988) “Testing for a unit root in a time series regression,” *Biometrika* 75: 335-346.

Pindyck, R. S. (1991). “Irreversibility, Uncertainty and Investment,” *Journal of Economic Literature*, 29, 3, 1110 – 1148.

Pindyck, R.S. (1988). “Irreversible Investment, Capacity Choice, and the Value of the Firm,” *American Economic Review*, Vol. 78, No. 5, 969-985.

Pindyck, R.S. (1993). ”A Note on Competitive Investment under Uncertainty,” *American Economic Review*, 83(1), 273.277.

Pindyck, R.S., Solimano, A. (1993). “Economic instability and aggregate investment,” *NBER Macroeconomics Annual*, 259-303.

Reinhardt, C. (1995) “Devaluations, Relative Prices and International Trade,” *Staff Papers. IMF*, 42, 290-312.

Rittemberg, L. (1986) “Export Growth Performance of LDC’s,” *Journal of Development Economics,* 24, 167-177.

Robinson, J. (1947). “The pure theory of international trade,” *Review of Economic Studies*, 14, 98-112.

Rose A.K. and Yellen J.L. (1989). “In there a J-curve?,” *Journal of Monetary Economics*, 24, 53-68.

Rose, A. K. (1991). “The role of exchange rates in a popular model of international trade: does the ‘Marshall–Lerner’s condition hold?,” *Journal of International Economics*, 30, 301–16.

Rose, A.K., (1990). “Exchange rates and the trade balance: some evidence from developing countries”, *Economics Letters*, 34, 271-275.

Servén, L. (2003). “Real-Exchange-Rate Uncertainty and Private Investment in LCDs,” *The Review of Economics and Statistics*, 85(1): 212-218.

Serven, L. and A. Solimano,(1993), “Debt Crisis, Adjustment Policies and Capital Formation in Developing Countries: Where do we stand?,” *World Development*, Vol. 21, No. 1, pp. 127-140.

Shirvani, H. and Wilbratte, B. (1997) “The relation between the real exchange rate and the trade balance: an empirical reassessment,” *International Economic Journal*, 11, 39–49.

Sylwester, K. (2001): “R&D and Economic Growth,” *Knowledge, Technology & Policy*, 13, 71–84.

Tobin, J. (1965). “Money and economic growth,” Econometrica 33, 671-684.

Upadhyaya, K. and Dhakal, D. (1996) “Devaluation and the trade balance: estimating the long run effect,” *Applied Economics Letters*, 1997, 4, 343–345

Vishwasrao, S. (2007). “Royalties vs. Fees: How Do Firms Pay for Foreign Technology?,” *International Journal of Industrial Organization*, 25: 741-759.

Weeds, H. (2002). “Strategic Delay in a Real Options Model of R&D Competition,” *The Review of Economic Studies* 69, 3, 729-747.

White, H., (1980). ”A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity,” *Econometrica* 48, 817–838.

Wilson, W. (1993). “J-Curve Effect and Exchange Rate Pass-Through: An Empirical Investigation of the United States,” *International Trade Journal*, 7, 463-83.

Wooldridge, J. M. (2002). “Econometric Analysis of Cross Section and Panel Data,” *MIT Press: Cambridge, MA.*