THE TRANSMISSION OF SHOCKS TO THE EXCHANGE RATE ON THE INFLATION OF IMPORTED GOODS IN THE PRESENCE OF ASYMMETRIES*

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April 2009

ABSTRACT

In this document we estimate the degree of short and long run transmission on the inflation of imported goods of a structural shock to the devaluation of the Colombian peso in the presence of asymmetries. We used a standard pass-through equation for models with imperfect competition, quarterly data from Colombia for the 1985 to 2007 period, and lineal and non-lineal econometric models. The results show that the transmission is less than proportional no matter what the time run and state of the economy are considered. The degree and dynamics of the transmission were also found to be endogenous and asymmetric to the speed of the changes and volatility of the exchange rate and the state of the economy. The transmission is greater when the economy is booming and more open, the devaluation/appreciation of the exchange rate accelerates and is less volatile, the real exchange rate is overvaluated, and the inflation rate is high and less volatile, and it decelerates.

***Classification JEL*:** F31, E31, E52, C51, C52

Keywords: Transmission of shocks to exchange rate devaluation on inflation (exchange rate pass-through), asymmetries, linear VAR model, logistic smooth transition vector auto-regressive (LSTVAR) model

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* We would like to express our appreciation to Munir Jalil and Lavan Mahadeva from the Banco de la República, and Fernando Oliveira from the Central Bank of Brazil for their valuable comments and suggestions. We also thank those who participated in the Banco de la Republica's "Intermediate Conference on the Project for the Transmission of Monetary Policy in Colombia", the ECLAC Researchers' Network Meeting 2008, and in the Seminario CEDE of the Universidad de los Andes for their comments. Jose Luis Torres, Mauricio Arango, Gisell Pugliese and Johanna Ramos helped us with part of the literature review and with the construction of the series. The points of view expressed in the document are those of the authors and do not represent those of the Banco de la Republica or its Board of Directors. The authors are the only ones responsible for any error in the document. Send comments to hrincoca@banrep.gov.co.

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1. INTRODUCTION

The objective of the document is to estimate the degree of short and long run transmission of a structural shock to the devaluation of the Colombian peso on the inflation of the prices of imported goods (exchange rate pass-through - ERPT) in the presence of asymmetries. The conceptual framework is a standard ERPT equation that captures the behavior of a foreign exporter who sells his goods locally and acts under imperfect competition.[1] Quarterly data from Colombia for the 1985-2007 period and linear VAR and logistic smooth transition vector auto-regressive models are used (LSTVAR).

The asymmetries may appear when there are non-competitive market structures and rigidity in prices and/or quantities and they relate to the sign, size and nature (transitory versus permanent) of the exchange rate variations, their volatility and the state of the economy: economic cycle, degree of economic openness, degree of misalignment in the real exchange rate and its inflationary environment (level, variation, and volatility of the inflation rate).

The study of ERPT is motivated by two main reasons. The first one is to have knowledge about the ability of short term macro-economic adjustment that the nominal exchange rate has. If the prices of tradable goods respond proportionally (complete) to the variations in the exchange rate, that is to say, in a one to one correspondence, the *expenditure-switching* effects will act fully and the exchange rate will have a stabilizing role. This is a fundamental supposition of the potentiality of a real short term adjustment that the nominal exchange rate has and that we verified with the impulse-response functions. For example, we will answer the question of how much the inflation of imported goods rises or in other words, how stabilizing the exchange rate is in the presence of a shock to itself.

In the second place, it is useful for analysis and as an element of criteria for making

[1] We assume that the exporter fixes his/her prices in a similar manner for all small economies where he/she exports, among them to Colombia. The pertinence of utilizing a model that captures a non-competitive behavior on the part of foreign and domestic firms acting locally is corroborated in the Colombian case by the results of Julio and Zarate (2007).

monetary policy decisions.[2] If the degree of transmission is complete, the variations in the exchange rate, *ceteris paribus*, are transmitted one by one to the inflation of imported goods which consequently should be responded to on the part of the monetary authority in order to reach their inflation goals. Otherwise, there could be room, for example, for the monetary policy to play an anti-cyclic role at times of severe macro-economic break down. In addition, if the transmission is not symmetrical, that is to say, for example, if the degree of ERPT does not have the same magnitude in the devaluation/appreciation of the country's currency, the authorities should meet the variations in the exchange rate with consistent responses. Doing it wrongly could bring about incorrect decisions that would imply a high cost to their credibility and to reaching inflation goals.

ERPT manifests itself through at least two channels. The first channel is the direct effect of the changes in the exchange rate on the prices of imported goods (intermediate and/or final) that increase the cost of production and with it the total inflation. The degree of transmission through this channel will depend on the market power that importing firms have on the internal market, on the ability of said firms to compensate *menu costs* in price changes and on the state of the economy. In the case of the country under study, imported goods represent 25% of the Colombian Consumer Price Index (CPI) and 34% of the tradable goods. At the same time, the intermediate consumption of imports represents 13% of the costs of production in the economy, based on the social accounting matrix for the year 2004. Therefore, it is very important for the central bank to know the degree of ERPT on said goods.

In the presence of a country's currency devaluation (or depreciation), the second channel manifests itself in the stimulation of a demand for domestic goods derived from the increase in the prices for imported goods that compete with them which puts upward pressure on the general price level. The degree of substitutability between imported and local goods will be the determinant of the degree of transmission through this channel.

[2] As Ball (1999) and Taylor (2000) emphasized, the coefficients in the monetary policy rule and the operative procedures explicitly linked to the prediction of inflation depend on the degree of ERPT.

Recent literature has highlighted the fact that the degree of ERPT responds endogenously and asymmetrically to the size, sign, volatility and nature of the variations in the exchange rate, the inflationary environment, economic cycle, the degree of economic openness, and the degree of misalignment in the real exchange rate. It is clear that if the ERPT behaves asymmetrically, the models used by central banks, and particularly by the Banco de la Republica, for inflation forecasts should include that behavior. At the same time, the monetary authority should take those asymmetries into account when they evaluate the scope of their policy decisions as well as at the time they appraise their achievements. Surely, for example, if the degree and dynamics of the ERPT depend positively on the level of inflation, the authorities will be inclined, *ceteris paribus*, to maintain low levels of inflation.

Our findings show that the ERPT is incomplete both in the short and in the long run, and this result does not depend of the size and sing of the shock to the currency´s devaluation. A structural shock to devaluation is transmitted to inflation of imported goods of between 6% in the first two quarters and 58% in the long run. Furthermore, the degree and dynamics of the ERPT are found to be endogenous and asymmetrical to the speed of the changes and volatility of the exchange rate and the state of the economy. The transmission is greater when the economy is booming and more open, the devaluation/appreciation of the exchange rate accelerates and is less volatile, the real exchange rate is overvaluated, and the inflation rate is “high” and less volatile, and it decelerates.

The document consists of six sections in addition to this introduction. In the second section, some empirical, institutional, an economic policy facts about the Colombian economy are highlighted. In the third, the conceptual framework is introduced and recent empirical and theoretical literature in which the topic has been studied is reviewed. In the fourth, the data, the linear regression model, and the test of linearity are presented. In the fifth, the non-linear model, the ERPT estimates and the impulse response functions for the inflation of the prices of imported goods in the presence of shocks to the devaluation are presented. In the

last section, the conclusions are summarized.

2. SOME EMPIRICAL, INSTITUTIONAL AND ECONOMIC POLICY FACTS ABOUT THE COLOMBIAN ECONOMY

The rate of devaluation of the Colombian peso, the inflation of imported goods and the inflation of the CPI show a descending tendency throughout the sample (Appendix A.1.). The direction, not the level, of the movements of the devaluation rate and of the inflation rate for imported goods seems to hold to a close relationship which has been more evident since the beginning of the 90s. The same thing does not happen with these two variables and total inflation.[3] Also the real exchange rate, that which utilizes the CPI as a deflator, has depreciated over the period of the sample (Appendix A.2.). Nevertheless, two prolonged cycles of strong depreciation/appreciation, each lasting approximately ten years, have occurred. The misalignment, deviation in the observed real exchange rate with respect to the tendency using the Hodrick and Prescott decomposition, has oscillated between 10% and -10% especially between mid-2006 and mid-2007. The described evolution of prices and exchange rates occurred in an environment of substantial changes.

During the 90s, Colombia experienced a series of institutional and economic policy changes that affected macro-economic performance and may possibly have altered the relationship between the exchange rate variations and inflation. Among them, the process of commercial and financial liberalization at the beginning of the 90s stand out. The constitutional reform that gave independence and autonomy to the central bank (Banco de la República) explicitly established defending the purchasing power of the currency as the main objective of monetary policy. Starting in 1992, the inflation goals were announced and starting in the year 2000, a regime of inflation targeting was formally adopted. Inflation

[3] The correlation of the current values of the devaluation, the inflation of the CPI and the inflation of the price of imported goods of PPI was 0.44 and 0.94 respectively. The correlation between the first 12 lags of the devaluation and the inflation of CPI did not vary significantly and oscillated between 0.37 and 0.44. In the case of the inflation of import prices, the correlation diminished to the degree in which the order of the lags increases and oscillates between 0.55 and 0.94 for the first five lags and dropping to 0.08 in the 12^{th} lag.

was reduced from 32.4% in 1990 to 8.8% in 2000 while its volatility went from 1.7 to 0.5. Inflation reached 5.7% in December, 2007.

The exchange regime managed by the central bank went through a radical transformation during the period under study. From the second half of the 80s and until June 1991, the crawling peg regime that had been in force since 1967 continued. Between July, 1991 and February, 1994 the floating exchange rate was controlled by means of securities (exchange certificates) issued by the bank which had a varying maturity period in order to affect the level of the exchange rate (Villar and Rincon, 2001). The exchange rate was allowed to float beginning in September, 1999[4] after a exchange rate band transition period between 1994 and August, 1999 had gone by.

In regards to real activity, the economy grew on average more than 4% after the middle of the 80s. During the 90s, the economy experienced extreme swings in the economic cycle. After registering an average growth of 5% in the first half of the decade, the growth slowed down and in 1999 there was a contraction of 4.2%, the largest registered in almost 100 years. After a slow recovery process, the Colombian economy has returned to average growth rates of above 4% (the economy grew slightly above 7% in the year 2007).

3. THE CONCEPTUAL FRAMEWORK AND THE LITERATURE ON THE PASS-THROUGH OF THE EXCHANGE RATE

Theoretically, the assumption of complete transmission of the exchange rate on prices arises from the exchange rate monetary models and specifically from the assumed validity of the law of one price or its generalization (hypothesis of purchasing power parity) at all moments in time. This “law” says that the prices of goods sold in a country should be equal to the prices of the goods sold abroad when measured in the same currency. In other words,

[4] The flotation did not occur in the strict sense of the term. The authorities intervened in the market through a publicly known exchange intervention rule. Between 2004 and mid-2007 the authorities combined the rule with discretional policy.

any movement in the exchange rate of a country's currency should be reflected to the same order of magnitude in the price of the imported good. This is what we define as complete transmission of the exchange rate.

The validity of this assumption was put in doubt in models that go back to Krugman (1986) and Dornbusch (1987). Among the factors that could affect the degree of transmission of exchange rate variations to prices are the market structure and its degree of concentration, the degree of homogeneity and substitutability of tradable goods, strategic market behavior on the part of the foreign firms with respect to local competitors, the perception of the variability and the nature of the exchange rate variations (transitory versus permanent), the presence of nominal rigidities and the prevailing inflationary environment at the time they occur.[5] In Appendix 3 a static model of partial equilibrium and imperfect competition is presented for a foreign firm that exports a good to the domestic economy and that is derived from this branch of the literature.[6] Starting with this model we built our econometric model.

The Neo-Keynesian models of the open economy, which the central technical instruments of the monetary regimes of current inflation targeters assume that the degree of ERPT is incomplete (in the short term) due to the presence of imperfect competition and nominal price rigidities. These models constitute an advance in the study of ERPT since their nature is of general equilibrium. They are dynamic and stochastic which allows them to explicitly incorporate a forward-looking behavior on the part of the firms. They will not be developed here; nevertheless, we believe that the implications that are derived here should be kept in mind when they are modeled and implemented.

Recent Colombian and international empirical evidence has concluded almost unanimously that the ERPT is incomplete in both the short and the long run independently of the

[5] The majority of these models correspond to static partial equilibrium models with flexible prices. In other words, they adjust instantaneously to changes in the conditions of supply and demand and with non-forward looking agents.

[6] Since the foreign exporter who sells a product locally is being modeled directly in this document, we do not study matters related to the costs of marketing the product. Here they are assumed to be equal zero.

theoretical and empirical approximation, of the country sample, of the period and of the data frequencies that are analyzed (Table 1). Here the main conclusions of some of the documents that were reviewed are summarized.

Campa and Goldberg (2006) argue that the ERPT will vary in relation to the imported product. In as far as the composition of industry imports favors goods whose sensitivity to exchange rate movements is low, a decline in the effect at the aggregate level will be registered. Otani et. al. (2006) found that the change in the primary commodities share of the total imports explained the decreasing tendency of the effect in the case of the Japanese industry.

Taylor (2000) argues that the decrease in the degree of ERPT, interpreted as a loss of price-fixing power on the part of the firms, is one of the main consequences of maintaining low and less persistent inflation levels. This could be the explanation for why the periods in which the demand behavior is more dynamic do not translate into considerable rises in the general price levels as was the case for the United States towards the end of the 90s.

Moreover and utilizing the same argument of market power and price fixing on the part of the firms, Taylor (ibid.) points out that the *pass-through* coefficient depends on the firms' expectations regarding the nature of the exchange rate variations. If the domestic firms expect that the increases in cost caused by changes in the exchange rate will be permanent, they will increase their prices accordingly. If they expect those increases to be transitory, the firms will transmit the changes in the exchange rate to their prices less than proportionally. In other words, the less persistent changes in the exchange rate should lead to a lower ERPT coefficient. In the empirical exercises implemented below, the volatility of the exchange rate was utilized as a measurement of the expectations of the firms in regards to the above variable. Low volatilities are identified with expectations of permanent changes in the exchange rate and vice versa.

Table 1: Recent Literature on the Exchange Rate Pass-through

Authors	Year	Freq.[1]	Sample	Countries	Econom. model	Approach[2]	Variables[3]	Inflation[4]
Goldfajn and W.	2000	M, Q	1980-98	71	Uniequation	NL	L	↓
Rincón	2000	M	1980-98	Colombia	VECM	LR	L and Dif.	NA
Choudri and H.	2001	Q	1979-00	71	Panel	NL	L	↓
García and R.	2001	Q	1986-01	Chile	Uniequation	LR	Dif.	NA
Campa and G.	2002	M	1989-01	Euro	30 products	LR	Dif.	NA
Devereux and Y.	2002	Y	1970-01	122	Uniequation	LR	Dif.	NA
Rowland	2003	M	1983-02	Colombia	VAR, VECM	LR	L and Dif.	NA
Winkelried	2003	M	1993-02	Peru	SVAR	NL	Dif.	NA
Alburquerq. and P.	2004	Q	1980-02	Brazil	Uniequation	DC	Dif.	CPI: ↓ Pm: __
Mendoza	2004	M	1989-02	Venezuela	VAR	NL	Dif.	NA
Rosas	2004	M	1991-02	Colombia	VECM	LR	L and Dif.	NA
Bouakez and R.	2005	Q	1973-03	Canada	SGEM	LR	Gaps	CPI: ↓ Pm: ___
Frankel et. al.	2005	Y	1990-01	76	ECM, Panel	LR	L and Dif.	↓
Campa and G.	2005	Q	1975-03	23 OECD	OLS	LR	Dif.	---
Marazzi et. al.	2005	Q	1972-04	USA	Uniequation	LR	Dif.	↓
Rincón et. al.	2005	M	1995-02	Colombia	VECM	DC	Dif.	↑
Campa and Goldberg	2006	Q	1975-04	18	5 categories	LR	Dif.	CPI: ↑ Pm: ↓
da Silva and M.	2006	Q	1995-05	Brazil	Uniequation	NL	Dif.	NA
Gaytan and G.	2006	M	1992-05	Mexico	MS-VAR	NL	Dif.	↓
Ihring et. al.	2006	Q	1975-04	G7	Uniequation	LR	Dif.	↓
Muntaz and O.	2006	Q	1984-04	UK	6 categories	LR	Dif.	↓
Otani et. al.	2006	M	1980-03	Japan	8 categories	LR	Dif.	↓
Rodríguez et. al.	2006	M	1994-05	Paraguay	Uniequation	LR	Dif.	NA
Sekine	2006	Q	1974-04	G7	Uniequation	DC	Dif.	↓
Wolden	2007	Q	1980-03	UK, Norw.	GMM,VAR,VECM	LR	L and Dif.	NA
Bandt et. al.	2007	M	1995-05	Euro	4 categories	NL	L	↑

Source: authors' compilation.
[1] Q: Quarterly; M: Monthly; Y: Yearly.
[2] NL: Non-Linear; LR: Linear; DC: Dynamic coefficient.
[3] L: Levels; Dif.: Differences.
[4] ↑: pass-through increases; ↓: pass-through decreases; __: pass-through is stable; ---: ambiguous result; CPI; Consumer Price Index; Pm: Price Index of imported goods; NA: not apply.

Beginning with the formulation of what is called the *Taylor hypothesis*, a large number of studies that evaluate the fulfilling of this hypothesis have been done. Devereux and Yetman (2003) found that the lower the mean inflation rate and its volatility is, the lower the adjustment frequency and therefore, the degree of ERPT will be. In another case, Muntaz and Oomen (2006) stated that the most important factor in the decrease of the degree of ERPT is greater macro-economic stability, particularly the lower volatility in the inflation rate and the type of change.

The dependence of the degree of ERPT on the state of the economy and the inflationary environment not only implies a lower degree of elasticity in the prices with respect to the exchange rate but could also generate asymmetries and non-linearities in the transmission of the exchange rate to prices. Alburqueque and Portugal (2004) found that the lower inflationary environment as a consequence of Brazil's so-called *Real Plan* and the adoption of a floating exchange regime in 1999 reduced the degree of ERPT in that country. A similar result was found by Sekine (2006) who discovered that the low ERPT coefficient is associated with the lower, more stable and less persistent level of inflation.

Rincon, Caicedo and Rodríguez (2007) estimated the ERPT for the import prices of a sample of the sectors in Colombian manufacturing industry. The authors found evidence on the heterogeneity in the degree of sensitivity of prices to the variations in the exchange rate as well as in the incomplete transmission of the exchange rate both in the short and long term. The degree of estimated ERPT is located between 0.1 and 0.8 for the long term and between 0.1 and 0.7 for the short term. The authors did not find evidence that supports the hypothesis that affirms that in a floating exchange rate regime and in an environment of low inflation the degree of ERPT is low. Nevertheless, and in spite of the fact that they did not develop it, they make explicit the possible presence of non-linearity in the relationship between the exchange rates and prices for the Colombian case. The present document goes in that direction.

Finally, Mishkin (2008) points out that a stable monetary policy, supported by an institutional framework that allows the central bank to have a policy that is independent of fiscal considerations and political pressures is one that effectively removes a potentially important source of high ERPT.

4. THE DATA, LINEAR MODEL AND TESTS OF NON-LINEARITY

4.1 The Data

Quarterly data from Colombia for the period between 1985:I and 2007:IV were used (Appendix A.4 explains the series and their sources). The only seasonally adjusted series was the CPI and the TRAMO-SEATS methodology was used. Indexes weighted for foreign trade were constructed for the variables of the foreign country represented here by Colombia's three main trading partners: United States, Germany and Japan. These countries represent an average of 45% of the total Colombian imports throughout the sample. Unfortunately, it was impossible to get all of the required series for Ecuador, China and Venezuela which also have a significant share (an average of 10% in the last eight years).

4.2 The Linear Model and the Tests of Linearity

The estimations of the possible asymmetries in the transmission of the fluctuations in the exchange rate to the inflation of imported goods start from the equation (A-6) in Appendix A.3. Starting with this equation we first specify and estimate a linear vector autoregression model (linear VAR model) and afterwards, the linearity tests on that were carried out.

The variation in the prices of imported goods depends on the lagged variation in the price for goods that compete internally with the imported goods and their lags, the lagged variation in the exchange rate and its lags and the lagged variation in external production costs and their lags. The first-order linear VAR model is the following,

$$(1) \qquad Y_t = \begin{bmatrix} \Delta pm_t \\ \Delta pl_t \\ \Delta e_t \\ \Delta c_t^* \end{bmatrix} = A(L)Y_{t-1} + \boldsymbol{u}_t$$

with the natural logarithm of the wholesale price index of imported goods being *pm*; the natural logarithm of the price index for locally produced and consumed goods being *pl*; the natural logarithm of the effective index, weighted by trade, of the average nominal exchange rate (local currency/foreign currency), e; and a measurement of the marginal costs for foreign exporters being *c**. The structural shocks are identified by using the Choleski decomposition, in other words, we define $\boldsymbol{u}_t = \boldsymbol{A}^{-1}\boldsymbol{\varepsilon}_t$, with $\boldsymbol{A}$ being a superior triangular matrix and $\boldsymbol{\varepsilon}$ the vector of the structural shocks.[8] This arrangement implies that shocks to the devaluation contemporaneously affect the inflation of imported goods and that of their substitutes but not the foreign marginal costs. The equation (1) can then be rewritten as,

$$(2) \qquad Y_t = \begin{bmatrix} \pi_t^{pm} \\ \pi_t^{pc} \\ \Delta e_t \\ \Delta c_t^* \end{bmatrix} = A(L)Y_{t-1} + \boldsymbol{u}_t$$

with π_t^{pm}=Δpm_t and $\pi_t^{pl} = \Delta pl_t$. The transmission coefficient for the variations in the exchange rate on the inflation of imported goods ERPT for a period τ is calculated beginning with the accumulated response functions of the imported goods inflation before an impulse (shock) to devaluation, with respect to the accumulated response of the same devaluation:

$$(3) \qquad ERPT_\tau = \frac{\sum_{j=0}^{\tau} \frac{\partial \pi_{t+j}^{pm}}{\partial \varepsilon_t^e}}{\sum_{j=0}^{\tau} \frac{\partial \Delta e_{t+j}}{\partial \varepsilon_t^e}}$$

That is to say, the degree of ERPT measures the relative change in accumulated inflation of imported goods up to moment τ in the presence of a shock in the devaluation in period 0,

[8] Unitary root tests were previously completed on the series in first differences. The tests indicated that the presence of stationarity.

with respect to accumulated changes up to period τ of the devaluation with respect to the change in itself in period 0. Upon correcting for this last effect, the possibility of overestimating the degree of ERPT is avoided. The formulation given by equation (3) also corrects by the endogenous response of the exchange rate to the shock itself.[9]

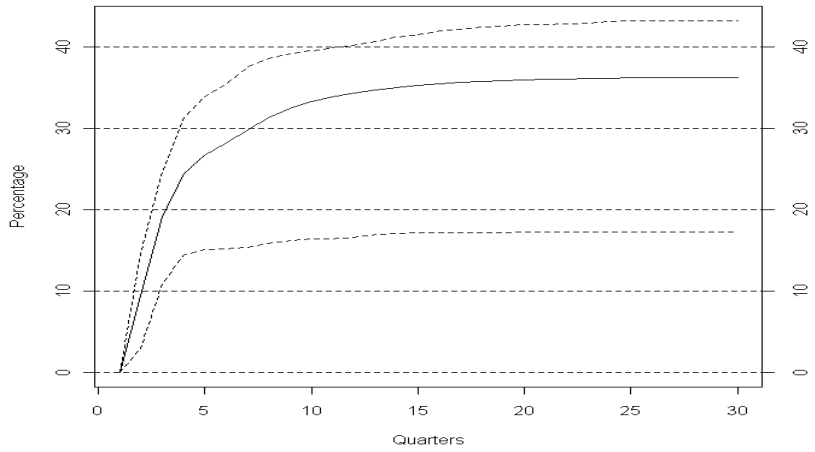
If the ERPT is complete (equivalent to 100%), we say that the markup of the foreign exporters does not change with the changes in the domestic currency (the peso). In terms of the Neo-Keynesian models, it is said that the prices are fixed in the exporting country's currency ("producer currency pricing"). If the ERPT is equal to zero, it is said that there is no ERPT and that the markup of the foreign exporters completely absorbs the changes in the exchange rate of the importing country. In this case, it is said that the prices are fixed in the currency of the importing country ("local currency pricing").

Figure 1 shows the path of the degree of estimated ERPT for the linear model of the equation (3) in the presence of a standard deviation shock to the devaluation and a horizon of 20 quarters.[10] The impulse response function shows that the ERPT is incomplete. The ERPT rises to values of between 10% and 18% in the first year of the shock (short term), around 25% in the second year and stabilizes at a maximum of 38%. In other words, 38% of the peso devaluation is transmitted to the inflation of imported goods in the long run. Notice the sizable uncertainty captured by the magnitude of the confidence intervals.

[9] Goldfajn and Werlang (2000) originally introduced the definition of the pass-through coefficient in the terms given by the equation (3). Winkelried (2003) formulates and applies the definition given in equation (3), and Mendoza (2004) applies it for studying the Venezuelan case.

[10] A standard deviation shock to the devaluation equals 3.8%. The dotted lines correspond to the confidence intervals built with Bootstrapping simulations at 80% of confidence.

Figure 1: Path of the Estimated ERPT (Linear VAR model) in the Presence of a Shock to the Devaluation



To carry out the tests of linearity, the three stages recommended by Granger and Teräsvirta (1993) were followed. In the first stage, the best possible linear model is estimated and selected which we did by starting from the equation (2) estimated. In the second one, the test of linearity was applied by following the procedure of the third order test introduced by Lukkonen et. al. (1988). Last of all, if linearity is rejected, a choice is made between the vector auto-regressive regression model that admits a logistic smooth transition and that admits an exponential smooth transition through the confirmation of a hypothesis sequence. We selected the transition model on the basis of the test and the economic theory, which suggests the use of a logistic smooth transition model in order to capture possible asymmetrical behaviors for extreme values of the variable that describes the transition or the state of the economy.

To choose the lag structure of the model for equation (3) we utilized Akaike, Hannan-Quinn and Schwarz's information criteria and the Final Prediction Error. The tests did not coincide in indicating a single lag length and point out, as possibilities, 1, 3, or 5 as the degrees of the polynomial. Nevertheless, the white noise, normality, and the parameter

stability tests indicated that the best model was the third-order VAR.[13] As a selection criteria, the ERPT estimate, which also indicated a p=3 as the most indicated degree for the polynomial, was also used.

After choosing the VAR order, the linearity tests were implemented. We tried as transition variables the first eight lags of the: CPI inflation (π^{CPI}), the inflation variation ($\Delta\pi^{CPI}$), the volatility of inflation ($V(\pi^{CPI})$), the variation of the devaluation ($\Delta(\Delta e)$), the output gap (Gy), the degree of economic openness ($Open$), the volatility of the exchange rate ($V(\Delta e)$), and a measurement of misalignment of the real exchange rate (Dq), estimated as the cyclical component of the Hodrick-Prescott decomposition on the real exchange rate index. It is worth noting that we use the volatility of the exchange rate of the peso as a measurement of the nature of its changes: if the volatility is high we suppose that exporters perceive such changes as transitory, while if it is low, we assume that exporters perceive such changes as permanent. An additional transition variable that was analyzed was inflation without its trend ($\bar{\pi}^{IPC}$), as an effort to differentiate a "high" inflation regime from a "low" one.

Table 2 contains the results of the individual linearity tests, as well as the joint test ("All"), for the different transition variables which are organized according to the value of the F statistic (the null hypothesis is linearity). As can be seen, the statistic does not, in all cases, indicate the presence of non-linearity in an equation or in the whole system with respect to a possible transition variable. For example, the level of commercial openness generates non-linearity in the system through the equation of imported goods inflation and of the inflation of the competing goods by both its d=1 and its d=2 lags. Summarizing, the F joint test shows evidence of non-linearity in the system when commercial openness, the degree of misalignment of the real exchange rate, the output gap and the variation of CPI inflation and devaluation are utilized as transition variables.

[13] Portmanteau Test (asymptotic): χ^2_{208} = 227.6, p-value = 0.166; Asymmetry (multi-varied): χ^2_4 =7.43, p-value = 0.114; nevertheless, the kurtosis shows: χ^2_4 = 30.4858, p-value = 0.00.

Table 2: Results of the linearity tests*

Transition variable	*d*	*Dependent Variable*									
		π^{pm}		π^{pl}		Δe		Δc^*		**All**	
		F	***P-Value***	***F***	***P-Value***	***F***	***P-Value***	***F***	***P-Value***	***F***	***P-Value***
Open	1	2.16	0.02	4.14	0.00	1.57	0.11	1.15	0.33	1.48	0.02
Dq	1	2.32	0.01	1.08	0.39	2.46	0.01	1.41	0.17	1.40	0.04
Open	2	1.97	0.03	3.83	0.00	1.26	0.26	0.82	0.66	1.41	0.04
Dq	1	2.36	0.01	1.01	0.46	2.40	0.01	1.73	0.07	1.38	0.05
Gy	1	1.91	0.04	1.60	0.10	1.97	0.03	2.08	0.02	1.36	0.06
$\Delta\pi^{CPI}$	3	0.97	0.49	3.27	0.00	1.32	0.22	1.51	0.13	1.35	0.06
$\Delta\pi^{CPI}$	3	0.97	0.49	3.27	0.00	1.32	0.22	1.51	0.13	1.35	0.06
$\Delta(\Delta e)$	3	3.07	0.00	2.65	0.00	1.89	0.04	1.16	0.32	1.32	0.07
Open	7	0.73	0.75	4.18	0.00	0.52	0.92	1.68	0.08	1.28	0.10
Gy	2	2.41	0.01	1.45	0.15	2.41	0.01	1.35	0.20	1.23	0.14
Gy	5	1.90	0.04	1.20	0.30	2.17	0.02	1.81	0.05	1.22	0.15
Gy	4	1.60	0.10	0.78	0.69	2.10	0.02	2.08	0.02	1.18	0.20
π^{CPI}	1	0.75	0.72	5.91	0.00	0.73	0.75	1.50	0.13	1.16	0.22
$V(\Delta e)$	8	0.97	0.50	0.74	0.74	0.60	0.86	2.50	0.01	1.16	0.22
$V(\pi^{CPI})$	5	1.59	0.10	4.49	0.00	1.29	0.24	0.62	0.84	1.09	0.33
$\bar{\pi}^{CPI}$	2	1.82	0.05	1.94	0.03	1.86	0.05	1.58	0.11	0.96	0.56
$V(\pi^{CPI})$	2	2.05	0.02	3.12	0.00	1.17	0.32	1.21	0.29	0.89	0.69
π^{CPI}	5	1.74	0.07	3.30	0.00	1.48	0.14	1.77	0.06	0.85	0.77
$V(\Delta e)$	5	1.98	0.03	1.76	0.06	1.02	0.45	0.95	0.52	0.45	1.00
$V(\Delta e)$	1	2.17	0.01	0.91	0.62	1.66	0.07	1.19	0.31	0.53	1.00

Source: Authors' calculations

* The definitions of the variables are: π^{pm}: Inflation of imported goods; π^{pl}: Inflation of the local competing goods; Δe: Nominal devaluation; Δc^*: Foreign firm's marginal cost; *Open*: Degree of economic openness; *Dq*: Measurement of the degree of misalignment in the real exchange rate; *Gy*: Output gap; π^{CPI}: CPI inflation; $\Delta\pi^{CPI}$: Inflation variation; $\Delta(\Delta e)$: Variation in devaluation; $V(\Delta e)$: Volatility in the exchange rate; $V(\pi^{CPI})$: Volatility of inflation; $\bar{\pi}^{CPI}$: Inflation without linear tendency; *p*: VAR order; *d*: Transition variable lag.

It is good to emphasize that when only the interest equation is considered, that is to say the equation of the inflation of the imported goods, the non-linearity result is robust to the changes in the VAR order and of the number of lags in the transition variable in the cases of the devaluation variation, the output gap and the degree of misalignment of the real exchange rate. Moreover, in the case of this equation, the inflation level and its volatility, inflation without tendency and volatility of the exchange rate appear as sources of non-linearity.

5. THE NON-LINEAR VECTOR REGRESSION MODEL AND ESTIMATIONS

5.1 The Regression Model

We used a logistic smooth transition vector auto-regressive (LSTVAR) model which makes it possible to model and diagnose the types of asymmetries discussed:

$$Y_t = \begin{bmatrix} \pi_t^{pm} \\ \pi_t^{pc} \\ \Delta e_t \\ \Delta c_t^* \end{bmatrix} = A(L)Y_{t-1} + F(V_{t-d}\,;\gamma,c)B(L)Y_{t-1} + \boldsymbol{\mu}_t \tag{4}$$

with $F(V_{t-d}\,;\gamma,c)$ being a diagonal matrix whose elements f_j are transition functions, $f_j(\cdot) = \{1 + \exp[-\gamma_j(V_t - c_j)]\}^{-1}$ represents the cumulative function of logistical probability, $V_{j,t}$ the transition variable, γ_j the smoothing parameter ($\gamma_j > 0$), c_j the localization parameter, and $\boldsymbol{\mu}_t$ the error vector.[14] The parameters γ_j and c_j together with $V_{j,t}$ govern the transition between regimes. Thus when $\gamma_j \to \infty$ and $V_{j,t} < c_j$ we are in the regime $A(L)Y_{t-1}$, while when $\gamma_j \to \infty$ and $V_{j,t} > c_j$ we are then in $[A(L) + B(L)]Y_{t-1}$. For finite values of γ_j, we have a continuum between the two extreme regimes.

The advantages of a non-linear model with respect to a linear one can be summarized by the following: 1) it is state or regime dependent, which means that the effect of the exogenous on the endogenous variables depends on the level of the two; 2) the responses of the dependent variable depend on the size of the shocks, as in the one we are analyzing. Prices could react different ways in the presence of different sizes of shocks; and 3) the response of the dependent variable depends on the sign of the shock. In summary, non-linear models make it possible to study the asymmetries in the transmission of the shock to the exchange rate on the rest of the variables which is the objective of this study.

The choice of definitive transition variables for the estimation of equation (4) took into

[14] See He, Terävirta and Gonzalez (2009) for more details.

account the following criteria: first, the chosen transition variables in the previous step; second, the statistical meaning of the transition variables in the equation of the inflation of imported goods; finally, the *d* lag, in accordance with the estimated and expected path of the degree of ERPT. The selected transition variables were: commercial openness, the degree of misalignment of the real exchange rate, the output gap, the variation in inflation and devaluation, the volatility of inflation and of the exchange rate, and inflation without trend.

5.2 Estimation

The estimate of the regression model given by equation (4) is done by using the Newton-Raphson algorithm. This algorithm requires having initial values. This is done by utilizing genetic algorithms.[15] For the localization parameter c_j, the search is limited to the range of the percentile 15% to 85% of the transition variable under consideration, and for y_j, the search interval is from 0.1 to 300. Values above 300 produce the same value in the likelihood function in so far as the LSTVAR approximates a VAR with very high failure values. As could be expected, the value of *c* is usually located in the center of the distribution of the chosen transition variable. The importance of the parameter *c* value is that it allows the regimes to be cataloged based on the values of the transition variables. For example, highs and lows, high, middle and low, or as rises and falls, etc.

The most relevant results for the LSTVAR models that were finally selected are shown in Table 3. For the different transition variables considered, the values of the transition function coefficients, the number of observations for each regime and the value of the *Threshold* used to generate each regime are presented. As can be seen, when the transition variable is the output gap, the transition parameter estimated and the value of the *Threshold* are both equal to 1.02. The number of observations that are classified in the "Low" regime

[15] The algorithm is introduced by Brooks and Morgan (1994) and the calculations were carried out with the R program (See Ihaka and Gentleman, 1996). The distribution of R is free under the terms of GNU (www.r-project.org).

is 53 and in the "High," 16. That is to say, the observed real GDP was 1.02 points of the GDP above the potential GDP in 77% of the analyzed quarters. In contrast, in the case of the variations in inflation or devaluation, the *Threshold* is zero since we are interested in estimating the effect on the ERPT if the peso accelerates (+)/decelerates (-) its depreciation/appreciation or if CPI inflation accelerates (+)/decelerates (-).[16]

Table 3: Results of the estimation of the LSTVAR regression
According to the Transition Variable

Transition Variable	Estimated Parameters		No. observations per regime		Threshold
	γ	c	Low	High	
Gy	65.9	1.02	53	16	1.02
$Open$	300.0	0.39	28	41	0.34
$V(\Delta e)$	300.0	0.02	5	61	0.02
Dq	295.8	-1.77	14	55	-1.77
$\Delta(\Delta e)$	69.5	-3.78	35	33	0
$\Delta\pi^{IPC}$	300.0	0.21	37	30	0
$V(\pi^{IPC})$	300.0	1.62	9	60	1.62
$\bar{\pi}^{IPC}$	233.5	6.67	28	41	6.67

Source: Authors' calculations.

Figures A.6.1 to A.6-8 (Appendix A.6) show the transition variables, their thresholds and their transition functions. For the purpose of illustrating the results, the figures of the volatility of the exchange rate (Figure A.6-3) and the inflation without tendency (Figure A.6-8) are explained. In the first case, the transition between one regime and another is very smooth (center figure). Not only the trajectory of the variable (upper figure) but also its historical transition function (lower figure) show three critical moments throughout the sample. The first one, between the middle and the end of the 90s due to the turbulence of the international capital markets (in 1999 the emerging markets faced the second year of massive capital out-flows due to the Asian crisis and Russia's default) and the internal fiscal unsustainability, which put an end to the exchange rate band regime in force in the country as of 1994. The second, around the year 2002 with the rise in the spreads in

[16] In the case of the *Open* variable, the value of the *Threshold* was modified in such a way that the observations were distributed between the two regimes in a more balanced fashion and a better estimate was achieved.

emerging countries after the economic slowdown of industrialized economies and the regional economic and political deterioration, especially because of the Argentine debt crisis (the spreads of Colombian debt rose by 500 base points between June and September 2002). The third, at the end of the sample, was due to the turbulence in the international markets because of the mortgage crisis in the United States and other industrial countries.

In the case of the inflation, an abrupt transition between the "high" and "low" inflation regimes is seen (central figure). Clearly, the historical transition function (lower figure) shows the known periods of high inflation between the beginning and end of the 90s and of low inflation under the inflation targeting regime (2000 and now). The behavior of inflation in the latest observations in the sample, which anticipates a change from a regime of low inflation to one of high inflation due to the internal and external shocks that have recently confronted the economy, is to be highlighted.

5.3 Estimations of the Degree and Dynamic of the ERPT

Table 4 and figures A.7-1 to A.7-8 (Appendix A.7) show the degree and path of the ERPT coefficients for the non-linear model given by equation (4), for different periods and for the selected transition variables in the presence of a standard deviation shock to the devaluation.[17]

The first conclusion we can extract is that the degree of ERPT is incomplete for the analyzed data both in the short and long run. This is evidence against a complete exchange rate transmission, just as competitive models predicts, and to the hypothesis of purchasing power parity. When there is a structural shock to the devaluation of the peso, between 6% is transmitted in the first two quarters and 58% in the long run independently of the sing and size of the shock and the state of the economy.

[17] In Appendix A.5 the methodology used to estimate the ERPT coefficients is explained step by step.

Table 4: Average Estimates of the ERPT coefficients from the LSTVAR regression

Transition variable	Shock size		Positive structural shock to devalaution				Negative structural shock to devalaution			
	# Est. Dev.	% points	Two quarters	One year	Two years	Five years	Two quarters	One year	Two years	Five years
						Econonic expansion				
Gy	1	3,5	33,7	52,4	58,0	58,4	41,4	62,8	59,1	58,1
	5	17,3	33,7	52,4	58,0	58,4	23,6	36,3	41,7	42,9
						Econonic contraction				
	1	3,5	27,5	40,0	45,5	46,6	31,4	43,3	47,7	51,3
	5	17,3	27,5	40,0	45,4	46,6	21,2	32,6	38,7	40,3
						High economic openness				
Open	1	3,5	25,3	32,6	36,5	37,2	25,3	32,7	36,5	37,2
	5	17,7	25,3	34,3	36,5	37,1	25,3	32,6	36,5	37,2
						Low economic openness				
	1	3,5	25,3	32,5	36,4	37,2	25,3	32,5	36,4	37,2
	5	17,7	25,3	34,3	36,4	37,2	25,3	32,6	36,4	37,2
						High exchange rate volatility				
$V(\Delta e)$	1	3,7	17,1	27,3	34,2	36,9	17,1	27,3	34,3	37,0
	5	18,5	17,1	27,3	34,2	36,9	17,1	27,3	34,2	36,9
						Low exchange rate volatility				
	1	3,7	19,4	29,5	40,0	43,4	19,4	29,5	40,0	43,3
	5	18,5	19,3	29,4	39,9	43,3	19,3	29,5	39,9	43,3
						Undervalued real exchange rate				
Dq	1	3,5	19,4	27,7	32,6	33,8	19,4	27,7	32,6	33,8
	5	17,7	19,4	27,7	32,7	33,8	19,4	27,7	32,1	33,9
						Overvalued real exchange rate				
	1	3,5	22,3	34,2	40,4	41,7	22,4	34,2	40,5	41,8
	5	17,7	22,4	34,2	40,5	41,8	22,4	34,2	39,9	41,8
						Acceleration of depreciation/appreciation of the currency				
$\Delta(\Delta e)$	1	3,6	25,9	35,2	40,7	42,7	26,0	35,2	40,8	42,8
	5	18,2	26,0	35,2	40,8	42,8	26,0	35,2	40,8	42,8
						Deceleration of depreciation/appreciation of the currency				
	1	3,6	25,3	34,6	40,3	42,2	25,3	34,5	40,2	42,2
	5	18,2	25,3	34,6	40,3	42,2	25,3	34,6	40,3	42,2
						Acceleration of the CPI inflation				
$\Delta\pi^{IPC}$	1	3,2	24,6	34,8	39,8	41,6	24,6	34,8	39,8	41,6
	5	16,2	24,7	34,9	39,9	41,6	24,8	34,1	38,5	39,8
						Deceleration of the CPI inflation				
	1	3,2	24,2	36,8	42,4	44,2	24,2	36,9	42,5	44,2
	5	16,2	24,2	36,8	42,5	44,2	24,2	36,7	42,4	44,3
						High volatility of inflation				
$V(\pi^{IPC})$	1	3,6	6,3	9,7	10,8	10,9	6,3	9,7	10,8	10,9
	5	17,8	6,3	9,7	10,8	10,9	10,1	13,6	15,1	15,2
						Low volatility of inflation				
	1	3,6	13,7	26,9	27,6	27,5	13,7	26,9	27,5	27,5
	5	17,8	13,7	26,9	27,6	27,6	16,2	30,2	31,4	31,3
						"Hight" inflación				
$\overline{\pi}^{IPC}$	1	3,7	21,1	33,1	37,1	37,7	21,1	33,1	37,1	37,7
	5	18,6	21,1	33,1	37,1	37,7	21,1	33,1	37,1	37,7
						"Low" inflación				
	1	3,7	14,3	21,5	26,4	28,5	14,3	21,5	26,4	28,5
	5	18,6	14,3	21,5	26,4	28,5	14,3	21,5	26,4	28,5

Source: Authors' calculations.

In the second place, the results show overwhelming evidence of the endogeneity of the ERPT coefficient to the speed of the changes and volatility of the exchange rate and the state of the economy.

In the third place, the evidence indicates the presence of asymmetries in the degree and evolution of the ERPT. The ERPT is greater when the economy is booming, more open, the depreciation/appreciation of the peso accelerates, the exchange rate is less volatile (that is, the export firms expect the movements in the exchange rate to be permanent), the real exchange rate is overvaluated, and the inflation rate is "high" and less volatile, and it decelerates. These results go in the direction that has been reported recently in the literature as was discussed at the beginning of the document.

For example, if there is a slowdown in the economic activity (figure A.7-1), 27.5% of the structural shock to the devaluation of the peso is transmitted to import price inflation in two quarters, 40% in a year, 45.5% in three years and 46.6% if the recession continues. Meanwhile, if it is booming, the transmission rises from 33.7% in the short run to 58.4% in the long run.

It should be emphasized our findings from both the inflation variation and its volatility. In the first case, and independently of the sing and size of the shock to depreciation, the degree of the ERPT is higher in the first two quarters when the CPI inflation accelerates; however, starting the first year, that behavior reverses (figure A.7-6). In the case of the inflation volatility, if it is high, the degree of ERPT is lower (figure A.7-7). This means that the foreign firm transfers less of the devaluation of the peso to its prices when there is higher uncertainty on the nature of the inflation variations (trasnsitory versus permanent changes) than otherwise.

Finally, if the results of the linear VAR model are compared with those of the LSTVAR, there are apparently no important differences in the degree of ERPT or in its dynamic.

Nevertheless, the difference is clear; the results of the first model are statistically more uncertain and less informative.

6. CONCLUSIONS

There are two key motives for the study of ERPT. In the first place it is to know about the ability the nominal exchange rate has to make macro-economic adjustment in the short term. In the second place, it helps with the analysis and as an element of judgment for making decisions on monetary policy. In this document, the degree of transmission of the nominal exchange rate variations to the prices of the goods imported by Colombia in the presence of asymmetries is estimated.

The results show that the transmission of the shocks to the exchange rate on the prices of imported goods is incomplete not only in the short but also in the long run which subtracts from the ability of the nominal exchange rate to make automatic adjustments.

We also found that the degree and dynamic of the transmission are endogenous and asymmetrical to the behavior of the exchange rate and to the state of the economy.

The degree of transmission of the depreciation of the domestic currency to the inflation of import prices is greater when the economy is booming and more open, the devaluation/appreciation of the exchange rate accelerates and is less volatile, the real exchange rate is overvaluated, and the inflation rate is high and less volatile, and it decelerates.

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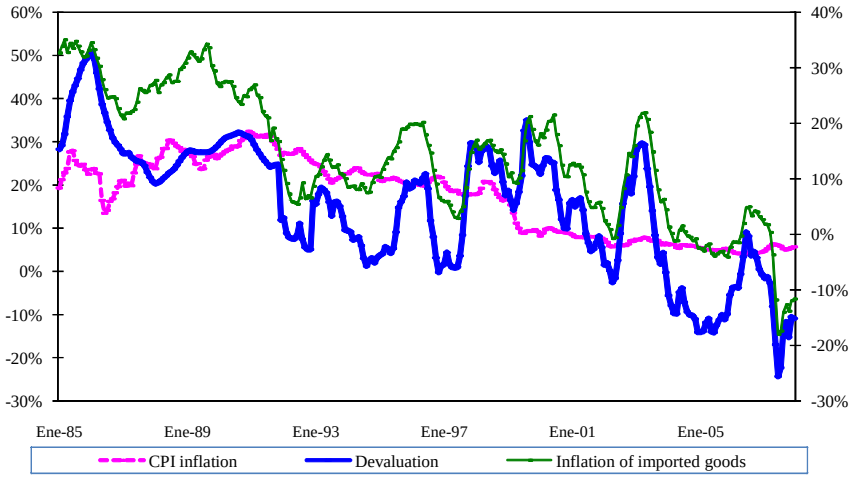
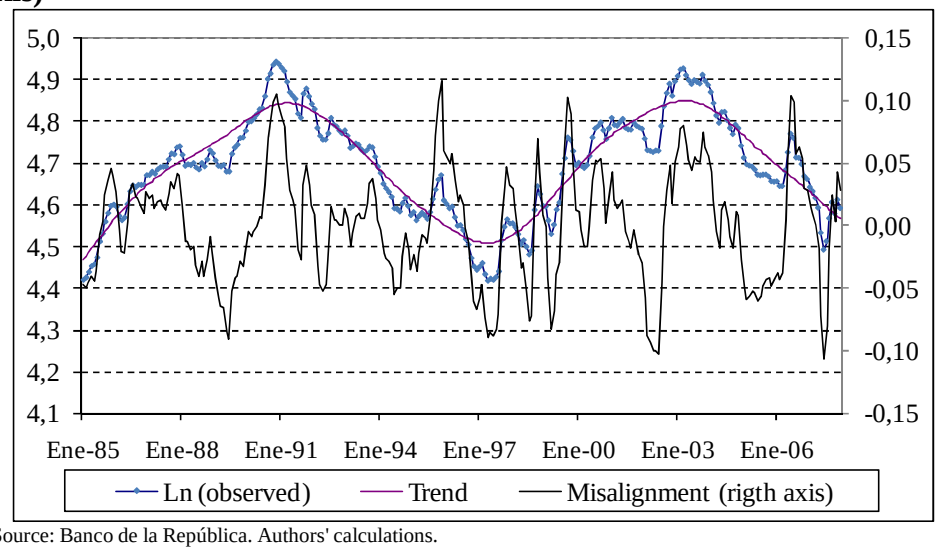
APPENDIX

A.1: CPI inflation (left axis), imported goods inflation and devaluation (right axis)



Source: Banco de la República. Authors' calculations.

A.2: Logarithm of the real exchange rate index and trend (left axis), and misalignment (right axis)



Source: Banco de la República. Authors' calculations.

A.3: A STATIC AND PARTIAL EQUILIBRIUM MODEL OF IMPERFECT COMPETITION

Suppose that the market equilibrium of this model implies that the foreign firm being analyzed fixes an export price above their marginal cost and that there is perfect substitutability between the good that is exported and the good that is produced in the importing country. The earnings of the firm are given by:

(A-1) $$\pi^* = P^* x^* - CT^*(x^*).$$

P^* is the price at which the good is sold in the importing country, x^* is the quantity produced of the good that is exported and $CT^*(.)$ is the function of the total costs. The first order condition for their problem of maximizing earnings is:

(A-2) $$P^*\{1 - S/\eta\} = C^*.$$

S is their market share and η is the price elasticity of demand in the importing country, and C^* is their marginal cost which is assumed to be constant in their currency. Rewriting the equation (A.2):

(A-3) $$P^* = \kappa C^*$$

k is the markup which is a growing function of their market share, S. The import price (in local currency) will then be:

(A-4) $$P_M = EP^* = E(\kappa C^*),$$

where E is the nominal exchange rate of the importing country (measured in units of the country's currency by unit of the exporting country's currency). Now assume that k can vary and that it depends on the pressures of demand and of the competition in the market of the importing country. These are captured by the price of the substitute good produced in the importing country (P_c) and by the production costs (C^*) in units of the importing country's currency. Thus the markup is defined as:

(A-5) $$\kappa = \{P_C / EC^*)^{\varsigma}$$

Now equation (A.5) is replaced in (A.4), the logarithm is taken and reorganized to get (the small letters indicate variables in natural logarithm):

(A-6) $$p_m = \varsigma p_c + (1-\varsigma)e + (1-\varsigma)c^*,$$

where the pass-through coefficient of the exchange rate (ERPT) is represented by $(1-\varsigma)$, $0 \leq \varsigma \leq 1$.

A.4: TIME SERIES AND SOURCES

- *Pm*: Whole prince index of Colombian imported goods (Base: 2006). Not seasonally adjusted. Source: Banco de la República (unpublished statistics).
- *CPI*: Colombian Consumer Price Index (CPI) (Base: December 98). Not seasonally adjusted. Source: Banco de la República (http://www.banrep.gov.co/series-estadisticas).
- *Pl*: Colombian wholesale prices index of domestic produced and consumed goods (Base 2006). Not seasonally adjusted. Banco de la República (unpublished statistics).
- *E*: Effective nominal exchange rate index (local currency / foreign currency). It is weighted using trade weights. Due to limited information, the only data used is exchange rate and trade weight from: United States, Germany and Japan, which represented about 50% of total Colombian imports during the sample period. Source: CD Room of the IMF International Financial Statistics (IFS-IMF). Source: series of exchange rate: Japan: "line 158 ..RF.ZF ..." Germany "line 134…RF.ZF ..." and "line 163 .. RF.ZF ..." of IFS-IMF; United States: bilateral exchange rate Colombian peso / dollar. Source: trade statistics: part of the External Sector, section of Economic Studies, Banco de la República.
- Δe: Exchange rate devaluation = $\ln E_t - \ln E_{t-4}$.

- $V(\Delta e)$: Exchange rate volatility. It is calculated as the standard deviation of Δe using a moving window of four quarters.
- *Open*: Indicator of the Colombian economic openness. It is calculated as the ratio between total imports plus exports and nominal GDP. Source: Banco de la República (http://www.banrep.gov.co/series-estadisticas/see_s_externo.htm#comercial and http://www.banrep.gov.co/series-estadisticas/see_prod_salar_94.htm).
- C^*: Trade weighted measure of the foreign country's marginal costs. First we obtained a proxy for each of the foreign countries' marginal costs (foreign countries: United States, Germany, and Japan). Each marginal cost was calculated as a weighted average of the unit labor cost (*ULC*), raw materials and energy costs. Weights were taken from the cost structure of each of the countries. Second, the weighted average costs were re-weighted by the respective trade weight into the Colombian imports coming from those countries.
- *ULC*: Unit labor cost index. It was built as each country's ratio of the rate of wages in manufacturing and the industry's productivity. Productivity is calculated as the ratio of production and employment rate.

Sources:

= United States: industrial production index "line 11166 ..CZF ...", manufacturing employment index "line 11167EYCZF", industrial wages index "line 11165 ... ZF ..." (rates taken from IMF-IFS). All indices are seasonally adjusted. The costs of raw materials and energy were taken from: http://data.bls.gov/cgi-bin/surveymost?wp.

= Germany: industrial production index "line 13466.ACZF...", industrial wages index "line 13465 ... ZF ..." (indexes taken from IFS-IMF). The industrial employment index "Mining and Quarrying Manufacturing Employment" taken from: http://www.bundesbank.de/statistik/statistik_zeitreihen.en.php?lang=en&open=&func=list&tr=www_s310_mb09_06. All indexes are seasonally adjusted. The costs of raw materials and energy were taken from: http://www.bundesbank.de/statistik/statistik_zeitreihen.en.php?lang=en&open=&func=list&tr=www_s310_mb09_07b.

= Japan: Industrial production index: line 15866 .. CZF ... " Manufacturing employment index:" line 15867EYCZF " industrial wages index " line 15865 ... ZF ... "(indexes taken from IMF-IFS). All indexes are seasonally adjusted. The costs of raw materials and energy were taken from: http://www.boj.or.jp/en/theme/research/stat/stop/wpi/index.htm.

- Effective real exchange rate index (weighted by the CPI). Source: Subgerencia Estudios Economicos, Banco de la Republica.
- Annual inflation = $(\ln CPI_t - \ln CPI_{t-1})*100$.
- Gross Domestic Product (GDP). Source: Programming and Inflation Department, Banco de la República.
- Gap of GDP. Source: Programming and Inflation Department, Banco de la República.

A.5: NON-LINEAR MODEL: ESTIMATE OF ERPT BY MEANS OF THE RE-SAMPLING TECHNIQUE (BOOTSTRAPPING)

In this Appendix the most important details of the methodology for the ERPT coefficient estimate are summarized. Specifically, the most important modifications that we did with

respect to similar procedures such as those of Koop et. al. (1996) and Wilkerlied (2003) are highlighted. The generalized impulse response function is defined as the effect of a shock on the model's predicted values. Formally, if:

(A-7) $$\mathrm{Y_t} = \mathrm{A(L)Y_{t-1}} + \mathrm{B(L)Y_{t-1}F(V_{t-d}\,;\gamma, c)} + \boldsymbol{\mu}_\mathrm{t} \quad ,$$

in the presence of a unitary shock to the k^{th}-element of the perturbations vector $\boldsymbol{\mu}_t$, the result is:

(A-8) $$G(j) = E\left[Y_{t+j}|\mu_{k,t} = s\sigma, W_{t-1}\right] - E\left[Y_{t+j}|\mu_{k,t} = 0, W_{t-1}\right],$$

where W_{t-1} denotes the initial conditions of the shock. Afterwards, the ERPT on a τ horizon is calculated by means of the following procedure (we are interested in knowing the degree of ERPT under the $V_{t-d} < Threshold$, where *Threshold* is the value of parameter *c*):

1. Choose all the points in the sample where the $V_{t-d} < Threshold$ is met. The number of these points will be written *N_inferior*.
2. For each one of these points forecast the model for *T* periods ahead through a resampling simulation, while considering the respective history for the elements of vector V_{t-d} and the observed values brought forward. This history is built by means of the bootstrapping technique: randomly capture (through a sampling with restitution) *T* historical values for each one of the estimated residuals in the system. With that you get $E\left[Y_{t+j}|\mu_{k,t} = 0, W_{t-1}\right]$ for $j = 0, 1, ..., T$.
3. Simulate the model for *T* periods ahead considering the same history for the elements of vector V_{t-d} from step 2, after subjecting the third element of V_t (corresponding to the devaluation) to a shock (add $s\sigma$ en $j=0$). With that you get for $E[Y_{t+j} \mid \mu_t = s\sigma, W_{t-1}]$ for $j = 0, 1, ..., T$. We considered different values of *s*.
4. Calculate $G(j)$ in accordance with (A-8).
5. Return to step 1 *B* number of times. *B* is considered to equal 600.

With this procedure, there is a resulting total of *N_inferior* x *B* trajectories for ERPT, considering $V_{t-d} < Threshold$ as initial conditions (for example, that the economy is in a regime of "high" inflation or in recession). Figures A.6.1 to A.6.8 show the median of these trajectories and their percentiles 15 and 85. To study the $V_{t-d} > Threshold$ case, the procedure should be repeated by taking this new criteria as the initial condition (step 1). In the simulations that are presented, shocks orthogonalized through the *Cholesky decomposition* were used.

A.6: FIGUERES OF TRANSITION VARIABLES, THRESHOLDS AND TRANSITION FUNCTIONS

Figure A.6-1: Output gap

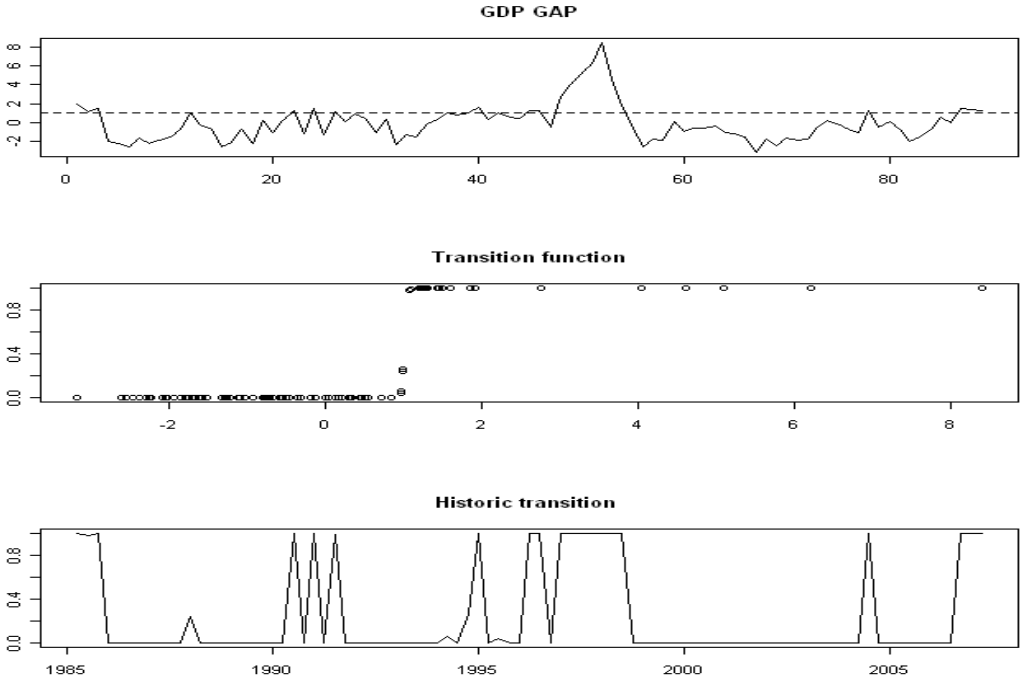


Figure A.6-2: Openness degree

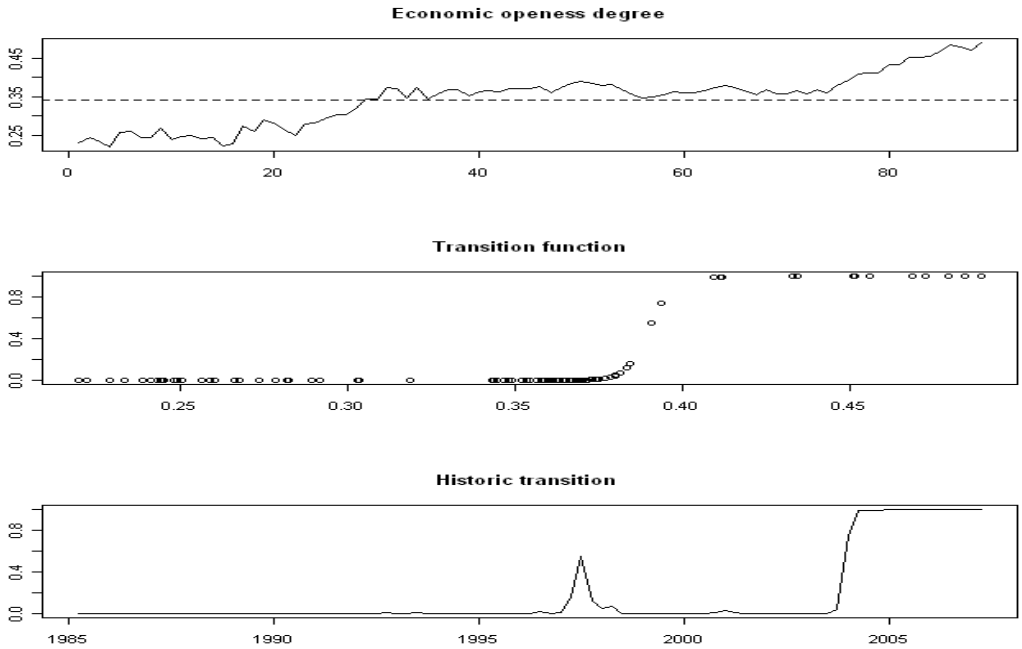


Figure A.6-3: Volatility of the nominal exchange rate

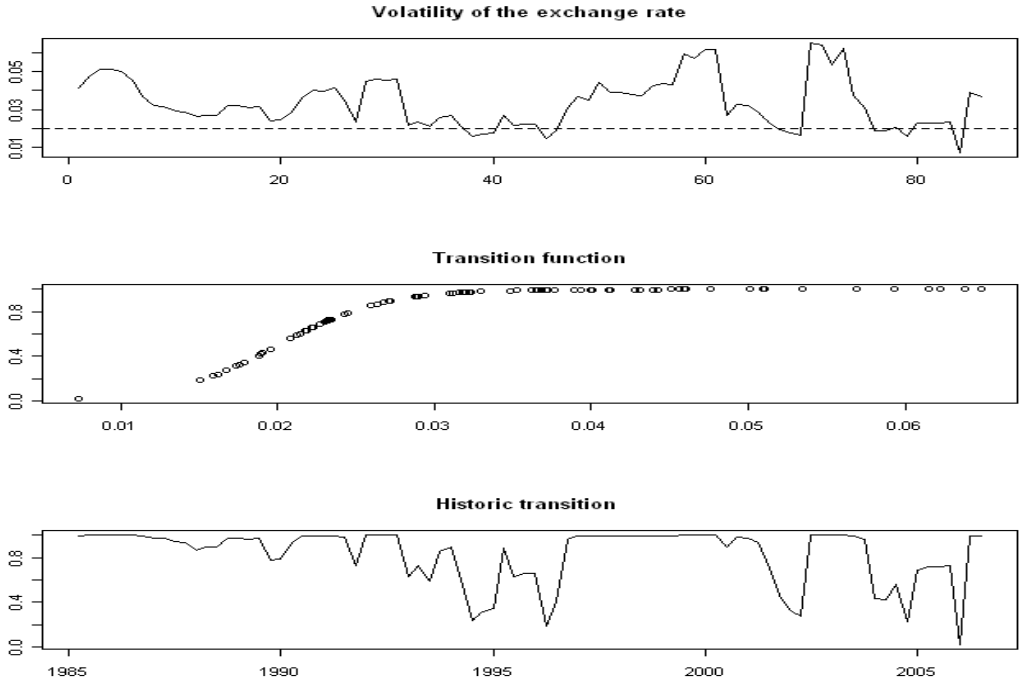


Figure A.6-4: Real exchange rate misalignment

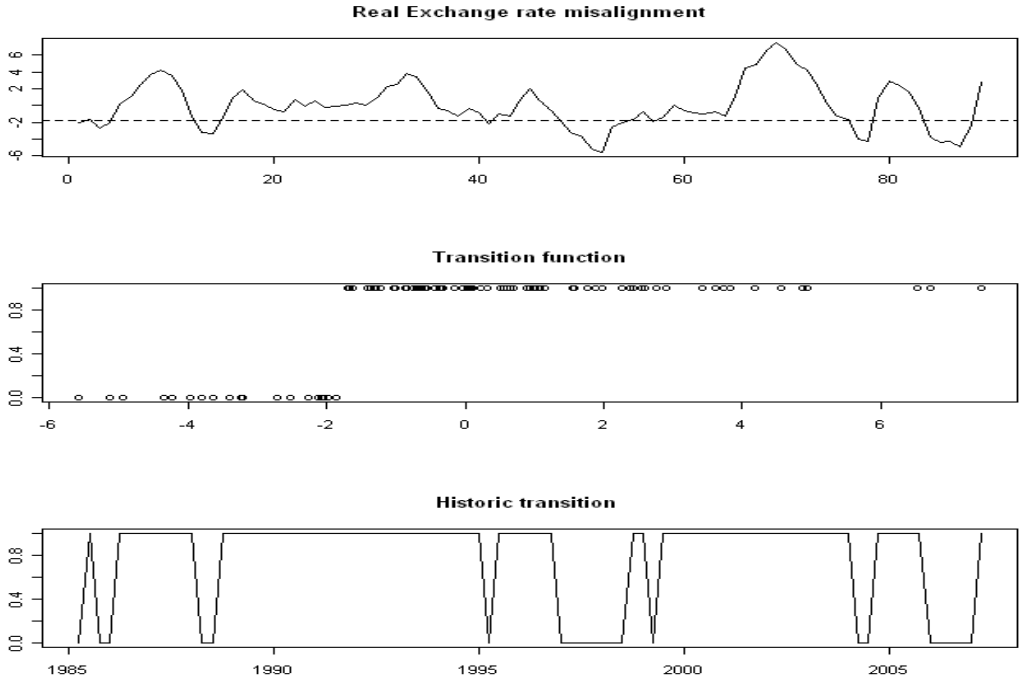


Figure A.6-5: Variation of devaluation

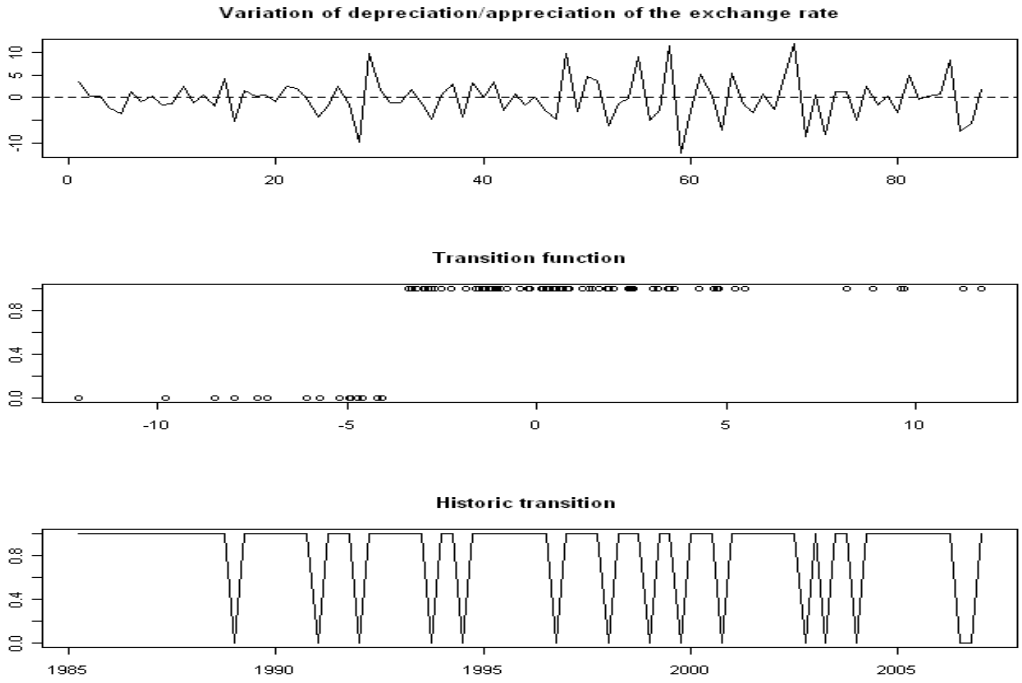


Figure A.6-6: Inflation variation

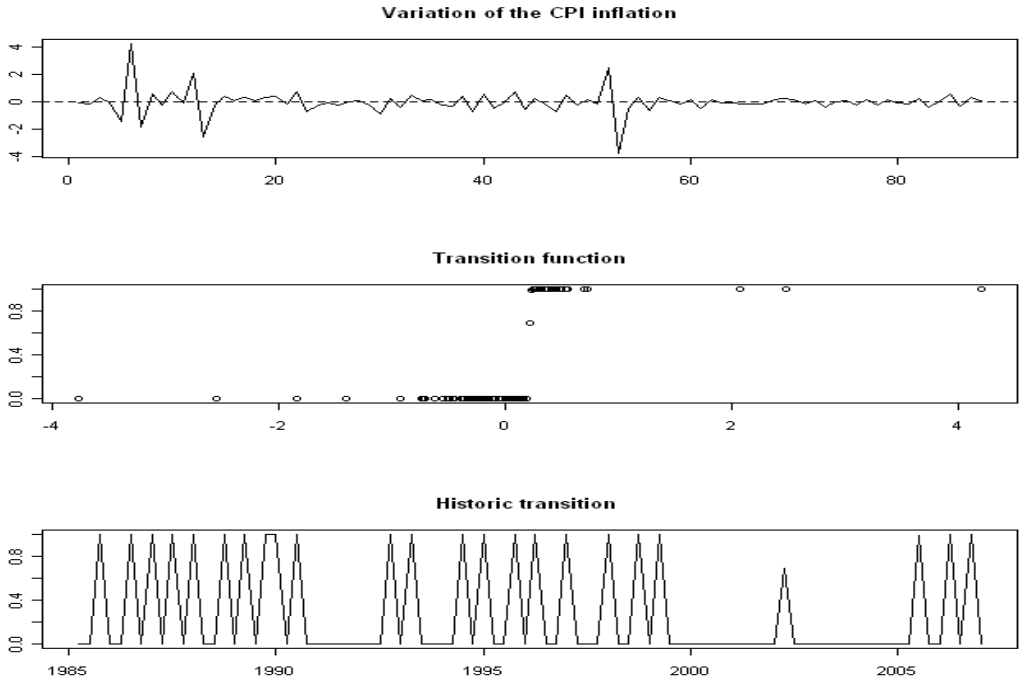


Figure A.6-7: Inflation volatility

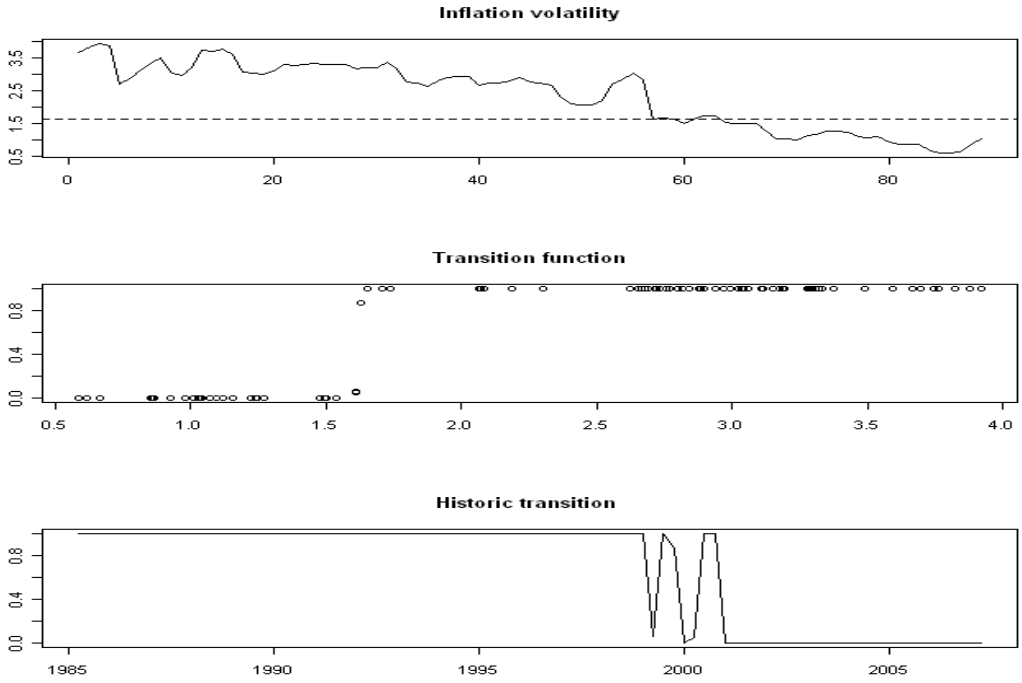
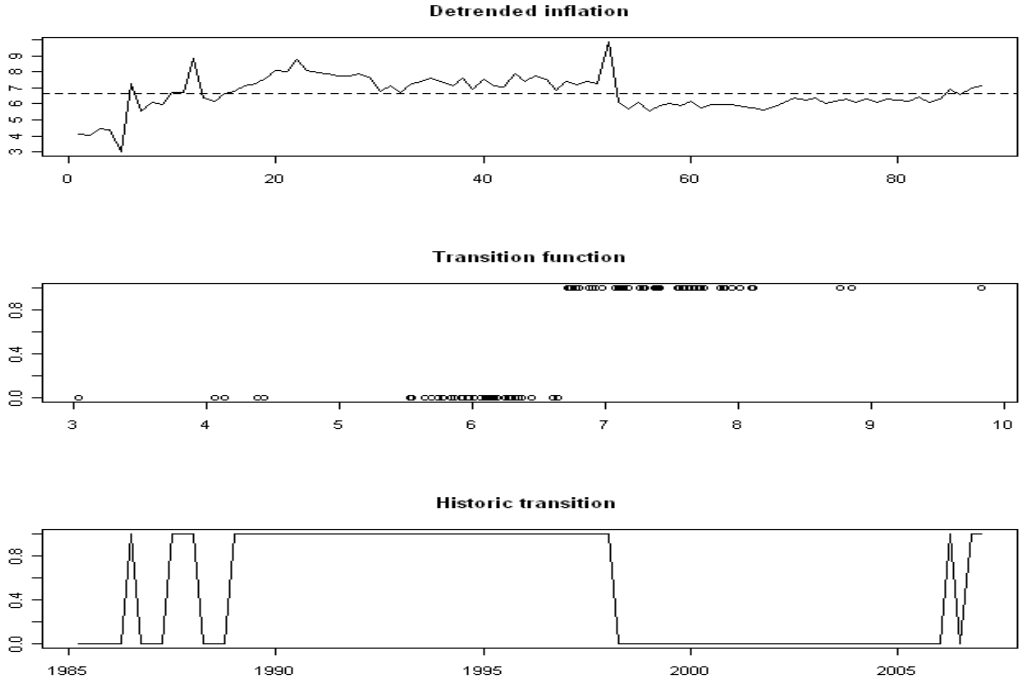


Figure A.6-8: Inflation without trend



APPENDIX A.7: ERPT estimated paths (LSTVAR model)

Figure A.7-1 Transition variable: Output gap

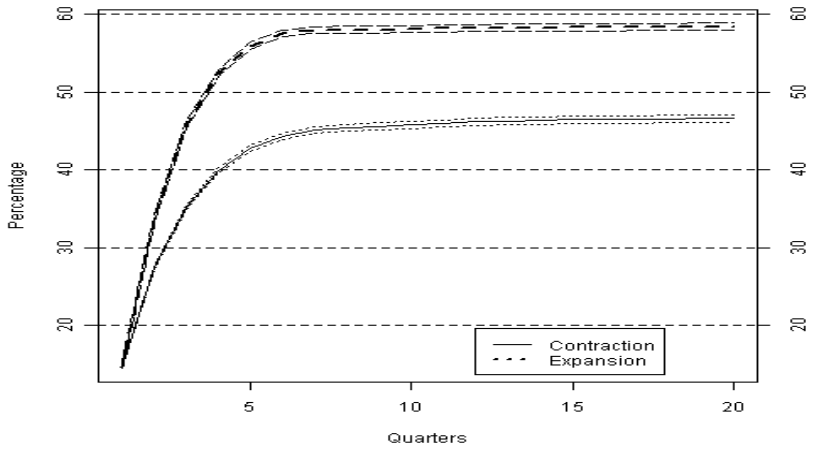


Figure A.7-2 Transition variable: Economic openness

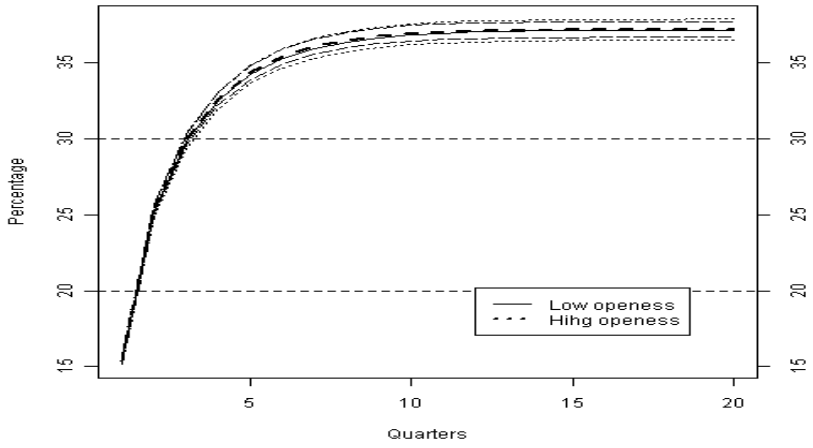


Figure A.7-3 Transition variable: Nominal exchange rate volatility

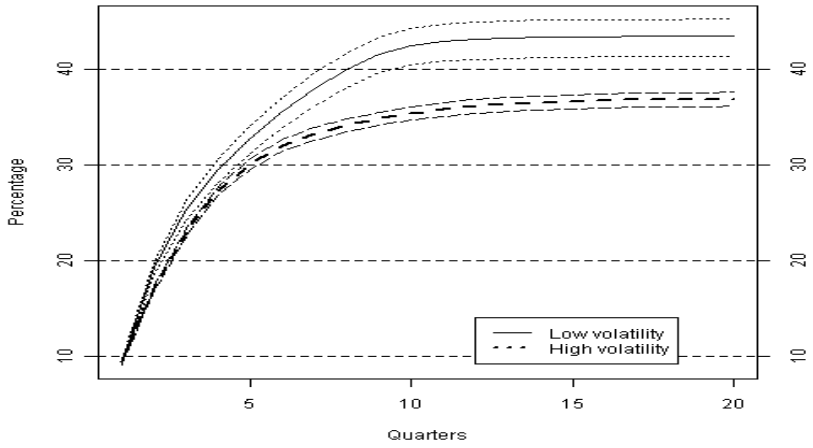


Figure A.7-4 Transition variable: Real exchange rate misalignment

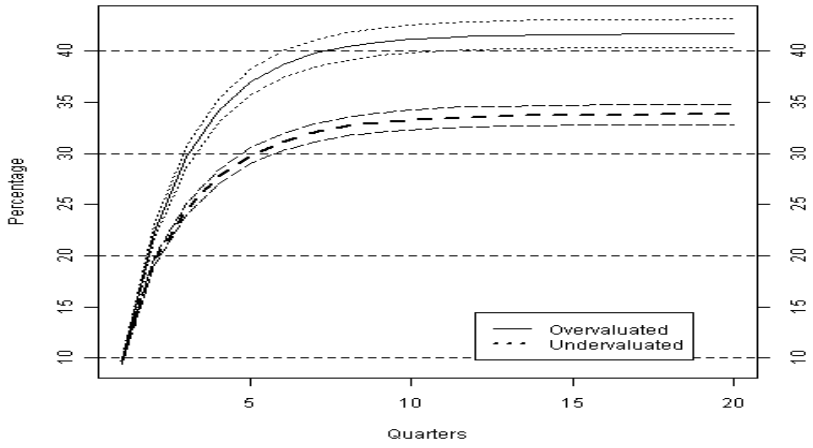


Figure A.7-5 Transition variable: Variation of devaluation/appreciation of the peso

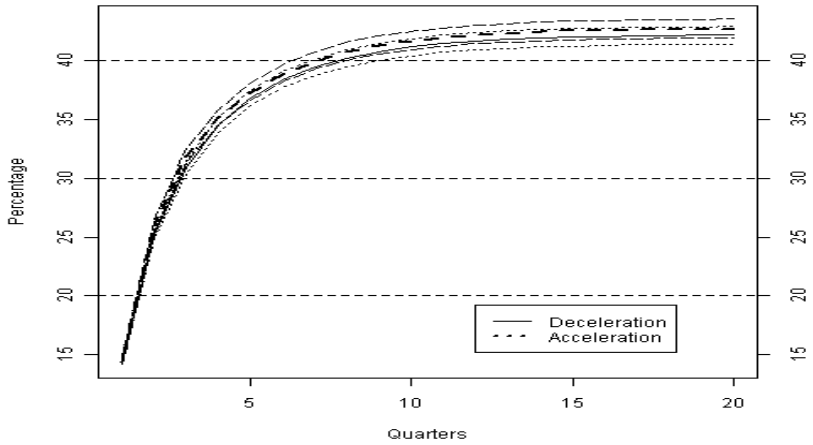


Figure A.7-6 Transition variable: Variation of CPI inflation

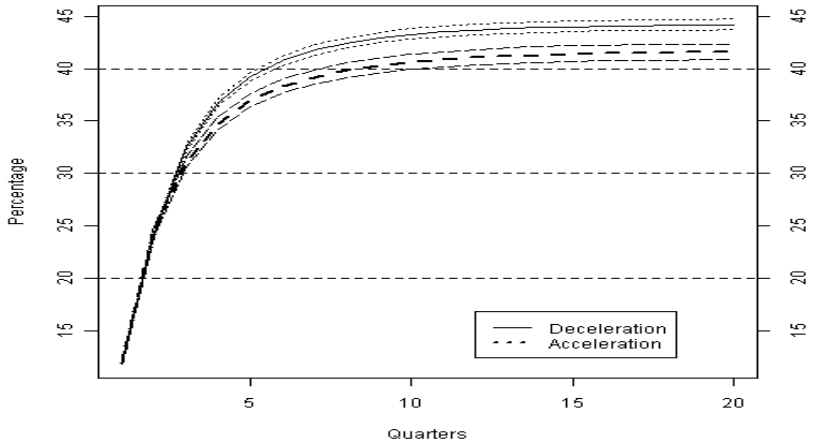


Figure A.7-7 Transition variable: Volatility of inflation

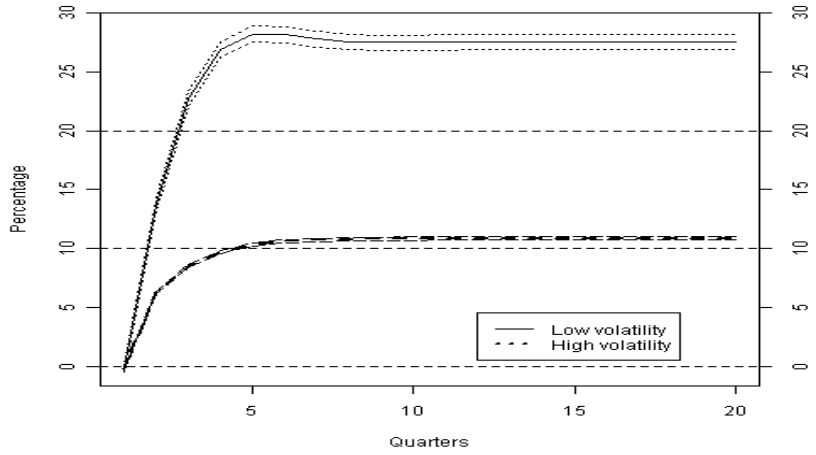


Figure A.7-8 Transition variable: Inflation level (inflation without trend)