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STABILIZATION, VOLATILITY, AND THE EQUILIBRIUM REAL EXCHANGE RATE*

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Abstract

This paper is composed of two parts. The theoretical part studies the effect of real exchange rate (RER) volatility on trade using a general equilibrium framework. The volatility of the RER is derived endogenously, and is caused originally by a demand shock. The model shows that inflation volatility has a positive effect on RER volatility, which, in turn, affects positively the equilibrium RER. The empirical part consists of two experiments. In the first one, we examine the behavior of several RER volatility indexes over the last fifteen years for Brazil, identifying the influence of stabilization plans and inflation volatility. We show that, in fact, inflation volatility explains most of the variation in RER volatility in Brazil over the last fifteen years. The second experiment performs the estimation of export supply equations for Brazil that include RER volatility as one of the explanatory variables. For most specifications we found that the RER volatility coefficient is negative, although not significantly different from zero. The implied elasticity for the most significant RER volatility coefficient is -0.05.

1. Introduction

There is a large theoretical and empirical literature on the effects of real exchange rate (RER) volatility on international trade (see Côté, 1994) for a recent survey). Traditional models consider risk averse exporters for whom the RER is the source of uncertainty. Two assumptions are crucial for the volatility of the RER to affect the exporting decision. One is that there is no perfect hedging - access to exchange rate forward market would reduce the effect. The other is that exporters have to be very risk averse. As Caballero and Corbo (1989) point out, profit is a convex function of prices; hence increased variability of prices increases profits. To capture the behavior of a risk averse agent facing risk, exporters are assumed to maximize a concave function of profits, because a concave function has the property of decreasing with the variability of its argument. Hence, exporters maximize a concave function (a utility function) of a convex function (the profit function) of prices. They will ultimately be maximizing a concave function of prices if the utility function is sufficiently concave, that is, if they are sufficiently risk averse.

There is an alternative line of research, in which the international market for the country's export sector is non-competitive. There are costs associated with entering and/or exiting the market; therefore an increased volatility of the RER would make the option of entering and/or exiting the market more valuable. More volatility of the RER would then make exports less responsive to variations in the RER level, as shown in Dixit (1989).

Traditional models, however, are better suited for the purposes of this paper than the "option" framework. This paper intends to study situations related to developing economies, for which the export sector is composed mostly of products that present high degree of competitiveness in the foreign markets. Therefore the behavior of the sector is better captured by the assumption of risk averse exporters in a competitive environment as in the traditional models.

One common feature of all models that relate the volatility of the RER to trade is that they use a partial-equilibrium approach. They usually focus on the export sector, and study the effect of an exogenously given volatility of the RER on the quantity of exports. This paper makes a step into using a general equilibrium framework. Substitution across sectors is considered, and the model allows the study of the effect of volatility on the equilibrium real exchange rate, that is, on the value of the RER that yields equilibrium in all markets of the economy. The volatility of the RER is derived endogenously. Its original source in the model is a demand shock.

The theoretical part of the paper shows that the value of the equilibrium real exchange rate is affected by its own volatility. Risk averse exporters, that make their exporting decision before observing the realization of the RER, choose to export less the more volatile is the RER. Therefore the trade balance and the variance of the RER are negatively related. An increase in the volatility of the RER, for instance, deteriorates the trade balance, and to restore equilibrium a RER depreciation has to take place.

Another point this paper intends to make is that price stabilization plans may affect the variability of the RER. The effect on volatility is clear when the price stabilization plan embodies a change in the exchange rate regime. If the exchange rate was flexible before the plan, and is fixed after the plan, for instance, then a lower volatility of the RER should be expected. However, even if the exchange rate regime remains unchanged, as in our model, price stabilization may affect the variance of the inflation rate. Price stabilization means that the inflation rate moves to a lower level, and that may affect its variability[1]. The lower inflation volatility would then probably affect the variability of the RER.

In sum, the message this paper wants to convey is that the variability of the RER may affect its equilibrium level, and price stabilization may affect that variability. If our theoretical results are correct, empirical studies should include the RER volatility as one of the explanatory variables of the RER itself.

The empirical section consists of two parts. In the first part we investigate an alternative source of RER volatility: the effects of stabilization plans in high-inflation countries. It contains an extensive description of the behavior of several measures of the RER volatility for Brazil, using monthly, weekly and daily data over the last fifteen years. Interesting patterns of volatility could be associated to the nature of the several stabilization plans adopted, and to changes in the exchange rate regimes. Simple OLS regression show that RER volatility was largely explained by movements in inflation volatility.

The effect of RER volatility on its equilibrium level suggested by the theoretical model depends crucially on whether exports decisions are affected by the variability of the RER. The second part of the empirical section performs the estimation of export supply equations for Brazil that include RER volatility as one of the explanatory variables. For most specifications the RER volatility coefficient was negative, although not significantly different from zero.

This paper is organized as follows. The next section presents the model. Section 3 contains the empirical results. Section 4 concludes and points directions for future research.

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[1] For an empirical study on the relation between inflation level and its variability for Brazilian data, see Issler (1991).

2. The Model

In a simple general equilibrium framework, the model presented here tries to capture the effect of the volatility of the real exchange rate on its equilibrium level. The effect arises from the assumption that firms are risk averse and the decision on how much to export is made before the RER is observed. When the export activity is riskier relative to the others, less resources will be allocated to it. To maintain external balance, the RER has to depreciate. Therefore, there is a negative relation between the equilibrium RER and its volatility.

Production

A small open economy is considered, which produces three goods: a non-tradable good (Q_N), an importable good (Q_M) and an exported good (Q_X). The importable good is a perfect substitute of the country's imports. The exported good is that good produced exclusively for export, and is not consumed locally. It can be thought as a good that is produced to attend foreign specifications. It is assumed that at the beginning of the period, before observing the realization of the RER, firms have to make a binding contract specifying the amount to be produced of the exported good. Assuming that the producer is risk averse, he will maximize the expected value of a concave function, which will be called utility function, of his profit. The problem of a representative firm at the beginning of the period is represented by:

$$\text{Max } E\left[U\left(\tilde{p}_X Q_X(L_X) + \tilde{p}_M Q_M(L_M) + Q_N\left(\bar{L} - L_X - L_M\right)\right)\right]. \quad (1)$$

For simplicity, only one mobile factor of production exists, L, presenting decreasing returns, and the firm's endowment of this factor is $\bar{L}$. $Q_X(L_X)$, $Q_M(L_M)$, and $Q_N(\bar{L} - L_X - L_M)$ represent the production functions of the exported, importable and non-tradable goods, respectively. The non-tradable good is the numeraire, and the relative prices of the exported and importable goods, $\tilde{p}_X$ and $\tilde{p}_M$, are uncertain. The price of the exported good is equal to its international price, p_X^*, exogenous and assumed constant, multiplied by the nominal exchange rate relative to the price of non-tradable goods, $\tilde{e}$. The price of the importable good is also equal to its international price, p_M^*, multiplied by $\tilde{e}$. These prices are represented in equation (2)

$$\tilde{p}_j = \tilde{e}p_j^*, \text{ for } j = X, M. \tag{2}$$

By solving the maximization problem above, the producer chooses how much labor to allocate for the production of the exported good.[2] The two first order conditions that define L_X and L_M are:

$$\frac{E[U'\,\tilde{p}_X]}{E[U']} = \frac{Q_N'}{Q_X'}, \text{ and} \tag{3.a}$$

$$\frac{E[U'\,\tilde{p}_M]}{E[U']} = \frac{Q_N'}{Q_M'}, \tag{3.b}$$

where U' is the derivative of the utility function with respect to profits, and Q_j' is the marginal product of labor in the production of good *j*, for *j=X,M,N*.

Given the properties of the production functions, the production of the exported good is positively related to $E[U'\,\tilde{p}_X]$ - which can be interpreted as the marginal utility for the producer of producing one extra unit of the exported good - and is negatively related to $E(U')$ - which can be interpreted as the marginal utility for the producer of producing one extra unit of the non-tradable good. The amount of exported good to be produced can then be represented by:

$$Q_X = q_X\left(E(U'\,\tilde{p}_X), E(U'\,\tilde{p}_M), E(U')\right). \tag{4}$$

2 The solution also yields the amount planned to be allocated to the importable and to the non-tradable goods. However, the decision of how much labor is allocated between them is made after the realization of the real exchange rate.

The derivative of the offer curve with respect to the first argument is positive, and with respect to the other two is negative.

After the realization of the random variable, the firm decides how much to produce of the importable and non-tradable goods with the labor net of the amount used in the production of the exported good. The offer functions of the two goods are represented as the functions:

$$Q_M = q_M\left(p_M, E(U'\,\tilde{p}_X), E(U'\,\tilde{p}_M), E(U')\right) \text{ and} \tag{5.a}$$

$$Q_N = q_N\left(p_M, E(U'\,\tilde{p}_X), E(U'\,\tilde{p}_M), E(U')\right), \tag{5.b}$$

where p_M is the realization of the random variable $\tilde{p}_M$. The derivatives of the two functions have the following signs: $\frac{\partial q_M}{\partial p_M} > 0$, $\frac{\partial q_M}{\partial E[U'\,\tilde{p}_M]} > 0$, $\frac{\partial q_M}{\partial E[U']} < 0$, $\frac{\partial q_N}{\partial p_M} < 0$, $\frac{\partial q_N}{\partial E[U'\,\tilde{p}_M]} < 0$, $\frac{\partial q_N}{\partial E[U']} > 0$, and $\frac{\partial q_j}{\partial E[U'\,\tilde{p}_X]} < 0$ for $j = M, N$.

Consumption

Now that the production side of the economy is defined, let's turn to the consumption decisions. The consumer in this model economy consumes two types of goods: importables and non-tradables. They maximize their utility from consumption, subject to their budget constraint. It is also assumed that their demand for goods depends positively on the amount of money they hold. Two possible ways to model this assumption are either by using a cash-in-advance constraint, or by placing money in the utility function. The role of introducing money in this model is to create a demand shock. Hence, money should be viewed here as a source of demand shocks. An alternative way to accomplish this could be made by introducing government expenditures, for instance, that would have a positive effect on the demand for both goods. The demand for each type of good may be represented by:

$$C_M = c_M(p_M, m) \text{ and} \quad (6.a)$$

$$C_N = c_N(p_M, m), \quad (6.b)$$

where m is the real amount of money in terms of the price of the non-tradable good, and $\frac{\partial c_M}{\partial p_M} < 0$, $\frac{\partial c_N}{\partial p_M} > 0$, and $\frac{\partial c_j}{\partial m} > 0$ for j=M,N.

Uncertainty is introduced in the model through the money supply. All economic agents know the distribution for the possible realizations of money supply, and the government sets a fixed nominal exchange rate without observing its realization. The rigidity of the nominal exchange rate is what makes the variability of money supply, and thus of inflation, to have real effects, as will be shown later.

Equilibrium Conditions

There are two equilibrium conditions in this economy. The first one is that the total production of the non-tradable good must equal its total consumption. Ex-post relative prices of importables and real money supply must satisfy the equilibrium condition in the non-tradables market, represented in equation (7).

$$c_N(p_M, m) = q_N(p_M, E(U'\tilde{p}_X), E(U'\tilde{p}_M), E(U')). \quad (7)$$

The second condition is that the country's balance of payments must be in equilibrium. The rigidity of the nominal exchange rate will make the trade balance depend on the realization of the nominal money supply, and hence the trade balance will also be a random variable. The government will, therefore, set the nominal exchange rate so as to make the expected value of the trade balance equal to some desired target in the capital account, $\overline{K}$.[3] The target is exogenously set, depending on whether the government is

[3] $\overline{K}$ may also include any desired change in foreign reserves holdings.

willing to repay previously contracted foreign debt, or contract new debt. The nominal exchange rate will, then, be determined by solving equation (8).

$$p_M^*\left\{E\left[c_M(p_M,m)\right]-q_M\left(E(U'\tilde{p}_X),E(U'\tilde{p}_M),E(U')\right)\right\}+ \\ -p_X^*q_X\left(E(U'\tilde{p}_X),E(U'\tilde{p}_M),E(U')\right)=\overline{K} \quad (8)$$

Depending on the realization of the random variables, there may be either a surplus or a deficit in the balance of payments, and the government will have to either increase or decrease its foreign reserves holdings. For simplicity, it is assumed that money supply variations resulting from reserve transactions are sterilized.

The equilibrium is represented in figure 1. The vertical axis depicts the relative price of importables, and the horizontal axis represents the real money supply. Ex-post relative price of importables and the real money supply must satisfy the equilibrium condition for the non-tradable good market, equation (7), which is represented by the NT schedule. The government sets the nominal exchange rate (which will determine the price of importables) so that the expected value of the balance of payments is in equilibrium.

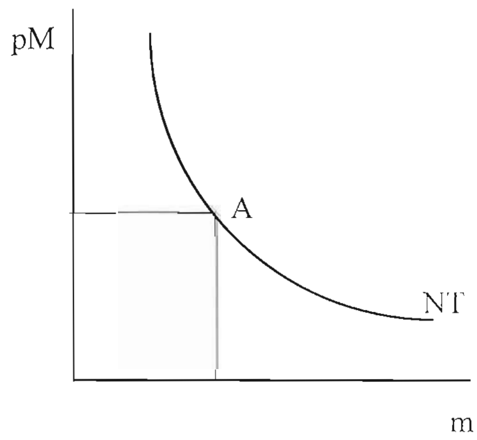

Figure 1

There is a realization of the nominal money supply that yields equilibrium in the balance of payments, given the nominal exchange rate chosen by the government. It is represented in Figure 1 by point A. When the realization of the money supply is larger than that value, for instance, the demand for both goods is also larger, and the economy will be at a point to the right of that equilibrium point. To establish equilibrium in the non-tradables market, the price of non-tradables has to increase, so that the relative price of importables and the real money supply decrease simultaneously until a point on the non-tradables market equilibrium curve is reached. Therefore, in the ex-post equilibrium point, the relative price of importables is lower and the real money supply is larger than in the ex-ante equilibrium point (i.e. the point that would result if the money supply were equal to the value that would yield equilibrium in the balance of payments). In that case, the trade balance will be smaller than the target value, resulting in a decrease of foreign reserve holdings by the government.

On the other hand, when the realized nominal money supply is smaller than the value that yields equilibrium in the balance of payments, the price of non-tradables decreases causing an increase in the relative price of importables and the real money supply. This would result in an increase of foreign reserves.

Intuitively, nominal exchange rate is set by the government targeting the equilibrium real exchange rate. However, prices are collected with a lag. Therefore, in an inflationary environment, prices may be different from expected, and the real exchange rate may result misaligned. The setting modeled here represents such a situation. Hence, the real exchange rate will be different from its equilibrium value whenever inflation, or, in the context of our static model, whenever money supply is different from expected. This means that the variability of the real exchange rate increases with inflation variability, or with money supply variability in our model.

The equilibrium real exchange rate and its volatility

The real exchange rate is the ratio of the price of tradables and the price of non-tradables. In terms of the model presented here, the RER is:

$$RER = \Pi(\tilde{p}_M, \tilde{p}_X), \tag{9}$$

where the derivative of the function $\Pi(.)$ is positive with respect to both arguments. The volatility of the RER will then depend positively on the volatility of the relative prices of importable and exported goods.

From equation (2), it is easy to see that the variability of the relative nominal exchange rate is positively related to the variability of the prices of exported and importable goods. This means that the volatility of the relative price of importables and exportables are positively related, and, as stated in the previous paragraph, both volatilities have a positive effect on the volatility of the RER.

Furthermore, from the solution of the model it is straightforward to see that the higher the volatility of the money supply the higher will be the volatility of the price of importables, and therefore the higher will also be the volatility of the price of exported goods. Hence, one of the results of this model is that the volatility of inflation and the volatility of the RER are positively related.

To assess the effect of changes in the variability of RER on its equilibrium level, one has to determine the effect of that variability on the equilibrium conditions, more specifically, on equations (7) and (8). To exemplify, the effect of an increase in the volatility of the RER will be analyzed. From equations (7) and (8), it is clear that the effect of the increased volatility of the RER will depend on its effects on $E[U' \tilde{p}_X]$, $E[U' \tilde{p}_M]$ and $E[U']$, and this effect, in turn, will depend on the concavity of the functions $U' \tilde{p}_X$, $U' \tilde{p}_M$, and U'. The intuition is that for a risk averse individual, the volatility of the price affects the marginal utility from producing one more unit of the good, even if the expected value of the price remains unchanged. The effect of volatility will then ultimately depend on the concavity properties of the utility function. An increase in volatility will decrease the marginal utility of production if this function is concave in prices. Assuming that the functions $U'\,\tilde{p}_X$ and $U'\,\tilde{p}_M$ are concave in prices, and the function U' is not concave in prices[4] , an increase in the variability of the RER will decrease $E[U'\,\tilde{p}_X]$ and $E[U'\,\tilde{p}_M]$, and will not decrease $E[U']$. This is a sufficient condition for the increase in the variability of the RER to increase the amount produced of the non-tradable good (in equation (7)), to decrease the amount produced of the exported good, and also to decrease the amount planned to be produced of the importable good (both in equation (8))[5].

Figure 2 represents the changes in the equilibrium conditions caused by an increase in the variability of the RER. The non-tradables market equilibrium condition will shift upwards: the increased variability in the tradables sectors will cause an increase in the production of non-tradable goods, so that, for any given price of importables, the real money supply has to increase to clear the market.

As for the balance of payments equilibrium condition, it is clear that the government will need to set a more devalued nominal exchange rate for this equilibrium to happen in expected value. The increased volatility depresses the production of both importable and exported goods, such that in point A, the lower variability equilibrium point, is now a point where there is a deficit in the balance of payments. Without further

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[4] The function $U'\,p_X$ can be concave and U' convex in p_X at the same time. We have that $\frac{\partial^2 U'\,p_X}{\partial p_X^2} = U'''\,p_X(Q_X)^2 + 2U''\,Q_X$, and $\frac{\partial^2 U'}{\partial p_X^2} = U'''(Q_X)^2$. The utility function $U(P) = \frac{P^{1-\gamma}}{1-\gamma}$ for $\gamma \neq 1$, for instance, satisfy this condition.

[5] A decrease in $E[U'\,\tilde{p}_X]$ will depress exports production, but the decrease in $E[U'\,\tilde{p}_M]$ will increase it. Hence, here we have to further assume that the direct effect of the decrease marginal utility of producing exported goods ($E[U'\,\tilde{p}_X]$) is greater than the indirect effect of the decrease of the marginal utility of producing importable goods ($E[U'\,\tilde{p}_M]$), so that there will be a net decrease of exported goods production when the variability of the RER increases. The same is true for the importable goods production.

assumptions, we can be sure that the new point that yields equilibrium in the balance of payments ex-post (point A' in figure 2) has a higher relative price of importable goods, but we cannot be sure whether the corresponding real money supply is greater or smaller relative to point A.

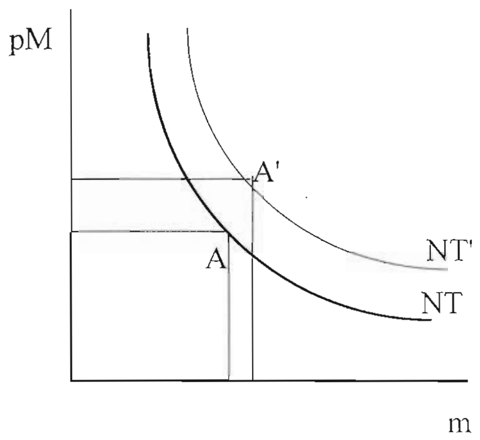

Figure 2

The figure shows that when the volatility of the RER increases, the government will set the nominal exchange rate targeting a higher expected value for the relative price of imports than before, and given any realization of the money supply, the ex-post relative price of importables (i.e. some point on the NT' schedule) will be higher than it would have been had the volatility been smaller.

In summary, the model shows that inflation volatility has a positive effect on RER volatility, which, in turn, affects positively the equilibrium RER.

3. Real Exchange Rate Volatility

There is a vast empirical literature on the effects of (nominal and real) exchange rate variability on trade flows and trade prices in several countries.[6] However, the results of this literature are still inconclusive. While most papers found a negative significant exchange rate volatility effect, the magnitudes of the coefficients are in general relatively small. Some recent work has used developing countries data, but the results are also mixed.[7]

On the other hand, the empirical literature usually considered the end of the Bretton Woods system and the introduction of economic integration areas (Nafta, the European Union, and Mercosul) as the main sources of change in exchange rate volatility. In fact, most authors tend to find an increase in exchange rate volatility after the collapse of the Bretton Woods regime, most notably in developing countries (see, for example, Edwards, 1989), and that regional economic integration reduces the effect of exchange rate variability on trade (see, for example, Frankel and Wei, 1993).

In this section, we perform two empirical exercises. First, we investigate an alternative source of changes in RER volatility: the effects of stabilization plans in high-inflation countries. As our model suggests, for a given exchange rate indexation regime, inflation variability and RER variability are positively correlated. Changes in the indexation regime or changes from a fixed to a floating exchange rate system are also other

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[6] For a good survey on the most recent empirical literature on exchange rate volatility and trade, see Côté (1994). Among other important contributions, see Gotur (1985), Kenen and Rodrik (1986), Caballero and Corbo (1989), and Gagnon (1993).

[7] For instance, Coes (1981), Paredes (1989), Caballero and Corbo (1989) and Grobar (1993) found evidence of a negative relationship between real exchange rate (RER) volatility and trade for some developing countries, while Paredes (1989), Caballero and Corbo (189) and Steiner and Wullner (1994) did not find any significant RER volatility effect on trade for some other developing countries.

potential sources of RER variability. By examining the behavior of several RER volatility indexes over the last fifteen years for Brazil, we try to identify the influence of stabilization plans and inflation volatility on these variability measures.

The second experiment is the estimation of export supply equations for Brazil that include RER volatility as one of the explanatory variables. Coes (1981) and Paredes (1989) performed the same task with Brazilian data, obtaining mixed results. In the second part of this section, we update their results using more recent data and new measures of RER volatility.

3.1 Real Exchange Rate Volatility: Measures and Sources

In order to measure RER volatility, we compute (unconditional) standard deviations of RER changes within pre-determined periods. This procedure is the most traditional way of measuring volatility (see, for example, Kenen and Rodrik, 1986, Grobar, 1993, Caballero and Corbo, 1989, among others). The first volatility measure examined is the standard deviation of 12-month (moving) consecutive observations of monthly RER changes. It is centered in the middle of each 12-month period, although this does not affect much the regression results of this section.

This RER volatility measure is computed for Brazil, Argentina and Mexico. Table 1 shows RER volatilities and inflation means for the three countries. Mexico experienced the lowest average level of inflation (3.5% a month) and the lowest RER volatility measure, in absolute terms. Argentina, on the other hand, experienced the highest RER volatility measure, both in absolute terms and relative to the inflation rate.

Table 1

Real Exchange Rate Volatility and Inflation:
Means (%) - Monthly Data, 1980-1995

	RER Volatility	Inflation
Brazil	3.02	15.39
Argentina	9.27	12.69
Mexico	1.72	3.45

Graph 1 displays the evolution of the monthly RER volatility measure for the three countries. We ignored the large 1989-1991 numbers for Argentina which were above 60% a month, so as to provide a better visual comparison between the three countries. Mexico experienced the lowest RER volatility among the three countries, specially after the events of late 1982. It remained below 2% a month throughout most of the period. Argentina's RER volatility is the highest of the group. After the convertibility plan in 1991, however, RER volatility remained below 0.5% a month, the lowest level reached by any of the three countries in the period.

The second measure of RER volatility used in this paper is identical to the first, with the difference that multilateral monthly real exchange rates are used, which are based on export weights of the seven largest Brazilian trade partners between 1985 and 1995.[8] It will be examined more closely later.

By construction, however, these two traditional measures of RER volatility, based on monthly RER changes, ignore the effects of any within-month RER movements. Since we believe these within-month variations are significant in countries with high (and

[8] We thank Paulo Levy, from the *Grupo de Acompanhamento Conjuntural*, IPEA/RJ, for providing this data.

volatile) inflation, two alternative measures of RER volatility using Brazilian data are proposed.

The first one, a daily measure, makes use of the daily bilateral nominal exchange rates.[9] By assuming a constant exponential growth for prices within each month, we were able to compute daily RERs for a period starting in January 1st of 1980.[10]

The second measure is also based on monthly RER changes. However, we make use of a weekly consumer price index for the state of São Paulo (FIPE-CPI), which measures monthly price averages ending in each week of each month since 1986 (4 indexes for each month). By computing the number of weekdays for each 4-week period since 1986, we were able to obtain 4-week nominal exchange rate averages. These series were then deflated by the FIPE-CPI index and inflated by weekly-interpolated WPI*, generating a weekly series of monthly (4-week) RER changes. The weekly volatility measure is the standard deviation of these monthly RER changes within a (moving) 3-month period.

In order to illustrate the gains in using the first of these two alternative series, graphs 1 and 2 display daily Brazilian RER levels and changes, respectively, from the beginning of 1980 to the end of June 1995. A very volatile RER picture emerges from these graphs. Large one-day swings were observed in the 30% maxi-devaluation episode of February 1983, and in mid-devaluations that preceded most stabilization plans of the 1980s. Months of steep inflation acceleration/deceleration not only brought changes in the

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[9] Daily nominal exchange rates (e) are published by the Central Bank: sell quotation, dollar/domestic currency. We thank Dionísio Dias Carneiro for providing the complete series. As usual in small economy models, real exchange rates are proxied by $RER = (e.WPI^*)/CPI$, where WPI^* is the U.S. wholesale price index and CPI is the Brazilian consumer price index (INPC, also from IBGE). See Edwards (1989) for a discussion on alternative measures of real exchange rates.

[10] The assumption of a constant exponential price growth within each month does not seem damaging to our results, since ex-ante RER expectations should be based on a hypothesis like this, as other distributions are unknown.

RER level but also caused an increase in (within-month) volatility, which is not perceived in monthly data.

Graph 4 shows the behavior of our daily RER volatility measure. Note that most peaks in the volatility measure are related to large devaluations, that were made either to deal with the external debt crisis, as in February of 1983, or preceding stabilization plans.[11] The remaining peaks reflect large appreciations that followed both the Collor and the Real plans.

If we do not consider those peaks, at least six volatility patterns can be identified:

- The first one, observed in the period running from 1980 to February 1983, is characterized by a relatively high volatility (around 0.7% a day), which resulted from a loose crawling peg regime without a fixed-period indexation rule.
- The second period, observed from February-1983 to mid-1985, was one of a daily exchange rate indexation. However, inflation acceleration (from 100% a year to 200% a year) compensated the indexation effect, resulting in a RER volatility of around 0.7% a month, similar to that observed in the first period.
- The third period, from mid-1985 to the end of 1988, was characterized by a low daily RER volatility (around 0.2% a day), which resulted from two price (and exchange rate) freezing attempts and a policy orientation of keeping the RER unchanged, despite the inflation acceleration at the end of the period.
- The fourth period runs from 1990 to the middle of 1991, period in which the Central Bank did not follow any indexation (parity) rule, letting the exchange rate float under unspecified thresholds, which characterized what is usually called a "dirty floating" regime. The result was a very high RER volatility (above 1% a day).

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[11] We stress the point that these peaks should be kept as part of the volatility index, since in all these periods, forward-looking agents were uncertain about future levels of the RER, anticipating the possibility of large devaluations or price freezing.

- A fifth period, from mid-1991 to mid-1994, illustrates the return to a daily indexation regime and was characterized by some attempts to point to a more devalued currency. Continuous inflation acceleration in that period, together with a lag on current price observation, resulted in a continuous increase in the daily RER volatility measure. The magnitudes, however, were not large, compared to other periods, averaging around 0.3% a day.
- The sixth pattern was the one introduced by the floating exchange regime that followed the Real Plan. After a brief period of relatively high volatility, which was caused by the large appreciation of the Real, inflation stabilization at low levels (below 2% a month), together with the introduction of exchange rate bands in March 1995 helped to decrease the RER variability. However, RER volatility is still larger than the one observed in the fourth period, period in which the average inflation rate was around 25% a month.

Of the four RER volatility measures used in this paper, we believe that the daily volatility measure gives the best picture in terms of picking up the effects of inflation acceleration/deceleration and of changes in the indexation regime for the last fifteen years, as described in the last two paragraphs, despite the arbitrary assumptions that were made in its construction.[12] The question, then, is to examine how all these volatility measures are related to each other.

Graphs 5 and 6 display the two pairs of RER volatility measures. Graph 5 pictures the monthly averages of the daily and weekly volatilities, both based on three-month periods (centered in the middle of each quarter).[13] Note that, despite their different methodologies, the two series follow similar paths. The main differences are that they are

[12] The weekly measure, although technically superior to the daily measure, begins in 1986, missing the first two periods described above.

[13] Monthly and quarterly averages of the RER volatilities are used in all monthly and quarterly regressions of this section, respectively.

measured in different scales and the weekly series is more sensitive to the large price swings observed in the period 1990-1991.

Graph 6 shows the bilateral and multilateral volatility indexes, both based on 12-month periods (centered in the middle of each period). They also follow similar paths, with the most notable exception being the period from October 1991 to June 1994. Historically, the Brazilian government has been more concerned with indexing the bilateral (US$/domestic currency) rate, letting the multilateral index flow, which makes the multilateral index more volatile whenever the dollar fluctuates relative to other currencies.

Table 2 shows the means of each RER volatility measure. The daily volatility index averaged 0.65% a day between 1980:1 and 1995:6. Remember that these averages are taken over weekdays only, excluding weekends, holidays, and bank holidays. The magnitude of the daily volatility measure is thus relatively high, of about the same size as the daily rate of inflation.

Table 2

RER Volatility Measures - Summary Statistics

Volatility	Obs	Mean (%)	Std Error (%)
Daily	187	0.653	0.612
Weekly	109	2.839	2.484
Monthly -Bilateral	170	3.161	1.974
Monthly - Multilateral	116	3.835	1.780

The multilateral real exchange rate volatility mean, on the other hand, is the highest among the monthly volatility indexes, which is a symptom that the government, in most of the period studied, looked much more closely at the bilateral dollar/domestic currency rate. The monthly average of the weekly index is the most volatile, which is part due to the fact that it is based on 3-month periods, contrary to the two other monthly measures.

All four RER volatility averages are much larger than those observed for developed countries. Kenen and Rodrik (1986), for instance, reported (24-month) monthly volatility means for eleven OECD countries from 1975 to 1984. Eight of the eleven countries have experienced RER volatilities below 1.5%, while the highest mean value, Sweden's, was 2.7%.

Table 3 below displays the correlations between monthly observations of our four measures of volatility (daily, weekly, monthly-bilateral and monthly-multilateral) over comparable periods (1986:4 to 1995:2). The results confirm that the series are positively correlated. The daily and the weekly volatilities are the most highly correlated (0.74).

Table 3

Correlation Matrix: RER Volatility Measures. Monthly data: 1986:4 - 1995:2

Volatility	Daily	Weekly	Monthly - Bilateral	Monthly - Multilateral
Daily	1.000	0.742	0.416	0.398
Weekly	0.742	1.000	0.477	0.502
Monthly -Bilateral	0.416	0.477	1.000	0.671
Monthly-Multilateral	0.398	0.502	0.671	1.000

One explanation for such high RER volatilities observed in Brazil, suggested by our model and the experiences of Mexico and Argentina, is high inflation volatility. We test this proposition by running OLS regressions, correcting for first-order serial correlation using the iterative Cochrane-Orcutt technique, of our RER volatility measures on compatible inflation volatility measures.[14] The results are displayed in Table 4 below. They confirm that inflation volatility should be considered as one of the main sources of RER volatility changes in Brazil. The inflation volatility coefficients are statistically significant and positive in all regressions. The large adjusted R^2's indicate that inflation volatility explains most of the variation in RER volatility in Brazil over the last fifteen years.

Table 4

Regression Results: RER Volatility on Inflation Volatility[a]

RER Volatility	Constant	Inflation Volatility	Adjusted R^2	Period
Daily	0.54^* (4.19)	0.62^* (3.51)	0.66	1980:4-1995:3
Weekly	2.46^* (3.00)	0.12^* (5.74)	0.95	1986:3-1995:3
Monthly-Bilateral	2.76^* (2.97)	0.06^* (2.45)	0.93	1980:6-1995:1
Monthly-Multilateral	3.31^* (3.01)	0.04^+ (1.77)	0.93	1985:6-1995:1

a *t-statistics in parentheses; *denotes significance at the 5% level; +denotes significance at the 10% level.*

[14] The inflation volatility measure in each regression was computed as follows: i) monthly averages of the 3-month standard deviation of daily inflation rates, used in the daily RER regression; ii) the standard deviation of 3-month changes in the FIPE-CPI index, used in the weekly volatility regression; iii) the 12-month standard deviation of monthly inflation in the monthly volatility regressions.

3.2 Real Exchange Rate Volatility and Export Flows

In this sub-section, we estimate export supply equations for Brazil that include RER volatility as one of the explanatory variables. The four measures of volatility described earlier are used in alternative specifications of the export supply function. We test whether their coefficients are negative and significant as our model predicts.

All specifications used here take the form of a typical export supply equation:

$$X=f(RER, Y, VOL),$$

where X denotes exports; RER is the real exchange rate defined as (e*WPI*)/CPI;[15] Y is a measure of domestic activity (GDP in the quarterly regressions; industrial production, IP, in the monthly versions); and VOL is the RER volatility measure. We take logs of all variables with the exception of the volatility measures. We also include a constant, a trend and a set of seasonal dummies in all regressions.

We run two sets of regressions, with different measures of exports: export volume and exports/GDP. The export volume index was taken from Pinheiro (1993). Although this series ends in June of 1992, it is still the most complete and accurate measure of export volumes available for Brazil.[16] To make use of the most recent observations, we use an alternative specification with exports over GDP (both measured in dollars) as our dependent variable, as in Grobar (1993).[17]

Theory predicts a negative coefficient for both the domestic activity and the RER volatility variables, and a positive coefficient for the RER series. If the country is small in

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[15] For consistency, the monthly multilateral RER series is used when testing the monthly-multilateral volatility measure. For the other three regressions of each set, the monthly bilateral RER series.

[16] Using a very disaggregated data on exports, Pinheiro (1993) constructs a Fischer index of export prices and volumes. For details on the adequacy of their methodology, see Pinheiro and Motta (1991).

[17] We also tested using manufactured exports (volumes and proportional to GNP) as the dependent variable without much change with respect to the results presented here.

the world market, OLS coefficients are consistent.[18] However, one can confidently reject absence of serial correlation for all regression residuals, according to Ljung-Box statistics, not reported here. First-order serial correlation was dealt with by using the Cochrane-Orcutt method, which removed any significant serial correlation in the residuals. To save space, only the results after serial correlation correction and after any eventual removal of trend and seasonal variables that were not significant in pre-testing regressions are presented.[19] Monthly regressions do not improve over the results presented below, with the disadvantage of showing a positive industrial production coefficient in most cases.[20]

Table 5 shows the results for the quarterly exports volume regressions. Export supply price elasticities are positive as expected in all four regressions. However, they were not large, being significantly different from zero (at 5%) in only two cases. The domestic activity term, real GDP, also has the expected (negative) sign, although its coefficient is not significant at 10% in any of the regressions. The RER volatility coefficients have the expected (negative) sign in the three regressions that use the bilateral RER volatilities. However, RER volatility coefficients are not significant in any of the four regressions for reasonable statistical levels of significance.

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[18] There is some evidence that the small country hypothesis is not very suitable to the Brazilian case (see, for example, Portugal, 1993, for a survey of the empirical literature on exports determination in Brazil and for some new estimates). Instrumental variables were used to deal with real exchange rate endogeneity. The instruments chosen were: a constant, seasonal dummies, a trend, the log of relative prices (U.S. wholesale price index divided by Brazil's CPI), the log of GNP, and the RER volatility measure. Instrumental variables estimation, however, did not improve on the results presented here.

[19] Seasonal variables were always significant. Trend was removed from the regression in three occasions.

[20] Dynamic specifications that included lagged endogenous variables as regressors, as used in Caballero and Corbo (1989) and in Gagnon (1993), were also examined. In general they produced statistically insignificant coefficients for the RER and domestic activity variables. Persistence coefficients were not large, which may indicate that costs of adjustment are relatively low in Brazil.

Table 5

Export Supply Equation - Quarterly Results
Dependent Variable: Exports Volume[a]

RER Volatility Measure	RER	Real GDP	RER Volatility	Trend	Adjusted R^2	Period
Daily	0.29* (2.02)	-0.70 (-1.32)	-0.44 (-0.13)	0.02* (4.02)	0.73	1980:2-1992:2
Weekly	0.69 (1.63)	-1.22 (-1.39)	-1.56 (-1.01)	-	0.66	1986:3-1992:2
Monthly - Bilateral	0.40* (2.22)	-0.94 (-1.66)	-1.05 (-0.60)	0.02* (3.63)	0.68	1981:4-1992:2
Monthly - Multilateral	0.48 (0.92)	-0.94 (-0.92)	2.11 (0.50)	-	0.44	1985:4-1992:2

[a] *t-statistics in parentheses; *denotes significance at the 5% level.*

Although not statistically significant, the coefficients of RER volatility (in absolute value) are positively correlated with the export supply price elasticities. This result was also obtained in Paredes (1989), and is intuitively appealing: the more important the RER level series becomes, the more important should be its variability.

The results for the quarterly exports/GDP regressions are much more in conformity with theory. Table 6 summarizes them. Positive and significant export supply price elasticities were obtained in the four regressions. Negative and significant GDP coefficients were also found for the four regressions. Although negative RER volatility coefficients were found in three cases, they are not statistically different from zero at conventional levels of significance.

Table 6

Export Supply Equation - Quarterly Results
Dependent Variable: Exports / GDP [a]

RER Volatility Measure	RER	Real GDP	RER Volatility	Trend	Adjusted R^2	Period
Daily	1.00* (6.34)	-1.98* (-3.90)	0.57 (0.179)	0.02* (4.12)	0.78	1980:2-1995:1
Weekly	1.21* (3.68)	-2.40* (-3.66)	-1.69 (-1.31)	0.02* (2.25)	0.72	1986:3-1995:1
Monthly - Bilateral	1.13* (6.93)	-2.23* (-4.70)	-0.10 (-0.08)	0.02* (4.83)	0.80	1981:2-1995:1
Monthly - Multilateral	0.69+ (1.88)	-2.02* (-2.37)	-1.22 (-0.44)	-	0.52	1985:4-1994:3

[a] *t-statistics in parentheses; *denotes significance at the 5% level; +denotes significance at the 10% level.*

The most significant (negative) RER volatility coefficient, obtained in the weekly volatility measure, is significant at the 20% level. Its implied elasticity is -0.05. Gagnon (1993), based on a similar model, simulates the decision rules of exporters for different choices of parameters. In the case that maximizes the effect of volatility on exports, he found that an increase of 300% in his volatility measure (from 0.02 to 0.08) would cause a decrease of exports of 1.2%, which corresponds to an elasticity of -0.004. Not only our implied elasticity is much larger, but also RER volatility observed for Brazil presented changes above 300% over the last fifteen years, as shown in graphs 5 and 6.[21]

[21] The changes in RER volatility for Argentina were even larger, as shown in graph 1.

4. Conclusions and Directions for Future Research

This paper is composed of two parts. The theoretical part studies the effect of real exchange rate (RER) volatility on trade using a general equilibrium framework. Substitution across sectors is considered, and the model studies the effect of RER volatility on the equilibrium real exchange rate through its effect on tradables production decisions. The volatility of the RER is derived endogenously, and is caused originally by a demand shock. The model shows that inflation volatility has a positive effect on RER volatility, which, in turn, affects positively the equilibrium RER.

The empirical part consists of two experiments. In the first one, we examine the behavior of several RER volatility indexes over the last fifteen years for Brazil, identifying the influence of stabilization plans and inflation volatility. We show that, in fact, inflation volatility explains most of the variation in RER volatility in Brazil over the last fifteen years.

The second experiment performs the estimation of export supply equations for Brazil that include RER volatility as one of the explanatory variables. For most specifications we found that the RER volatility coefficient is negative, although not significantly different from zero. The implied elasticity for the most significant RER volatility coefficient is -0.05, which is well above the highest elasticity in the simulation exercise performed in Gagnon (1993).

According to our theoretical model, RER volatility affects positively the equilibrium real exchange rate level. In a future paper, we intend to test empirically this result by estimating the equilibrium RER. A traditional method of estimating equilibrium RER has been applied to other developing countries' data by Edwards (1994) and Elbadawi (1994), among others, usually using real variables such as terms of trade and fiscal and monetary variables as the long-run determinants of the RER. We intend to apply this method to Brazil, including RER volatility as one of the variables that cointegrate with the RER.

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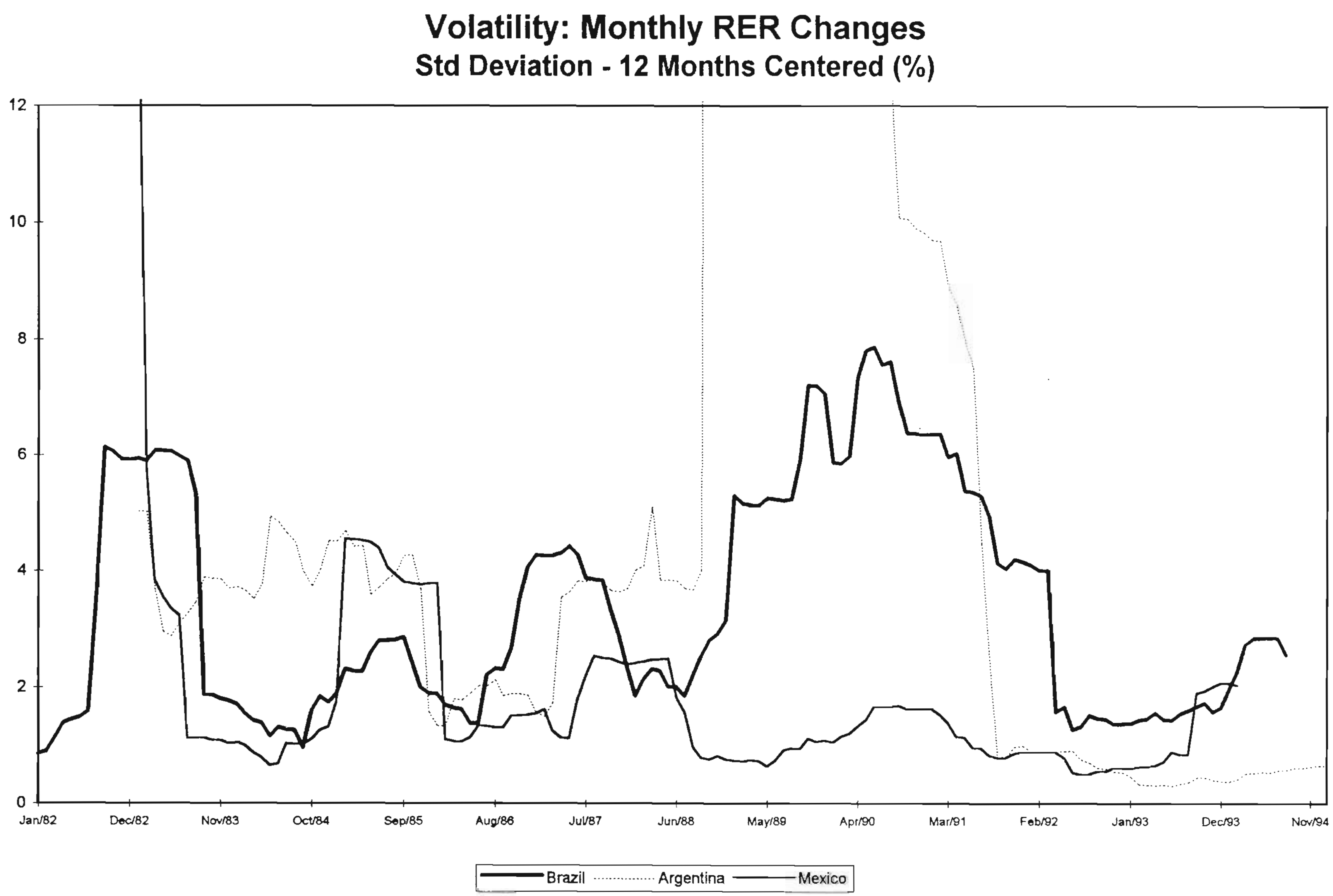
Graph 1



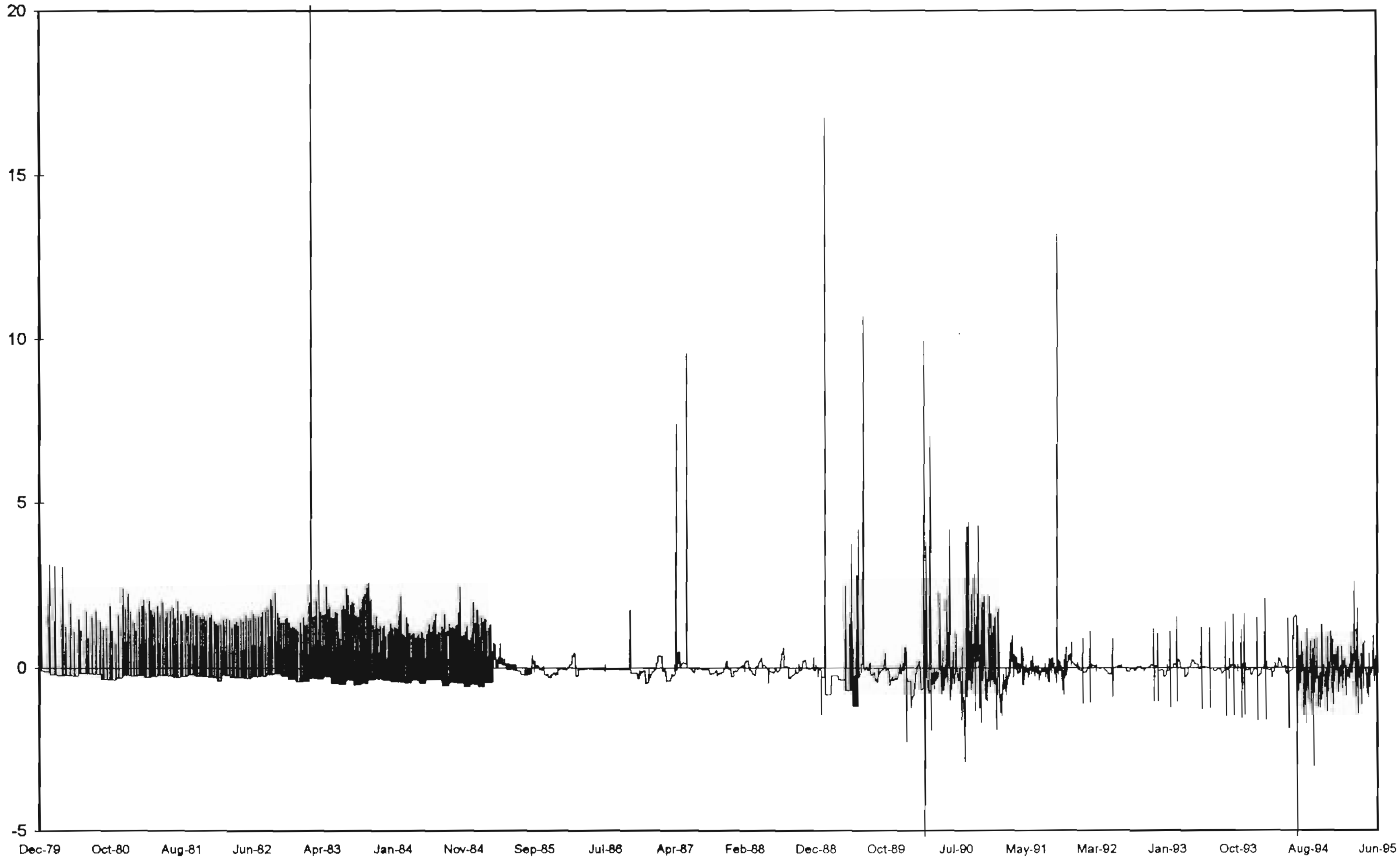
Volatility: Monthly RER Changes
Std Deviation - 12 Months Centered (%)
12
10
8
6
4
2
0
Jan/82
Dec/82
Nov/83
Oct/84
Sep/85
Aug/86
Jul/87
Jun/88
May/89
Apr/90
Mar/91
Feb/92
Jan/93
Dec/93
Nov/94
Brazil
Argentina
Mexico

Graph 2

Real Exchange Rate - Brazil
Daily - Reais of 6/15/95

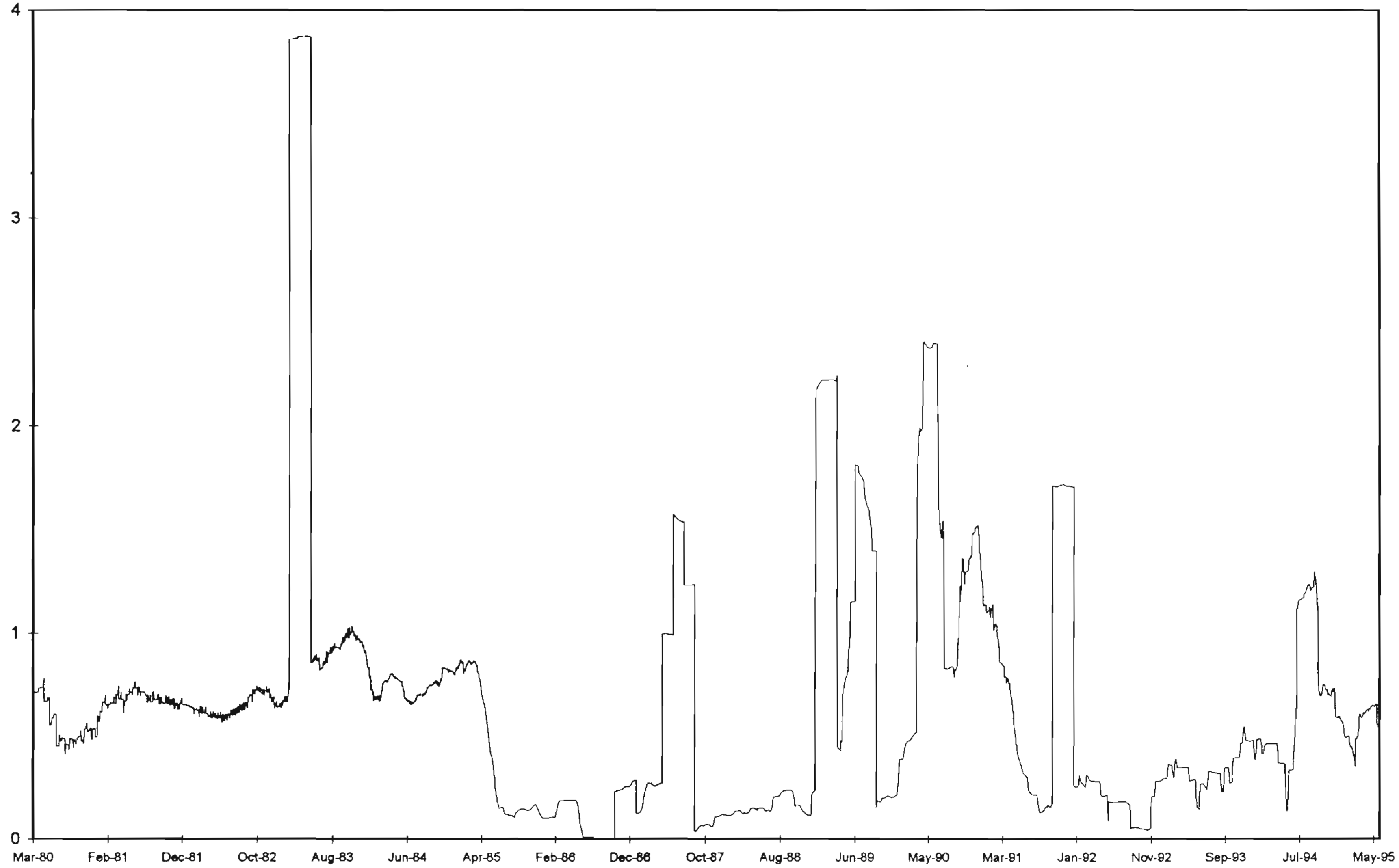
Graph 3

Real Exchange Rate - Brazil
Daily Variation (%)

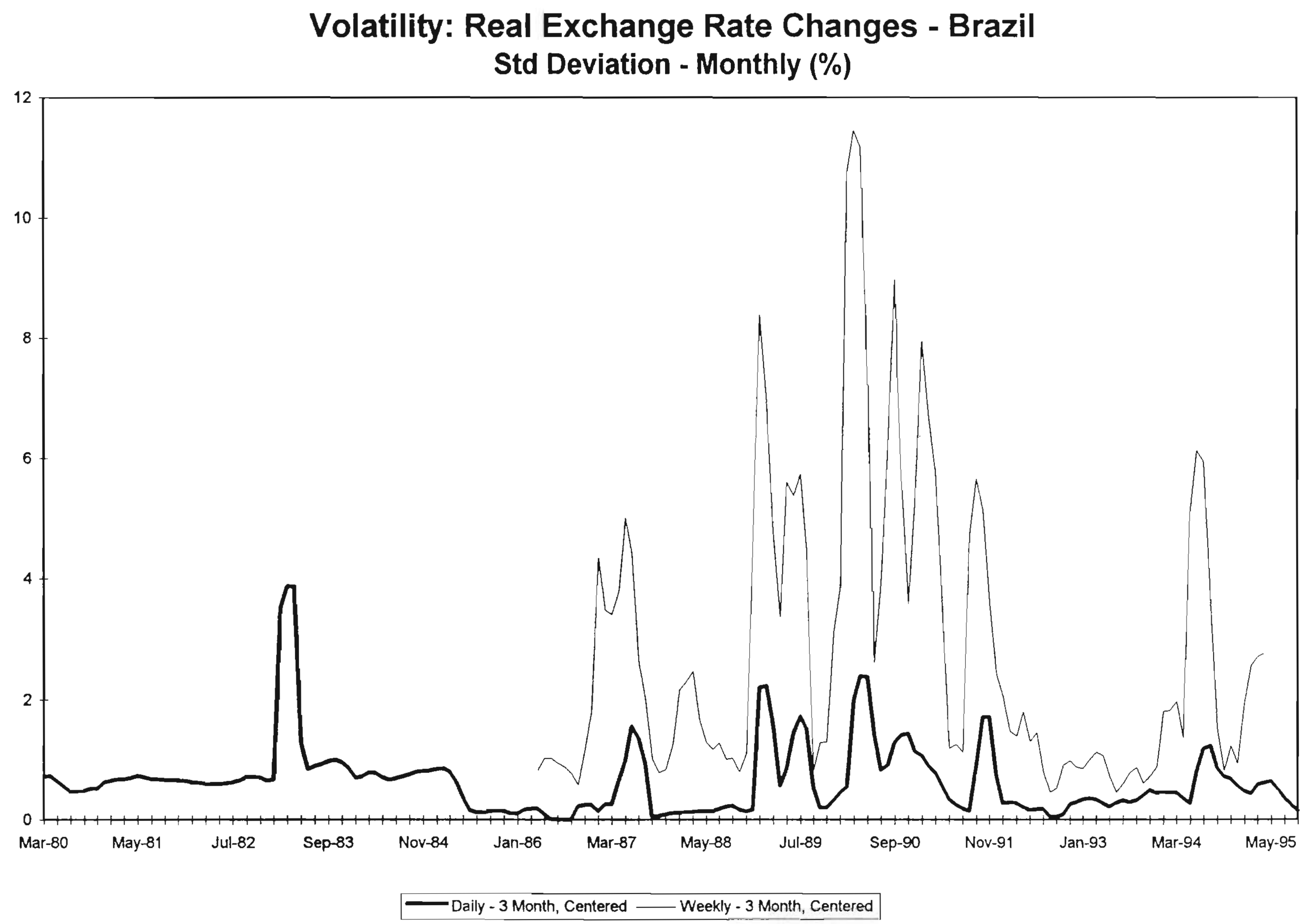


Graph 4

Volatility: Daily RER Changes - Brazil
Std Deviation - Quarter, Centered (%)

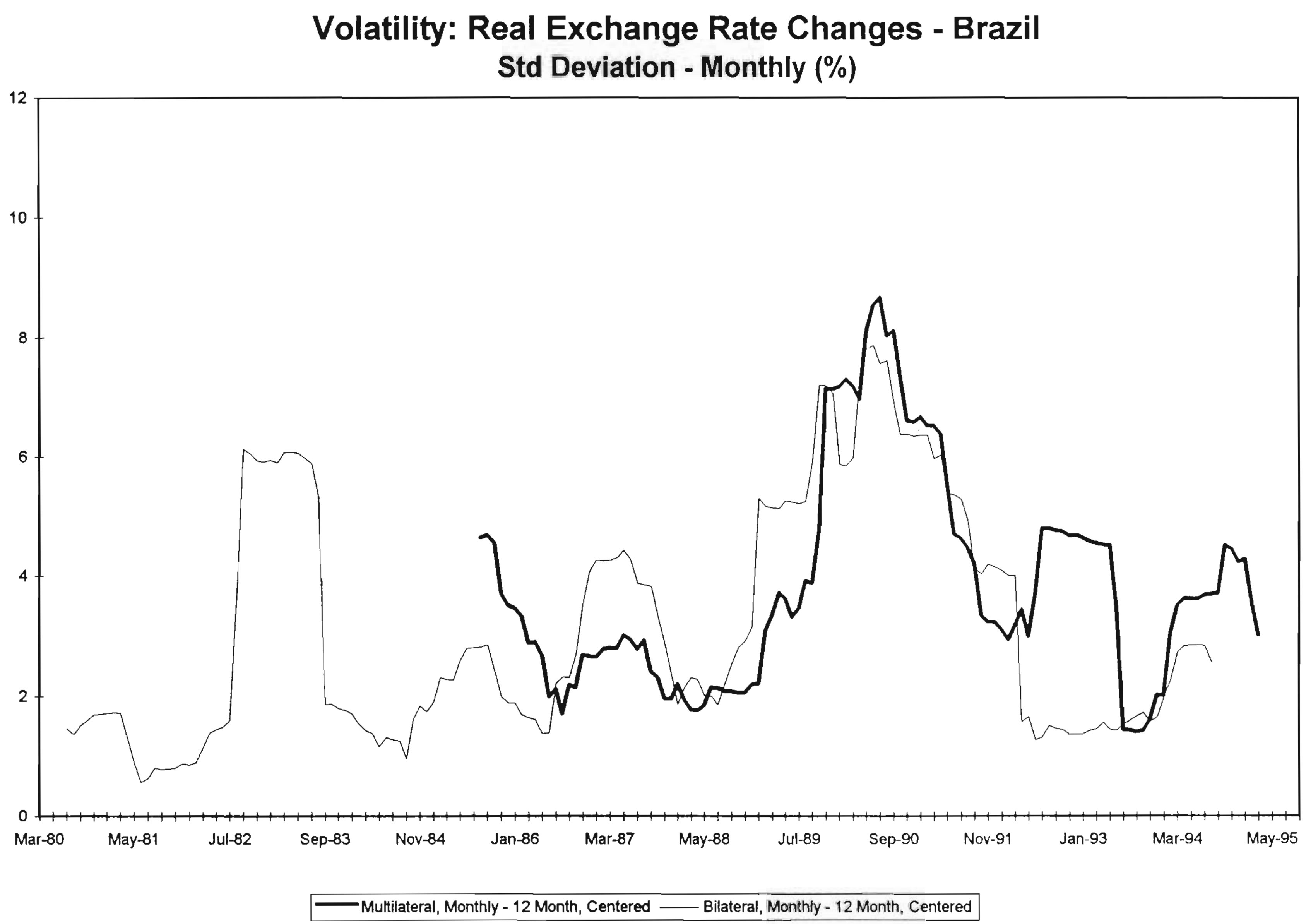


Graph 5



Volatility: Real Exchange Rate Changes - Brazil
Std Deviation - Monthly (%)
12
10
8
6
4
2
0
Mar-80
May-81
Jul-82
Sep-83
Nov-84
Jan-86
Mar-87
May-88
Jul-89
Sep-90
Nov-91
Jan-93
Mar-94
May-95
Daily - 3 Month, Centered
Weekly - 3 Month, Centered

Graph 6



Volatility: Real Exchange Rate Changes - Brazil
Std Deviation - Monthly (%)
12
10
8
6
4
2
0
Mar-80
May-81
Jul-82
Sep-83
Nov-84
Jan-86
Mar-87
May-88
Jul-89
Sep-90
Nov-91
Jan-93
Mar-94
May-95
Multilateral, Monthly - 12 Month, Centered
Bilateral, Monthly - 12 Month, Centered