THE IMPACT OF EXCHANGE RATE VOLATILITY ON BRAZILIAN MANUFACTURED EXPORTS[1,2]

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1. Introduction

Currency markets show different degrees of volatility, reflecting the particular economic circumstances that each country faces through time.

The problem of exchange rate volatility has given rise to a broad debate – theoretical as well as empirical– in the economics profession. There is no consensus as to whether exchange rate volatility influences trade volumes and the sign of the relation has also been a matter of dispute.

This question has been at the centre of the current economic policy debate in Brazil, involving academic researchers, policymakers and the business press, all pointing out the potential deleterious effects on the country's exports of the "excessive" volatility observed in the currency market since the adoption of a floating exchange rate in 1999.

In this paper, empirical evidence on the impact of exchange rate volatility on the volume of Brazilian manufactured exports in the period 1986–2002 is presented. The rest of this paper is organized as follows: in the next section we present a short review of the published literature about this matter. In section 3 we discuss the estimation procedure used in the analysis, while section 4 contains the empirical results. A final section offers some conclusions.

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2. Review of the Literature

From a broad survey of the literature on the relation between exchange rate volatility and trade flows, McKenzie (1999) extracted the following conclusions**:**

• Theoretical models are available postulating both positive and negative effects of the exchange rate volatility on trade flows;

• The empirical evidence, however, most commonly fails to identify a statistically significant relationship between exchange rate uncertainty and the volume of trade;

• When a statistically significant relation has been detected, both positive and negative signs have been found for the volatility coefficient;

• More recent research, often employing the error correction framework, appears to be obtaining greater success in finding a statistically significant relationship between volatility and trade;

• Since the effect of exchange rate volatility varies across markets, tests of its impact on trade flows should be based, whenever possible, on disaggregated data.

A quick look at the recent literature on this topic confirms the diversity of empirical results pointed out by McKenzie (1999).

Arize, Osang and Slottje (2004) found that the variability of the real exchange rate had a negative impact on export demand for the eight Latin American countries considered in their study. They considered this a surprising result, since all the countries in their sample are middle income countries, which, as such, should have developed forward markets able to allow traders to hedge exchange rate risk.

Interestingly, Wang and Barrett (2007), using data for Taiwan exports to the US from 1989 to 1999, found that agricultural exports are negatively affected by volatility, while exports from other sectors are not.

Recent papers that report no significant effect of exchange rate variability on trade flows include Aristotelus (2001) for the British exports to the US in the period 1889 – 1999, Abbot, Darnell and Evans (2001) for the UK exports in the period 1973 – 1990 and De Vita and Abbot (2004) for the UK exports to EU countries in the period January 1993 – June 2001.

Finally, Doyle (2001), Frankel (1992) and Sercu and Vanhulle (1992) report a positive effect of exchange rate volatility on trade.

To the best of our knowledge, Gonzaga and Terra (1997) is the only published work that examines the relation between the quantum of exports and exchange rate volatility for the Brazilian case.

Using ordinary least squares (OLS), these authors estimated eight export supply equations – combining two different definitions of the dependent variable (the volume of exports and the share of exports in GDP) and four different measures of the real exchange rate. Their regressions included as explanatory variables, besides the real exchange rate and its volatility, the level of GDP as a proxy for domestic activity, and a linear trend. They found the volatility coefficient to be negative in most specifications (six out of eight). However, in all eight regressions, this coefficient was not significantly different from zero.

Our exercise departs from that reported in Gonzaga and Terra (1997) in several respects. Apart from using more recent data and a different specification for the exports equation, we took into account the recommendations derived from McKenzie (1999) and adopted the cointegration/error correction framework to analyze the effects of volatility on the country's exports. Also our tests were conducted at a more disaggregated level, being based on data for manufactured (instead of total) exports.

3. Model Specification and Estimation Procedure

The manufactured exports of a country may be taken to be a function of (i) the real effective exchange rate, (ii) the level of world imports, which affect the demand for the country's exports, and (iii) the rate of capacity utilization in the domestic industry, which influences the country's supply of exports.

It is expected that exports will increase with the real effective exchange rate and the level of world imports, and decrease with the rate of capacity utilization.

Additionally, the literature mentioned in Section 1 suggests that the quantum of exports may also be affected by the volatility of the real exchange rate, with the sign of this relation not being known a priori.

In what follows, we adopt the procedures proposed by Pesaran, Shin and Smith (2001) (from now on PSS) and by Banerjee, Dolado and Mestre (1998)

(BDM from now on) to test for the existence of a long-term relation between Brazilian manufactured exports and the variables listed above.[4]

Both procedures permit the long-run relationship to include variables which are I(d), where $0 \leq d \leq 1$. They are, therefore, appropriate for our data set, since the unit root tests reported in the next section indicate that the quantum of Brazilian manufactured exports and the output gap are I(0), while the exchange rate, the volatility variable and the volume of world imports are I(1).

According to the PSS procedure, we may conclude that the volume of Brazilian manufactured exports is related in the long-run (cointegrated) to the real exchange rate and its volatility, to the rate of capacity utilisation in the domestic industry and to the level of world imports, if an F test rejects the null hypothesis that the coefficients c_i $(i = 0, \cdots, 4)$ in the following error correction model (ECM) are jointly equal to zero:

$$\Delta \ln x_t = a + c_0 \ln x_{t-1} + c_1 \ln e_{t-1} + c_2 \, v_{t-1} + c_3 \, g_{t-1} + c_4 \ln w_{t-1} +$$

$$+ \sum_{i=1}^{n} \alpha_i \, \Delta \ln x_{t-i} + \sum_{i=1}^{n} \beta_i \, \Delta \ln e_{t-i} + \sum_{i=1}^{n} \delta_i \, \Delta v_{t-i} + \sum_{i=1}^{n} \gamma_i \, \Delta g_{t-i} + \sum_{i=1}^{n} \lambda_i \, \Delta \ln w_{t-i}$$

where x = volume of exports, e = real effective exchange rate, v = standard deviation of exchange rate changes, g = output gap in the manufacturing sector and w = world imports.

Pesaran, Shin and Smith (2001) presented estimates of the critical values of the F statistic when all the regressors are I(0) as well as when all are I(1). If the estimated value of F in the ECM is larger than both critical values at the conventional significance levels, then the null hypothesis of absence of a long-term relation among the variables under analysis is rejected.

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[4] There are other methodologies to test a cointegration relationship. Johansen's (1988) is the most frequently used cointegration method in applied econometric work. This procedure tests the existence of a cointegration relationship in a system of equations, allowing, at the same time, to test for weak exogeneity (Johansen 1992, 1992b), in order to validate a conditional model. We did not use Johansen's technique in this case because it requires that all variables in the system have the same integration order.

In the BDM procedure, the presence of a long-run relation among the variables of interest is tested via the significance of the coefficient c_0, in the ECM (in our case, the coefficient on the lagged level of the volume of exports, $\ln x_{t-1}$).

Pesaran, Shin and Smith (2001) also provided critical values for this *t*-statistic, for the cases when all variables are I(0) and when all variables are I(1). Again, the null of no cointegration is rejected if the estimated *t*-value is larger in module than both these critical values.

As suggested by Pesaran and Shin (1999), after settling the question of cointegration, an autoregressive distributed lag (ARDL) model may be used to obtain estimates of the long-run coefficients relating the volume of exports to the explanatory variables.

4. Data and Results

The data used are quarterly and cover the period 1985.1/2002.2. Since in some of the tests performed we made use of first differences and four lagged values of the variables, five observations were "lost", reducing the sample period to 1986.2/2002.2.[5]

The volatility variable was proxied by the standard deviation of the changes in the real effective exchange rate for moving 8-quarter sub-samples, according to the following formula**:**

$$v_t = [\tfrac{1}{8}\sum_{i=1}^{8}(\ln e_{t+i-1} - \ln e_{t+i-2})^2]^{1/2}$$

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[5] Data files are available from the authors upon request.

Figure 1. Brazil – Exchange Rate Volatility
Period: 1986.2–2002.2
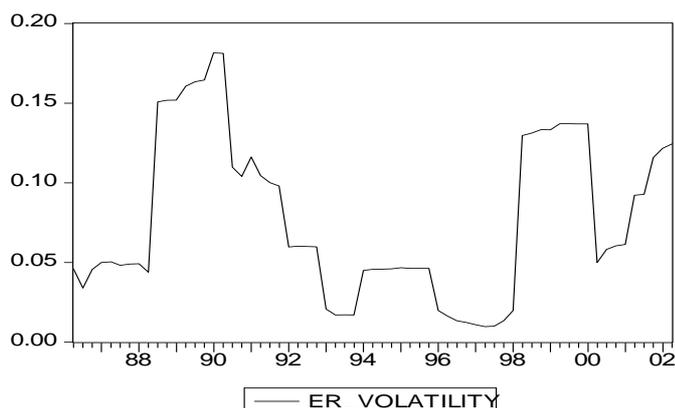
As can be seen in Figure I, Brazilian exchange rate volatility was relatively low in 1986/87, but increased sharply between 1988 and 1992, the hyperinflation period. It decreased again with the implementation of the "*Plano Real*" in 1994 and the adoption of a crawling peg between 1995 and 1998. Since the 1999 devaluation and the shift to a floating exchange rate, volatility has returned to higher levels.

A description of the rest of the data entering the exercise, as well as their sources, is given in the appendix.

The unit root tests reported in Table 1 (using the Akaike information criterion) suggest that the volume of exports and the output gap are I(0), while the real exchange rate, the volatility variable and the volume of world imports are I(1).[6] These differences in the order of integration of the variables entering the model justify the adoption of the PSS and BDM testing procedures, described in the previous section.

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[6] The same results are obtained when the Schwarz Bayesian Criterion is used to determine the lag structure of the test equations.

Table 1. Unit Root Tests

Variables	ADF Statistics	
	H_0: z is I(1)	H_0: z is I(2)
X	−3.77* [0.02]	−6.88 [0.00]
E	−1.85 [0.35]	−7.86 [0.00]
G	−3.51 [0.01]	−9.61 [0.00]
V^1	−2.05 [0.27]	−7.87 [0.00]
W	−2.71* [0.23]	−6.91 [0.00]

Notes**:** (i) the specification of the test equation was chosen on the basis of the Akaike Information Criterion; (ii) the asterisk (*) indicates that a linear trend was included in the test equation; (iii) figures in brackets are p-values.

We estimated the ECM for values of *n*, that is to say, the number of lags taken in the five first-difference variables on the RHS of the test equation, ranging from one to four.

A dummy variable was included in the equation to control for a policy shock that occurred in the fourth quarter of 1986. We gave this dummy variable a value "one" in that quarter and value "zero" elsewhere.

The values of the *F* statistic, used to test the null hypothesis that the coefficients c_i (i = 0, …, 4) are jointly equal to zero, varied from 5.66 to 8.08 (Table 2). These values exceeded, in all cases, the critical values for the 1%

level of significance presented by Pesaran, Shin and Smith (2001), when the variables are I(0) as well as when they are I(1).

Table 2. Cointegration Tests

Value of n	F-statistic	t-statistic
1	7.45	–5.52
2	8.08	–5.78
3	6.02	–4.52
4	5.66	–4.14

Critical values

5% level: for all variables I(0), F = 2.86; for all variables I(1), F = 4.01

1% level: for all variables I(0), F = 3.74; for all variables I(1), F = 5.06

5% level: for all variables I(0),   t = -2.86; for all variables I(1), t = -3.99

1% level: for all variables I(0),   t = -3.43; for all variables I(1), t = -4.60

The t-statistic values related to the c_0 coefficient varied from –4.14 to –5.78, also exceeding both critical values for the 5% level of significance.

Based on these tests, therefore, it is not possible to reject the existence of a long-run relation (cointegration) between the volume of Brazilian manufactured exports and the real effective exchange rate, its volatility, the output gap in the manufacturing sector and the level of world imports.

In order to obtain the values of the long-run coefficients, we used the procedure available in the Microfit® software (Pesaran and Pesaran, 1997), which allows the estimation of auto-regressive distributed lag (ARDL) models, setting the maximum value of n at 4.

When the Akaike Information Criterion was used, the specification chosen was that of an ARDL(2, 4, 2, 3, 2), *i.e.* the set of explanatory variables included two lagged values of the dependent variable, plus the contemporaneous and four lagged values of the real exchange rate, the contemporaneous and two lagged values of the volatility variable and of world imports and the contemporaneous and three lagged values of the output gap (see Table 3).

Table 3. ARDL Model Estimates

Variables	ARDL(2, 4, 2, 3, 2) (Akaike Information Criterion)		ARDL(1, 1, 0, 0, 0) (Schwarz Bayesian Criterion)	
	Sum of coefficients	Long-run coefficients	Sum of coefficients	Long-run coefficients
x_{t-i}	0.433	–	0.630	–
e_{t-i}	0.257	0.454 (5.324)	0.169	0.455 (3.415)
v^1_{t-i}	–0.436	–0.769 (–2.590)	–0.396	–1.070 (–2.219)
g_{t-i}	–0.954	–1.682 (–3.278)	–0.416	–1.125 (–2.003)
w_{t-i}	0.321	0.565 (13.300)	0.182	0.491 (6.503)
error corr. term	–0.567 (–6.411)		–0.370 (–5.003)	
Diagnostic Tests	Adjusted R^2 = 0.966 AIC = 86.325 LM(4) = 1.501 [0.219] RESET = 0.443 [0.509] Heteroscedasticity = 0.023 [0.879]		Adjusted R^2 = 0.945 SBC = 72.928 LM(4) = 0.374 [0.826] RESET = 0.373 [0.544] Heteroscedasticity = 1.021 [0.316]	

Notes**:** figures in parentheses are t-statistics; figures in brackets are p-values.

In order to investigate the adequacy of the estimated empirical model, we used a Lagrange multiplier test of residual serial correlation and found that the

null of absence of fourth order autocorrelation was not rejected at the usual significance levels. In the same way, a Ramsey RESET test showed that the functional form of our model is correct. Finally, the results of a White test allowed us to reject the hypothesis of heteroscedastic residuals.

The value of the error correction coefficient was –0.567, suggesting that about half of the previous quarter's deviation from the long-run relation tends to be corrected in the current quarter. This coefficient is statistically significant at the 1% level, which, again, confirms the existence of cointegration among the variables that entered the ARDL model.

All long-run coefficients reported in Table 3 present the *a priori* expected signs and are statistically significant at the 2% level.

These coefficient estimates suggest that**:**

• The elasticities of the volume of manufactured exports with respect to the real exchange rate and the level of world imports are 0.45 and 0.56, respectively;

• An absolute one-percentage point increase in the variability of the real effective exchange rate reduces manufacturing exports by 0.77%;

• A 1% deviation of manufacturing output above its long-run trend brings about a 1.68 % decrease in manufacturing exports.

Similar results to those reported above were obtained when we used the Schwarz Bayesian Criterion to determine the lag structure of the ARDL (see Table 3).

We also replicated the exercise using the same definition of the volatility variable adopted by Gonzaga and Terra (1997)[7]. The results, which are

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[7] The volatility measure, designated in this case as v^2, is the standard deviation of 6-quarters (moving) consecutive observations of quarterly changes in the real effective exchange rate, centered in the middle of each 6-quarter period, given by:

$$v_t = \left[\frac{\sum_{i=1}^{6} \left(e_{t+i-1} - \overline{e}_{t+i-1} \right)^2}{6} \right]^{1/2}$$

where:

$$\overline{e}_{t+i-1} = \frac{\sum_{i=1}^{6} e_{t+i-1}}{6}$$

available from the authors upon request, do not depart significantly from the ones reported above.

Finally, we followed the recent empirical finance literature, which uses the generalized autoregressive conditional heteroscedasticity (GARCH) model to allow for time-varying conditional variance (i.e., volatility clustering) in the exchange rate series.

We found this volatility measure (v^3) to be I(0) and again could reject the hypothesis of no cointegration among exchange rate volatility and the other variables entering our model[8]. Estimation of the ECM, however, as shown in Table 4, yielded a long run coefficient on the volatility variable, which was not statistically significant in both the Akaike and SBC specifications.

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[8] We obtained values of the F-statistic (PPS test) from 5.85 to 6.14 and values of the t-statistic (BDM test) in the interval from -4.84 to -6.00.

Table 4. ARDL Model Estimates

Variables	ARDL(2, 3, 1, 3, 2) (Akaike Information Criterion)		ARDL(1, 0, 0, 0, 0) (Schwarz Bayesian Criterion)	
	Sum of Coefficients	Long-run coefficients	Sum of coefficients	Long-run coefficients
x_{t-i}	0.525	–	0.665	–
e_{t-i}	0.201	0.424 (3.983)	0.149	0.444 (2.746)
v^3_{t-i}	7.080	14.902 (1.464)	2.653	7.924 (0.546)
g_{t-i}	–0.453	-0.954 (-1.771)	–0.253	-0.755 (–1.235)
w_{t-i}	0.266	0.559 (10.211)	0.160	0.479 (5.081)
error corr. term	-0.475 (-5.741)		-0.335 (-4.282)	
Diagnostic Tests	Adjusted R^2 = 0.948 AIC = 82.570 LM(4) = 4.566 [0.335] RESET = 1.488 [0.222] Heteroscedasticity = 0.13889 [0.709]		Adjusted R^2 = 0.935 SBC = 68.622 LM(4) = 1.180 [0.881] RESET = 1.237 [0.266] Heteroscedasticity = 0.678 [0.410]	

Notes**:** figures in parentheses are t-statistics; figures in brackets are p-values.

5. Conclusions

In this paper we investigated the possible existence of a long-run relation between Brazilian manufactured exports, on the one hand, and the real effective exchange rate and its volatility, the rate of capacity utilisation in the domestic industry and the level of world imports, on the other.

We tested for cointegration between the levels of these variables utilising the two estimation procedures proposed in Pesaran *et al.* (2001). Using quarterly data for the period 1986.2/2002.2, we rejected the null hypothesis of absence of cointegration, in the three tests that were conducted.

We also estimated several ARDL models with different lag structures, using the AIC and SBC criteria to choose the best specification for this structure. As usual, the Akaike Information Criterion produced a more generous parameterisation while the alternative Schwarz Bayesian Criterion chose a more parsimonious specification.

We found that, in addition to the other explanatory variables in the model, exchange rate volatility significantly affected Brazilian manufactured exports in the period 1986–2002, when volatility was measured by the standard deviation of the real effective exchange rate (v^1 or v^2). When we used the GARCH model, however, we could not detect a statistical significant relationship between volatility (v^3) and exports.

As shown in section 2, such a result is far from unusual. Quite often in the literature conclusions regarding the sign and statistical significance of the relationship between volatility and exports vary with the definition of volatility being adopted.

The volatility estimator derived from the GARCH model allows for the possibility that forward looking behaviour on the part of traders conditions the way in which exchange rate movements and the risks associated with them affect trade volumes (Wang and Barret, 2007). One possible explanation for the discrepancy in our results is that clustering effects and forward looking behaviour are less important in the Brazilian case.

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Data Appendix

Variable	Definition	Source	Seasonal adjustment
x	Quantum of manufactured exports	FUNCEX	Yes
e	Real effective exchange rate (15 main trade partners) / deflators: consumer price indices	IPEADATA	No
V1	See equation in page 6	–	–
V2	See equation in footnote 3	–	–
V3	GARCH (1,1)	–	–
Y ind	Manufacturing production	IBGE	Yes
g	*Y ind* detrended by the Hodrick-Prescott filter	–	–
w	*wimport$/wimportd*	–	Yes
wimport$	Value of world imports in current dollars	IFS–IMF	–
wimportd	Price index of world imports	IFS–IMF	–

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RESUMEN

Clasificación JEL: F3.

El objetivo de este artículo es examinar la relación existente entre la volatilidad de la tasa de cambio y el volumen de exportaciones, usando datos brasileños. Después de establecer la existencia de cointegración entre las variables incluidas en nuestro modelo, procedemos a estimar los coeficientes de largo plazo por medio de un modelo auto regresivo de rezagos distribuidas (ARDL). Nuestros resultados demuestran que la volatilidad de la tasa de cambio tuvo un efecto perceptiblemente negativo en las exportaciones manufacturadas brasileñas en el período 1986–2002.

Palabras claves: Volatilidad de la tasa cambiaria, cointegración, modelos autoregresivos con rezagos distribuidos.

SUMMARY

JEL Classification: F3.

The purpose of this paper is to examine the relation between exchange rate volatility and the volume of exports, using Brazilian data. After establishing the existence of cointegration among the variables included in our model, we estimate the long run coefficients by means of an auto-regressive distributed lag (ARDL) model. Our results show that exchange rate volatility has significantly affected —in a negative way— Brazilian manufactured exports in the period 1986–2002.

Keywords: Exchange rate volatility, cointegration, auto-regressive distributed lag models.