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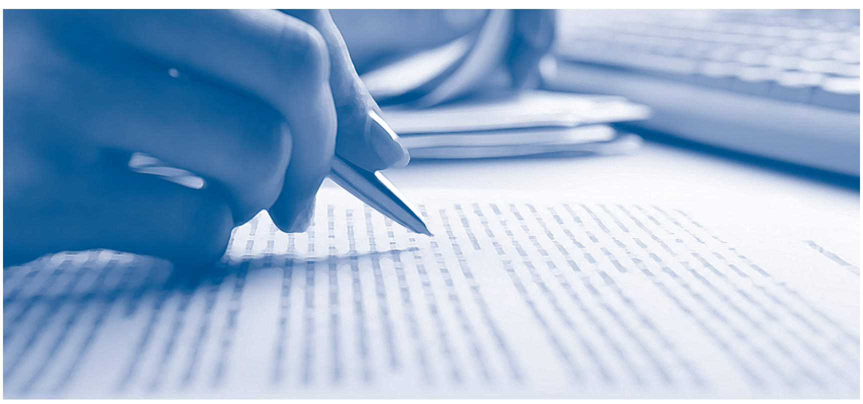

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Long-Run Determinants of the Brazilian Real: a Closer Look at Commodities*

Emanuel Kohlscheen†

Abstract

We use cointegration analysis to show that the long-run behaviour of the Brazilian real effective exchange rate betweeen January 1999 and September 2012 can largely be explained by the price variation of a basket of five commodities - that accounted for 51% of Brazilian export revenues in 2011. We estimate that a 25% real variation in the price of these five commodities moves the fundamental long-run real exchange rate by about 10%. Changes in interest rate differentials do not explain short or long term movements in the exchange rate during this period. Furthermore, we find that deviations of the real effective exchange rate from the long run equilibrium level have an estimated half-life of approximately 8 months. The growing exports of oil & fuel and of iron ores, as well as the important oil discoveries in the pre-salt layer, suggest that commodity prices will continue to influence the value of the Real in future.

Keywords: commodity currencies; exchange rate; Brazil

JEL Classification: F31; F41;

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1 Introduction

The value of the Brazilian Real has experienced considerable swings since the inception of the floating exchange rate regime in January 1999, both in bilateral and in effective terms. In particular, fluctuations in real exchange rates highlight important and persistent departures from principles of price equalization. Nominal exchange rates have tended to vary considerably without corresponding changes in good price differentials. While short term dynamics have been studied elsewhere, [1] the secular trend that led to an unprecedented period of real exchange rate appreciation between 2005 and 2011 begs a more thorough analysis of the long-run determinants of the value of the Brazilian currency. [2]

The present study is aimed at identifying the fundamental economic factors that drive the exchange rate in the long run in the case of Brazil. While our analysis started with a broad search of economic factors that have been found to be important in the theoretical and the empirical literature, theoretical considerations and our econometric results eventually led us to close in on monetary factors, fiscal policy variables, global and local risk factors and, last but not least, commodity prices. While we find that expansionary fiscal policy and reductions in global and local risk factors are associated with

[1] See, for instance, Kohlscheen (2012).

[2] It is also known that a good understanding of the equilibrium exchange rate is a necessary condition for consistency between the exchange rate policy and the inflation target (Benes, Berg, Portillo and Vavra (2013)).

movements of appreciations of the currency in the short run, [3] commodity prices that are relevant for Brazilian exports are found to be the single most important determinant of the long run trend of the Brazilian Real under the floating exchange rate regime. These econometric results may seem intuitive if one considers that the period of strong appreciation of the Real started during 2005, when the bulk of the reduction in country risk following the 2002 confidence crisis had already run its course.

Our analysis rests largely on three commodity price indicators. Two of them were created specifically to capture the dynamics of the international prices of the five commodities that currently represent more than 50% of Brazilian export revenues (i.e. oil & fuel, iron ores, soybeans, meat products and sugar & ethanol). What we find is that on average a 25% real variation in the price of these five commodities moves the fundamental long-run real exchange rate by about 10%. Changes in interest rate differentials do not explain short or long term movements of the exchange rate. Furthermore, we find that deviations of the real effective exchange rate from the long run equilibrium level have an estimated half-life of approximately 8 months. Alternatively, it would take 21 months to wipe out 90% of a given deviation from the equilibrium real exchange rate. While this estimated half-life may seem short, it is in line with the half-lives found for recent periods in other emerging economies.

[3] Tough not always in a manner that is significant from a statistical point of view.

Finally, we conjecture that the growing exports of oil and fuel and of iron ores that we show, as well as the important oil discoveries in the pre-salt layer, suggest that commodity prices will continue to be important determinants of the value of the Real in the near future. By any means, it becomes clear that the equilibrium exchange rate shows very sizable variations over time, even after we eliminate high frequency movements. Indeed, according to our preferred measure, by mid 2011 the equilibrium real exchange rate was 60% higher than in 1999. This observation only underscores the fact that it is entirely mistaken to expect the real exchange rate to always return to previous levels. Even more so if there are fundamental changes in the determinants of the demand for commodities in international markets.

Relation to the literature. The present study is related to the commodity currency literature that comprises a great number of articles. We do not aim to provide a complete review of this literature here. Instead we highlight a small number of landmark studies within this vein. Among them, Chen and Rogoff (2002) famously established the Australian and the New Zealand dollars as commodity currencies in the academic literature by showing that the US dollar prices of their commodity exports had a strong influence on their floating real exchange rates. Cashin, Cespedes and Sahay (2004) extended the search for long run relations between real rates and commodity prices by employing Gregory and Hansen's (1996a,b) methodology, that allows for structural breaks in the relation - an approach that was also used by Kohlscheen (2010). At the same time, MacDonald and Ricci (2004) found that the behavior of the South African Rand was tightly linked to the international prices of a number of alternative baskets of commodities and to the price of gold. More recently, Sidek and Yussof (2009) found similar results for the case of Malaysia. Paiva (2006) has also looked at the case of Brazil, covering the period 1970-2004, based on annual data. The exchange rate however was pegged in some way during most of this sample period - which included many regime changes, as well as stints of hyperinflation and high parallel market premiums. To the best of my knowledge, the present paper is the first academic paper to study the implications of international commodity price developments for the short and long run dynamics of the Brazilian Real under the current floating exchange rate regime, estimating a set of cointegrating equations and vector error correction models along the lines proposed by Johansen and Juselius (1990).

Outline. The paper proceeds as follows. Section 2 explains the dataset that is used in this paper and the construction of two commodity price indices that track the price evolution of a substantial share of Brazilian commodity exports. In Section 3, we estimate how developments in fundamentals affect the short and the long-run dynamics of the exchange rate. Section 4 proceeds to estimate the equilibrium real exchange rates that are based on these estimated cointegration vectors. The paper closes with some concluding notes.

2 Background and Data

The Brazilian Real was created in 1994 as part of a successful stabilization program that ended a period of hyperinflation in Brazil. Between 1994 and early 1999 the currency fluctuated within a narrow adjustable band against the US Dollar. In January 1999 the peg was abandoned and the currency allowed to float. Figure 1 shows the evolution of the real effective exchange rate, as computed by the International Monetary Fund, between January 1999 and September 2012. [4] The real exchange rate in the plot is based on relative movements in consumer price indices (CPIs). Throughout, this ratio is such that increases in the index imply appreciations and decreases depreciations. The time window comprises at least three periods of significant depreciations in real terms: the first one in 2001, another in the second half of 2002, and a third one during the period of the global financial crisis in 2008. Overall, however the period is dominated by a period of strong appreciation winds. Indeed, while at the peak of the 2002 confidence crisis that was associated with the government transition in October 2002, the Brazilian Real traded at 0.25 US Dollar cents, nine years later, in July 2011, it touched 0.65 cents. This extraordinary 157% appreciation coincided with a period in which the price of the 22 commodities that comprise the Commodity Research Bureau's (CRB) index increased by 136%. [5]

[4] International Financial Statistics.

[5] To be more precise, we are refering to the variation in closing prices between October 10th, 2002 and the peak of July 26th, 2011, as reported by *Bloomberg*.

The fact that, as Figure 2 shows, commodities represent a very significant and increasing fraction of Brazilian exports, makes it plausible that at least part of the extraordinary strenghtening of the Brazilian currency during this period is directly related to developments in international commodity markets. Indeed, exports of soybeans, ores, oil & fuel, meat products and sugar & ethanol alone increased their contribution to total Brazilian export revenues gradually from 24.2% in 1999 to 50.8% in 2011. [6] Among these, the rapid increase in the importance of iron ores and oil & fuel during the recent years is most noteworthy.

2.1 Commodity Price Indices

It remains to be established if the suggestive broad brush relation between the movements in the real rate and commodity prices is purely coincidental or indeed systematic. In order to analyze the possibility of existence of a common stochastic trend between the real exchange rate and international commodity prices, we have constructed a Commodity Price Index that is based on the price variations of the five most important groups of commodities for Brazilian exports (i.e., those that feature in Figure 2). The index is constructed from the monthly time series that are made available by the IMF's International Financial Statistics. [7] The weight attributed to each

[6] See also Table A1 in the Appendix.

[7] Price series were taken from IFS' lines 22374JFDZF (Br. Soybeans); 22376GADZF (Br. Iron Ore); 11276AADZF (Brent); 22374M.DZF (Br. Beef) and 22374I.DZF (Br. Sugar).

group of products in the index is proportional to the mean contribution of that product to Brazilian exports during the sample period. [8] Figure 3 shows the evolution of the P5-BR index in real terms, i.e., after deflating the nominal U.S. Dollar value by U.S. CPI variation. As the graph illustrates, after a prolonged period of relative stability in value between 1999 and 2004, the price index of the five commodities gained 262% (plus the accumulated U.S. inflation) between the end of 2004 and the April 2011 peak, before losing some ground. A visual inspection confirms that variations in the value of the price index have, by and large, coincided with real exchange rate swings. Indeed, the correlation between the two variables during the whole sample period is no less than 0.919.

We also estimate a commodity price index based on the unweighted average of the price variations of the five commodities, as arguably one would not know the weights that we selected at the beginning of the sample. The unweighted commodity price index tracks the (baseline) weighted one almost perfectly. [9] In other words, the indications are that one does not lose much information by ignoring precise weightings.

[8] The weights were 0.255 for soybeans, 0.231 for ores, 0.222 for oil & fuels, 0.165 for meat products and 0.127 for sugar & ethanol.

[9] In fact the correlation is 0.999.

2.2 Unit Root and Cointegration Tests

Given that the Phillips-Perron unit root tests does not allow the rejection of the null that the real effective exchange rate, the interest rate differential and each of the three commodity price indices that are used here possess a unit root (see Table A2 in the Appendix), we tested for the existence of cointegration between these variables, following the well known procedure suggested by Johansen (1995). The public sector borrowing requirements (as a fraction of GDP), the VIX, the EMBI country risk premia and the seasonally adjusted manufacturing productivity index relative to that of the United States, [10] were all found to be stationary variables. In particular, since there is clearly no trend in relative productivity during the sample period, it is difficult to attribute any long run movements that occurred during the period under study to Balassa-Samuelson type effects. (See Figure A1 in the Appendix. The hypothesis that the series has a unit root has a *p-value* of 0.0001.) [11]

Table 1 shows that both, the trace statistic and the maximum eigenvalue clearly suggest the rejection of the hypothesis of no cointegration between the real exchange rate and the unweighted commodity price index (PU5-

[10] The Brazilian manufacturing productivity was proxied by the seasonally adjusted ratio of manufacturing output to hours paid, as measured by the Brazilian statistics office (IBGE). For the U.S. we used an interpolated series of the quarterly s.a. output per hour of all persons.

[11] Note that when selecting a particular productivity index, one needs to be careful that the index is itself not (too heavily) contaminated by global commodity price effects. This is the reason why a manufacturing productivity index is appropriate.

BR) in column I, or the (baseline) weighted commodity price index (P5-BR) in column II at 1%. When we use the more generic Commodity Research Bureau's price index (in column III), the hypothesis of no cointegration is still rejected, but now only at 5%. In all cases, the tests indicate the existence of one cointegrating vector.

We have exhaustively attempted to include interest differential variables in the cointegrating relation as well, without success. Indeed, any attempt to include the interest rate differential vis-à-vis the United States in the cointegrating vector rendered counterintuitive signs, whether the differential was corrected by a *proxy* for country risk or not, or whether we used short-term or medium-term rates. It so happens that the long period of steady appreciation of the Real coincided with a period of unprecedented reduction in the interest rate differential. In other words, it is hard to rationalize the recent evolution of the effective or even the bilateral rate movements of the Brazilian Real with the (widely popular) interest rate arbitrage rationale. It has been shown elsewhere that the reaction of the exchange rate (or absence of it) following monetary policy events in Latin American economies corroborates such conclusion (see Gonçalves and Guimarães (2011) and Kohlscheen (2011)). The inclusion of a foreign interest rate on its own (to capture the "push factor" for capital flows) also did not change this assessment.

Cashin, Cespedes and Sahay (2004) suggest that the finding of a cointegrating relationship between commodity prices and the real exchange rate is a result of the fact that an increase in the international prices of commodities leads to higher wages, which in turn put upward pressure on the price of non-tradeables, causing an appreciation of the exchange rate. This assessment is clearly in line with the recent behavior of these variables in Brazil.

3 Short Run Dynamics and the Speed of Adjustment

Once the existence of a long-term relation between the Brazilian Real and commodity prices has been established, we proceed to estimate the dynamic models. These models take full account of the possible effects of interest rate differentials, variations in fiscal policy, in global risk aversion and in country risk premia.

For a given cointegrating equation

$$e_t = \beta_0 + \beta_1 . p_t$$

we estimated the corresponding VEC model

$$\Delta e_t = \alpha_0 . \left(e_{t-1} - \beta_0 - \beta_1 . p_{t-1} \right) + \theta(L) \Delta e_t + \alpha_1(L) . Z_t + \varepsilon_t$$

where L is the lag operator, e_t represents the IMF's real effective exchange rate, p_t a commodity price index, Z_t a vector of additional control variables and ε_t the error term. While we tested a myriad of other control variables, we ended up maintaining only four of them, for the sake of parsimony. More specifically, the interest rate differential was *proxied* by the change in the difference between the SELIC base rate and the Fed Funds rate. The stance of fiscal policy was captured by the nominal deficit/GDP ratio, while changes in global risk perceptions were *proxied* by changes in the VIX, and changes in country risk by changes in JP Morgan's EMBI for Brazil (stripped spread). The variation of these variables over time can be seen in Figure 4.

Both, the Akaike and the Schwartz information criterion indicate that the adjustment model with only one lag should be selected in all cases. Table 2 shows the outputs for the estimated vector error correction models using each of the three commodity price indices in turn. Each VECM estimation included dummies for the two observations with the largest absolute error terms. [12] As expected, given the almost perfect correlation between the PU5-BR and the P5-BR indices, estimation outputs for models I and II look very similar. We proceed by taking model II as the baseline case. The cointegrating equation suggests that a 25.5% variation in the P5-BR index would be required to move the Brazilian Real by 10% in the long run.

All three specifications deliver results that are qualitatively similar, both in the short and in the long-run, with the specification that is based on the P5-BR performing better in terms of the fit, the log-likelihood and the F-statistic. The effect of base interest rates on exchange rate changes gets the

[12] These were January and February 2002.

expected sign, but is negligible from a statistical point of view. Equally, an expansionary fiscal policy seems to strenghten the currency, but the effect is again far from being statistically significant. Both, increases in global risk aversion and in country risk premia lead to a significant weakening of the currency. A 10 point increase in the VIX rate is associated with a 0.6% depreciation of the Brazilian Real in real terms, while increases in the EMBI spread lead to depreciations as well. While the risk factors do influence the exchange rates, their effects appear to be relatively small from an economic viewpoint. In a way, the above results constitute further evidence for the (relative) prominence of commodity prices in exchange rate determination. Furthermore, exchange rate adjustments seem to follow trends at monthly frequency: all else equal, appreciation in a given month indicates further appreciation pressure in the following month.

Importantly, the error correction term is negative with an absolute value that is below unity in all cases - which means that deviations in valuation from the long run equilibrium are corrected in a gradual and stabilizing way. However, the error correction term is found to be of statistical significance at 5% in the adjustment equation only when we use the Brazil specific commodity baskets. The estimated half-life of deviations from equilibrium is just above 8 months - which is shorter than that found in an older study for South Africa (MacDonald and Ricci (2004)), but very similar to what was found in a more recent study for the Malayan Ringgit (Sidek and Yussof (2009)).

Alternatively, it would take 21 months to wipe out 90% of a given deviation of the Real from the equilibrium real exchange rate. [13]

It is well known that non-normality of residuals due to fat tails is a typical feature of return series and exchange rates are no different in this respect. Table 3 shows that in the specifications that use the PU5-BR and the P5-BR commodity price indices, normality of the residuals cannot be rejected at 5% or 10%, even though the kurtosis of the distribution is somewhat higher than that of a normal distribution. This is not the case in the specification that uses the CRB commodity price index. The results in Paruolo (1997) however support the view that non-normality as a result of excess kurtosis does not affect Johansen's results.

4 The Fundamental Long-Run Real Exchange Rate

While the Johansen and Juselius (1990) framework neatly separates short and long run dynamics and, as shown in the previous section, provides a very good fit for the behavior of the Brazilian Real since the inception of the floating exchange rate regime in 1999, the cointegrating equation enables us to pin down the long run equilibrium exchange rate. MacDonald and Ricci (2004) define the equilibrium real exchange rate as the level of the real

[13] Note that, to compute the adjustment speed, we need to take the lagged real rate variation into account, as well as the coefficient on the error correction term.

exchange rate that is consistent in the long run with the equilibrium values of the explanatory variables. As our cointegration analysis established that only commodity prices determined the long run dynamic of the exchange rate during this period in a significant way, the equilibrium real exchange rate will be tightly connected to the evolution of the commodity prices of the five main Brazilian commodity export product groups.

Obviously, commodity prices tend to fluctuate sharply. Because of this, we filter out high frequency fluctuations, focusing on the lower frequency movements. Figure 5, shows the path of the long run equilibrium exchange rate when we detrend the movements using a standard Hodrick-Prescott filter with smoothing parameter $\lambda = 14400$, which is normally deemed as appropriate for data at monthly frequencies. The graph suggests a period of undervaluation of the Real between late 2002 and early 2005, as well as a period of overvaluation after 2007, with a sign of reversal during the height of the global financial crisis and again in the most recent period (the analysis reaches until September 2012). The underlying long-run trend suggests that the period of strong appreciation that started during 2005, when the bulk of the reduction in country risk had already taken place, is indeed linked to the period of extraordinary increase in the P5 commodity price indices.

It is well known, however, that Hodrick-Prescott filtering suffers from bias in end-of-sample trend estimation. For this reason, in Figure 6 we also show the evolution of the equilibrium exchange using a 13-month centered moving average for detrending. What is clear from both figures is that the equilibrium exchange rate shows sizable variations over time. Indeed, by mid 2011, the equilibrium exchange rate was 60% higher than what it was at the beginning of the sample. [14] This underscores the fact that it is entirely unjustified to expect the real exchange rate to always return to previous levels in a mechanistic way.

Finally, Figure 7 shows the magnitude of the deviations from the estimated cointegrating relationship over time. In particular, the graph confirms that the exchange rate was depreciated relatively to what would have been suggested by the behavior of commodity prices in the aftermath of the confidence crisis (i.e. between the second half of 2002 and the first half of 2005).

5 Concluding Remarks

The analysis of this study provides strong new evidence for a prevalent role for international commodity prices in the determination of the equilibrium exchange rate in the case of Brazil. Similar results had already been reported for countries such as Australia, Indonesia, Malaysia, New Zealand and South Africa, among others.

We have shown that the international developments in the price of five

[14] Judging by the 13 month moving average of the fundamental REER. If one uses the HP trend as a basis instead, the variation is of 53%.

prominent commodities among Brazilian exports are capable of explaining the substantive appreciation of the real exchange rate that took place between 2005 and 2011. Importantly, changes in interest rate differentials do not explain short or long term movements of the exchange rate during this period - a result that confirms findings of previous studies on the topic. Furthermore, we find that deviations of the real effective exchange rate from the long run equilibrium level have a relatively short half-life, of approximately 8 months. We conjecture that the growing exports of oil & fuel and of iron ores, as well as the important oil discoveries in the pre-salt layer, suggest that commodity prices will continue to influence the value of the Real in future.

Throughout, we abstracted from foreign exchange market intervention as we focused on lower frequency movements. At high frequencies, however, interventions are known to have an effect on the exchange rate. At least in principle, and as an example, an intervention strategy that buys foreign currency when commodity prices and the value of the Real are excessively high, and sells when commodity prices and the Real are excessively low, could end up smoothing fluctuations and play the role of an insurance mechanism. In the long run, however, the value of the exchange rate under a floating exchange rate regime will in all likelihood be determined by more fundamental forces that reflect the underlying conditions in the economy, such as the ones we have analyzed here.

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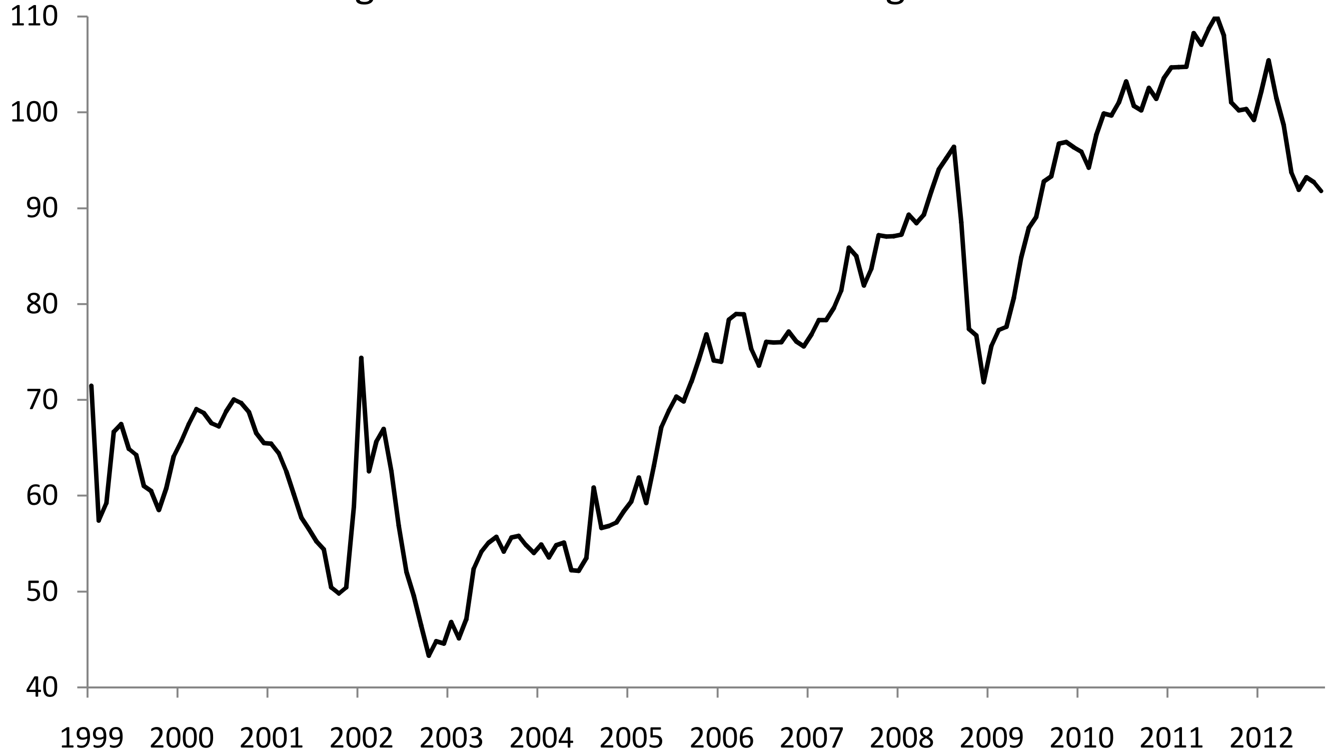
Fig. 1 - The Real Effective Exchange Rate



Source: IMF

Fig. 2 - The Growing Importance of the P5 Commodities
(share of total exports, in %)

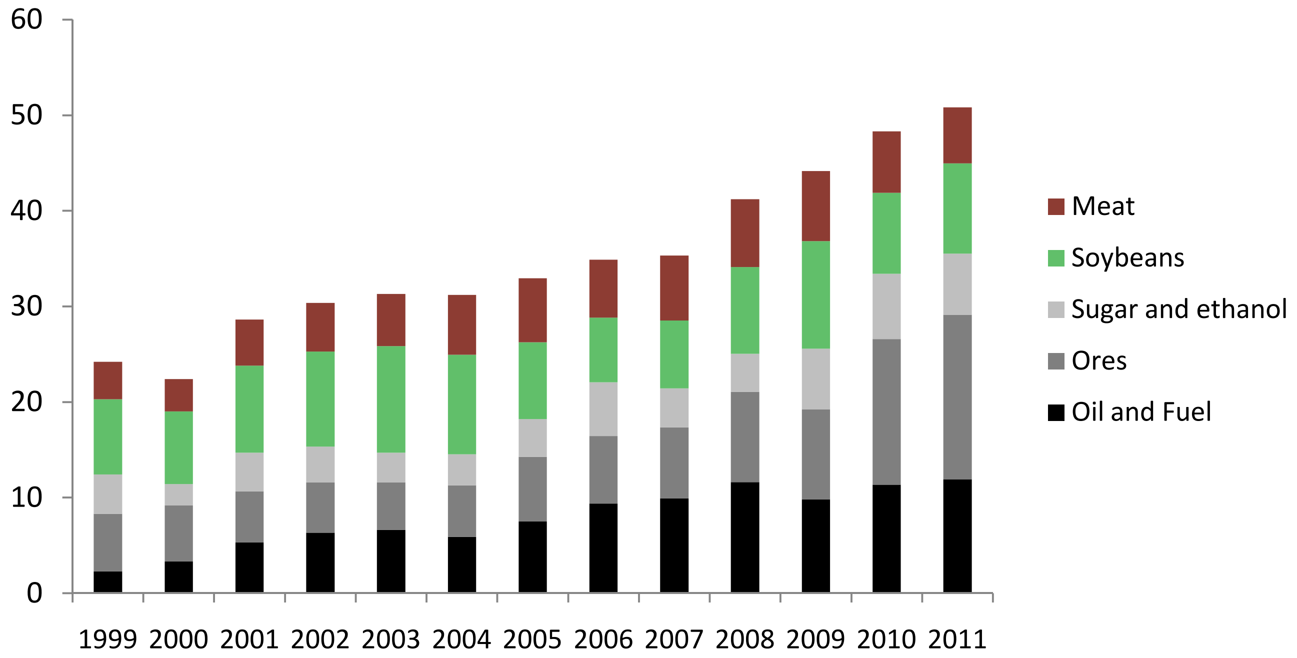
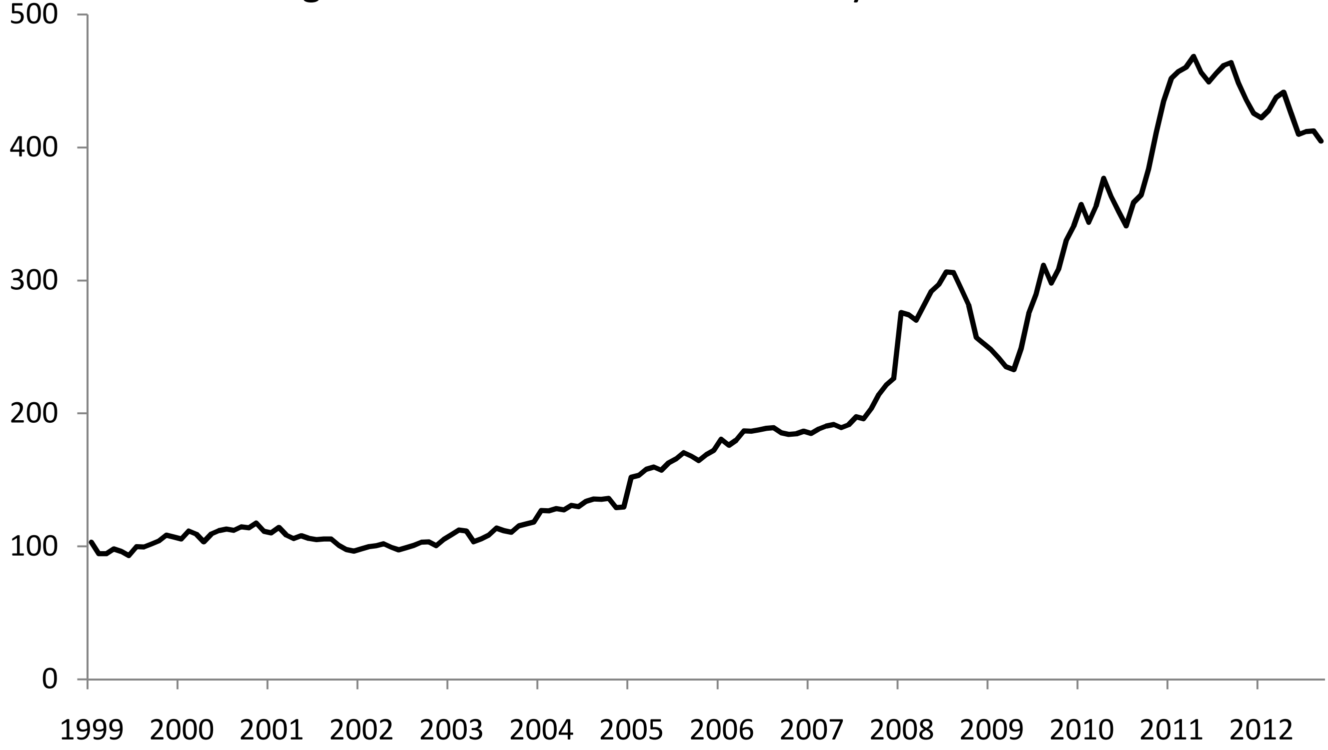


Fig. 3 - The P5-BR Real Commodity Price Index



Source: Own computation

Table 1
Johansen Cointegration Tests

	I	II	III
	between REER and PU5-BR	between REER and P5-BR	between REER and CRB
Trace Statistic	22.261***	22.292***	17.150**
number of cointegrating vectors	1	1	1
Max Eigenvalue	22.180***	22.240***	15.963**
number of cointegrating vectors	1	1	1

Note: *, ** and *** denote rejection of the null of no cointegration at the 10%, 5% and 1% confidence levels, respectively.

Figure 4 - The Evolution of Control Variables

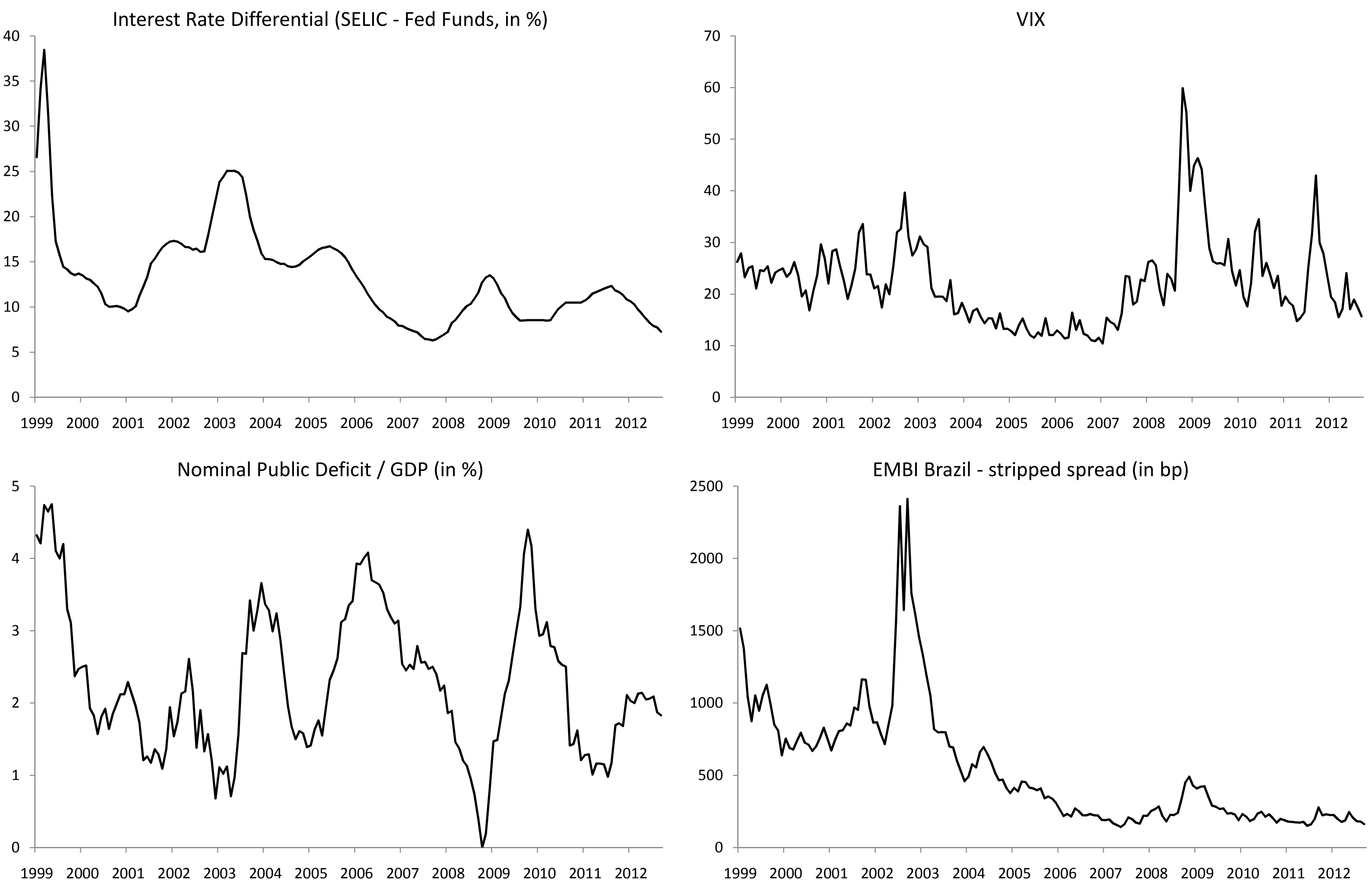


Table 2
Vector Error Correction Estimates

	I	II	III
	PU5-BR	P5-BR	CRB
estimates of the cointegrating equation			
constant	-51.757	-52.545	-30.657
REER	1	1	1
Real Commodity Price Index	-0.401***	-0.392***	-0.551***
	6.22	6.17	2.61
error correction			
C	1.907*	1.929*	1.876*
	1.87	1.89	1.80
lag D (REER)	0.169**	0.168**	0.138*
	2.11	2.10	1.66
lag D (Real Commodity Price Index)	0.042	0.029	0.041
	0.46	0.35	0.50
D (Interest rate differential)	14.924	15.084	6.507
	0.37	0.38	0.16
VIX	-0.059**	-0.060**	-0.056*
	2.04	2.09	1.74
Nominal deficit	13.182	13.854	3.240
	0.45	0.47	0.11
lag (EMBI)	-0.151**	-0.152**	-0.114
	2.04	2.06	1.48
cointegrating equation	-0.092**	-0.092**	-0.046
	2.53	2.55	1.63
no. of observations	158	158	158
adjusted R2	0.3393	0.3400	0.3239
Log-likelihood	-362.66	-362.59	-364.49
F	9.961	9.985	9.357

Note: t-statistics below coefficients. *, ** and *** denote statistical significance at the 10%, 5% and 1% confidence levels, respectively.

Table 3

Tests of Residuals

	I	II	III
	PU5-BR	P5-BR	CRB
Skewness (chi ^ 2)	0.567	0.620	0.282
	[0.4511]	[0.4307]	[0.5948]
Kurtosis (chi ^ 2)	3.782	3.943	5.554
	[0.0518]	[0.0471]	[0.0184]
Normality (Jarque-Bera)	4.350	4.564	5.838
	[0.1136]	[0.1021]	[0.0540]

Note: Numbers in [ ] are probability values.

Fig. 5 - Actual vs. Long-Run Fundamental REER (HP)

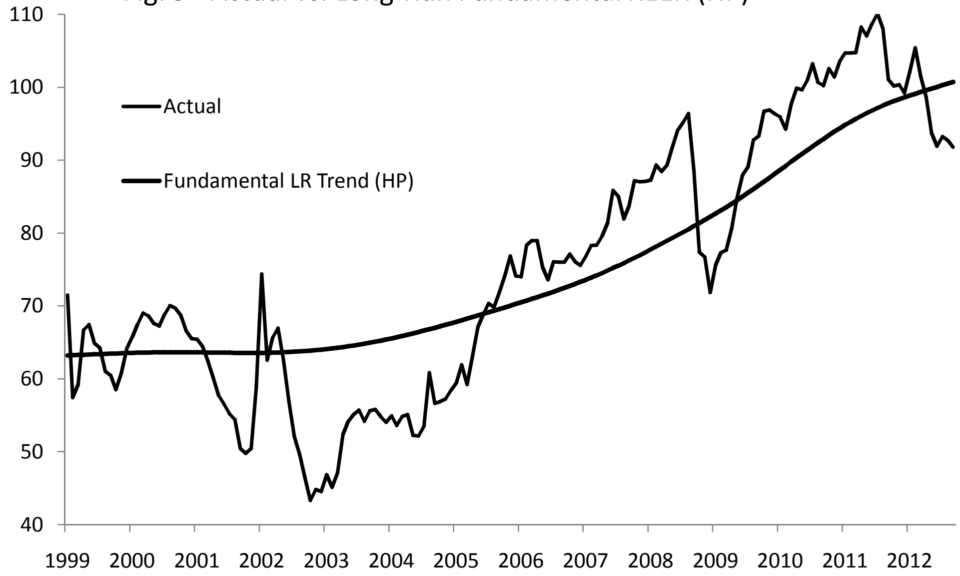


Fig. 6 - Actual vs. Fundamental REER (13 month MA)

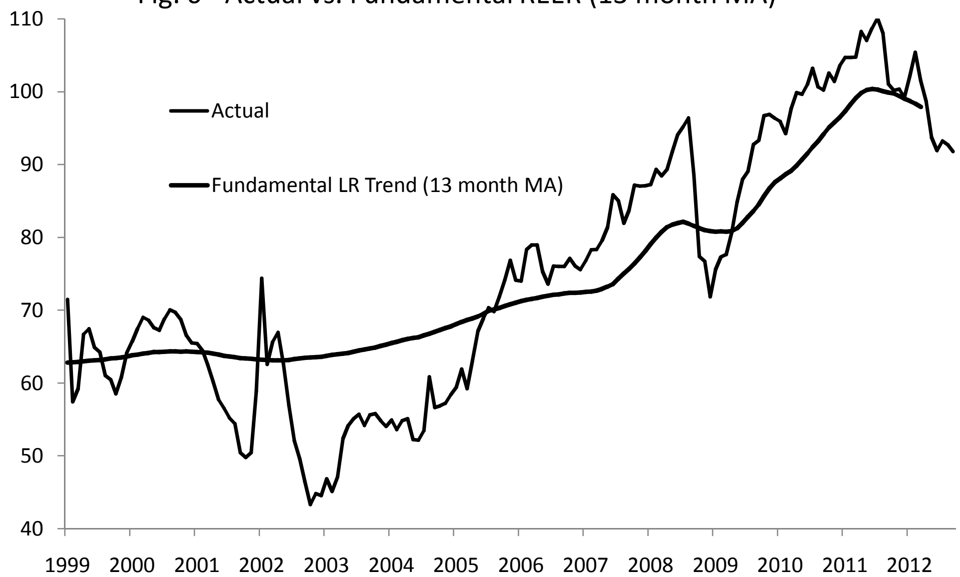


Fig. 7 - Cointegration Factor

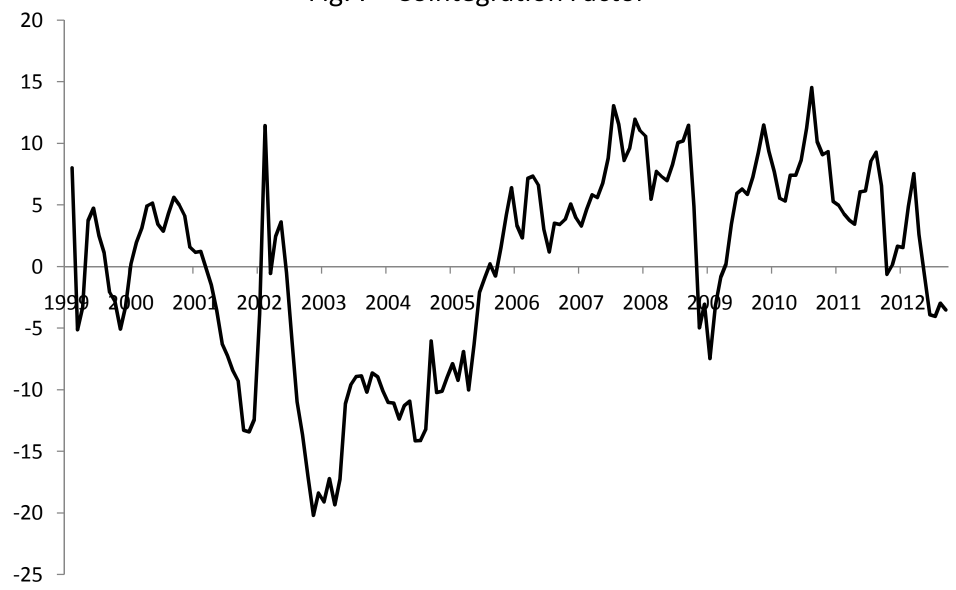


Table A1

Participation of Commodities in Brazilian Exports (in %)

	Soybeans	Ores	Oil and Fuel	Meat	Sugar and ethanol	Share of 5	Total Exports ($ mn)
1999	7.88	6.04	2.27	3.91	4.12	24.21	48 011
2000	7.62	5.84	3.32	3.39	2.24	22.41	55 086
2001	9.10	5.31	5.32	4.82	4.07	28.62	58 223
2002	9.95	5.27	6.31	5.09	3.75	30.37	60 362
2003	11.12	4.96	6.61	5.48	3.14	31.31	73 084
2004	10.42	5.41	5.88	6.25	3.25	31.21	96 475
2005	8.01	6.75	7.52	6.72	3.96	32.95	118 308
2006	6.76	7.06	9.37	6.06	5.64	34.88	137 808
2007	7.09	7.44	9.91	6.78	4.09	35.32	160 649
2008	9.09	9.43	11.63	7.08	3.98	41.20	197 942
2009	11.28	9.41	9.81	7.31	6.35	44.15	152 995
2010	8.48	15.25	11.34	6.44	6.82	48.32	201 915
2011	9.43	17.19	11.92	5.85	6.42	50.82	256 040
Mean	8.94	8.11	7.78	5.78	4.45	35.06	

Source: DEPEC/BCB and Ministério do Desenvolvimento, Indústria e Comércio Exterior.

Table A2
Phillips-Perron Unit Root Tests

REER	-1.195
PU5-BR	-0.256
P5-BR	-0.276
CRB	-1.092
Interest rate differential	-1.804
Nominal public deficit/GDP	-3.218***
Relative productivity index	-4.829***
VIX	-3.338***
EMBI	-2.242**

Note: *, ** and *** denote rejection of the null that the series possesses a unit root at 10%, 5% and 1% confidence levels, respectively.

Figure A1 - Relative Manufacturing Productivity (BRA/U.S.)

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