Essays on Exchange Rates and Emerging Markets

Ezequiel Aguirre

Submitted in partial fulfillment of the

requirements for the degree of

Doctor of Philosophy

in the Graduate School of Arts and Sciences

COLUMBIA UNIVERSITY

2011

ABSTRACT

Essays on Exchange Rates and Emerging Markets

Ezequiel Aguirre

This dissertation consists of three essays on exchange rates and international finance with an emphasis on emerging economies.

In Chapter 1, I provide empirical evidence that supports the hypothesis that exchange rate based stabilization programs are expansionary during their early phases. I derive a new set of stabilization episodes using extensive country chronologies from Reinhart and Rogoff (2004) and I find that even after controlling for external conditions, the initial expansion associated with the introduction of an exchange rate based program, is caused by both, the program itself and positive external conditions. These expansionary effects are robust to different estimation methods and different criteria for detecting stabilization episodes.

In Chapter 2, I study the relationship between foreign interest rates, country spreads, terms of trade and macro fundamentals in emerging markets. I estimate a structural VAR for 15 emerging economies. I find that country spreads explain 12% of output fluctuations, foreign interest rates an additional 7% and the terms of trade about 5%. I also find that country spreads account for a quarter of real exchange rate variability while the terms of trade account for just 1%. To further validate these results, I develop a dynamic stochastic general equilibrium (DSGE) model for a small open economy. The model incorporates several open economy frictions: i) bond-holding adjustment costs, ii) investment adjustment costs, iii) a working capital constraint, and iv) a country spread component that depends upon macro fundamentals, which is taken from

the estimated VAR. The model is able to replicate fairly good the propagation effects of foreign rates and country spread shocks but overestimates the importance of the terms of trades.

In Chapter 3, I investigate the relation between volatility in the foreign exchange market and excess returns on carry trade portfolios for the G10 currencies. I develop and compare three different investment strategies that aim at avoiding losses when volatility jumps, a common feature of the carry trade. I find that two trading strategies, one based on implied volatility from FX options and the other on exponentially-weighted moving averages, provide better risk-adjusted returns than the standard carry trade. A third strategy, based on Markov-switching exchange rate forecasts, provides excess returns for some currencies but fails for portfolios of currencies. I also show that currency investing provides superior Sharpe ratios than a benchmark bond portfolio and a benchmark stock portfolio, even after including the recent global financial crisis.

Contents

List of Tables

List of Figures

Acknowledgments

Several people helped me during my doctorate studies. I would like to first acknowledge my advisors Richard Clarida and Martin Uribe, for their invaluable support and guidance throughout my dissertation writing process. My understanding of economic science have greatly benefited from stimulating conversations with them. I would also like to express gratitude to the other members of my dissertation committee: Guillermo Calvo, Stephanie Schmitt-Grohe and Jaromir Nosal. I thank them for their helpful comments and suggestions.

I am especially indebted to Juan Dubra, who encouraged me to pursue my graduate studies in the first place. His constant advice as an economist, stimulating discussions and unconditional support as a friend were of immense value to me over all these years.

Finally, this dissertation would have not been possible without the support and love of my grandfather Victor, my parents Viviana and Fernando, my sister Victoria and my uncle Ludovico. I dedicate this to all of them.

A Victoria y Victor

Chapter 1

Exchange rate based stabilization programs and external conditions

1.1 Introduction

High and persistent inflation has long been a major economic issue for developing countries, being Latin America one of the most affected regions by chronic inflation as defined by Pazos (1972). Governments across the region have undertaken several stabilization programs in the past in order to stop inflation. Most of the times, these programs used the exchange rate as a nominal anchor and not the money supply.[1] Programs based on the money supply usually induced the expected Phillips curve outcome of a recession at the beginning, followed by a later economic boom, as shown by Calvo and Végh (1994) and Fischer (1988). On the other hand, the empirical literature on exchange rate-based stabilization programs (henceforth ERBS) shows that actually the opposite is true. Specifically, these plans are characterized by a different set of stylized facts: initial expansions in output and consumption, appreciation of real exchange rates,

[1] For an overview of the most important stabilization episodes in Latin America, see Agenor and Montiel (1999), chapter 10.

convergence of inflation rate to the rate of devaluation, current account deficits and later contractions of output (Kiguel and Liviatan 1992, Végh 1992, Calvo and Végh 1999). This difference in the timing profile of the economic cycle (initial recessions under money-based plans versus initial booms under exchange rate based plans) has been named the “recession now-recession later” hypothesis.

Several theoretical models have been developed that try to account for the stylized facts associated with ERBS programs. They usually reduce to models with “inflation inertia” where inflation expectations are backward looking, like in Rodriguez (1982) or models with “lack of credibility”, where inflation expectations may be forward-looking but government policies are not fully credible, as in Calvo and Végh (1994).

The empirical literature on ERBS programs supports the notion that this programs tend to be associated with initial expansions. It is not always easy and straightforward to identify stabilization attempts, not to mention the dating of the programs. There are two different approaches for the identification of stabilization episodes. The “episodic” approach involves selecting only the best-known stabilizations episodes. This is the approach followed by for example Reinhart and Végh (1994). The disadvantage of this approach is that since it is subjective, it may omit lesser-known episodes. A second alternative, is to follow a “mechanical” approach, where stabilizations are defined based on some objective criteria, for example, inflation behavior. This is the approach taken by Easterly (1996). He defines as stabilization programs those where a country is going from 2 years or more of above 40% inflation to 2 years or more of below 40% inflation. He then finds that stabilizations from chronic inflation are typically expansionary. Output and per capita output increase in the first years after the launch of the stabilization program.[2] However, it should be noticed that this approach identifies programs based on their outcome, so it will invariably bias the sample towards successful programs. Only those countries that succeeded in bringing down inflation will be identified. Therefore, we may be overestimating the expansionary effects of stabilization.

Reinhart and Végh (1994) use panel data for seven Latin American countries from 1964 to 1993. They find that ERBS programs are associated with an economic boom in the early phases of the programs, and with a recession in the later phases. However, one should be careful when concluding that ERBS programs are indeed expansionary, that is, that they *cause* an expansion. As was argued by Echenique and Forteza (2000), the political decision of launching a stabilization program may be correlated with international conditions. The empirical evidence in their work casts doubts on the stylized fact that the "expansion now – recession then" hypothesis is caused by the stabilization plan. They argue that once variables representing external conditions are included in the regressions, the results are no longer robust. Calvo, Leiderman and Reinhart (1993 and 1996) also argue that international conditions may be critical in determining capital inflows and thus limit the set of policies that a country can use in order to stabilize capital flows. This may suggest that exchange rate programs are an endogenous response of governments to external conditions. Calvo and Végh (1999) run panel regressions on several dummies intended to capture the different stages of the programs. They use a

[2] Easterly (1996) results are common to both, ERBS and MBS programs. Furthermore, no evidence of later recessions is found in his work.

smaller sample of ERBS programs and they find that even after controlling for external conditions, ERBS are expansionary at the beginning.

In the present paper, we try to determine if using the exchange rate as an anchor is unequivocally expansionary during the early stages. We try to improve upon the previous work along two dimensions. Firstly, we avoid using a pure “episodic” or a pure “mechanical” approach in detecting stabilization episodes, with the associated shortcomings of each method, by instead comparing inflation rates with actual exchange rate regimes for a large set of emerging economies. In order to do this, it is crucially important to know the actual, true exchange rate regime for each country at each point of time. We will use country exchange rate arrangements chronologies from Reinhart and Rogoff (2004) for this purpose. Reinhart and Rogoff (2004) develop a novel system of reclassifying historical exchange rate regimes. By using monthly data on market-determined parallel exchange rates, they are able to pin down the actual, true exchange rate policy that were in place for almost any country going back to 1946. Secondly, we try to improve the econometric methodology by using Arellano-Bond estimators. When working with dynamic panel data models, as in our case, additional complication arise in estimation of such a model. For example, in fixed and random effects settings, the difficulty is that the lagged dependent variable is correlated with the error term. Arellano and Bond (1991) provide a more convenient way for looking at efficient instruments and using additional information.

The paper proceeds as follows. In section 1.2, we discuss the methodology used for stabilization episodes identification. In section 1.3, we describe the data used and provide some summary statistics. In section 1.4, we estimate a probit model that explains the probability of launching a stabilization program. In section 1.5, we analyze the empirical evidence of the effects of stabilization programs on the business cycle. Section 1.6 provides some robustness checks. Section 1.7 concludes the paper.

1.2 Identification of the Stabilization Programs

A critical methodological issue when studying stabilization programs involves identifying the programs in the first place. For this purpose, two alternative approaches have been used in the existing literature. Following Calvo and Végh (1999) terminology, one approach may be named the "episodic" approach, which consist in working with stabilization episodes that have received a good deal of attention. This is the approach followed by Reinhart and Végh (1994), Calvo and Végh (1999), and Echenique and Forteza (2000) among others. As an example, these three papers use a subjective list of stabilization programs first defined in Reinhart and Végh (1994).[3] A potential problem with this approach is that since it is subjective it may omit smaller less-known episodes. The mechanism proposed in this paper is able to detect several additional ERBS programs in Latin America, thus expanding the set of programs that can be used to study empirical relations between stabilizations and macroeconomic performance.

[3] The original Reinhart and Végh (1994) list includes 11 programs in 5 countries. Echenique and Forteza (2000) add the Brazilian "Plan Real" to that list, whereas Calvo and Végh (1999) work with a subset of that list plus one program from Israel.

An alternative approach might be what they call the "mechanical" approach, were stabilizations programs are defined according to an explicit rule. A good example of this approach is Easterly (1996), who defines a stabilization program as an episode characterized by a switch from at least two consecutive years with inflation rates above 40% followed by a period of at least two consecutive years with inflation rates below 40%. However, as was pointed out by Echenique and Forteza (2000), this approach is problematic since it defines a stabilization plan by its outcome, the inflation rate, and thus possibly omitting programs that failed and biasing the results towards successful programs.

Given that the previous two approaches involve some disadvantages, we propose a new method here. The approach we will follow uses extensive country chronologies from Reinhart and Rogoff (2004), so it is worthwhile to review the main aspects of their work. The authors develop a major reinterpretation of modern history exchange rate arrangements. Until their work, most of the empirical literature dealing with exchange rates used the official classification published in the IMF's *Annual Report on Exchange Rate Arrangements and Exchange Restrictions.* The problem with such classification is that until very recently the IMF just asked member states to self-declare their arrangement into one of four categories yet many countries deviate from their announced exchange rate regime.[4] To sort out this problem, Reinhart and Rogoff (2004) employ an extensive database on market-determined parallel exchange rates and then use an

[4] Calvo and Reinhart (2002) and Alesina and Wagner (2006) provide some explanations why countries do not follow their *de jure* exchange rate regimes.

algorithm to obtain what they call a "natural" classification. The algorithm employed, relies mainly on the absolute percent change in the exchange rate on a monthly basis over two and five year rolling windows, and then sorting them across several exchange rate arrangements.

The differences from Reinhart & Rogoff's "natural" classifications and that of the IMF are not minor. As an example, they find that when the official classification is a form of a peg, almost half of the time their algorithm reveals the true underlying monetary policy to be a variant of a float. Conversely, when the official classification is a form of a float, their "natural" classification reveals that the underlying policy was something closer to a de facto peg. They develop from this a detailed exchange rate chronology for 153 countries that goes back to 1946. Their algorithm allows for fourteen different categories of exchange rate regimes, ranging from strict pegs and no separate legal tender to hyper-floats and freely falling. Table 1.1 lists all categories in their classification.

Table 1.1: Reinhart & Rogoff Classification Scheme

Natural classification bucket	Number assigned to category in: Fine grid	Coarse grid
No separate legal tender	1	1
Preannounced peg or currency board arrangement	2	1
Preannounced horizontal band narrower than or equal to ±2%	3	1
De facto peg	4	1
Preannounced crawling peg	5	2
Preannounced crawling band narrower than or equal to ±2%	6	2
De facto crawling peg	7	2
De facto crawling band that is narrower than or equal to ±2%	8	2
Preannounced crawling band that is wider than ±2%	9	2
De facto crawling band that is narrower than or equal to ±5%	10	3
Noncrawling band that is narrower than or equal to ±2%	11	3
Managed floating	12	3
Freely floating	13	4
Freely falling (includes hyperfloat)	14	5

Source: Reinhart & Rogoff (2004)

Using the country classifications in Reinhart and Rogoff (2004), we proceed to identify exchange rate-based stabilization episodes in the following manner. First, we divide the 14 exchange rate categories into two groups: “fixed” (categories 1-9) and “floating” (categories 10-14). The “fixed” category groups all R&R categories that involve some sort of exchange rate policy where the exchange rate is being used as an anchor. The “floating” category groups all other R&R categories, namely, those regimes where the exchange rate was largely let free. We then look for all cases in which a country moved from a “floating” regime to a “fixed” regime, for all countries in the dataset. Finally, we identify that change as an ERBS program, if the change in exchange rate policy was preceded by at least two years of high inflation. We define as a high inflation period, any year in which the inflation rate was at least 20 percent.[5]

The reason for following the just described procedure is that it allows us to identify not only well-known episodes, but also smaller episodes that may have not been publicly announced by the government. However, the change in exchange rate policy coupled with the fact that inflation was above 20 percent for at least the previous two years, suggest that policymakers were indeed using the exchange rate to stabilize inflation.

Using this procedure on emerging countries for the period 1945-2001 we detect 34 ERBS programs. Most of these episodes took place in Latin American countries. A

[5] 20 percent is our baseline cutoff for defining high inflation periods. In section 8, we perform some robustness checks by using two different cutoff levels, 10 and 40 percent.

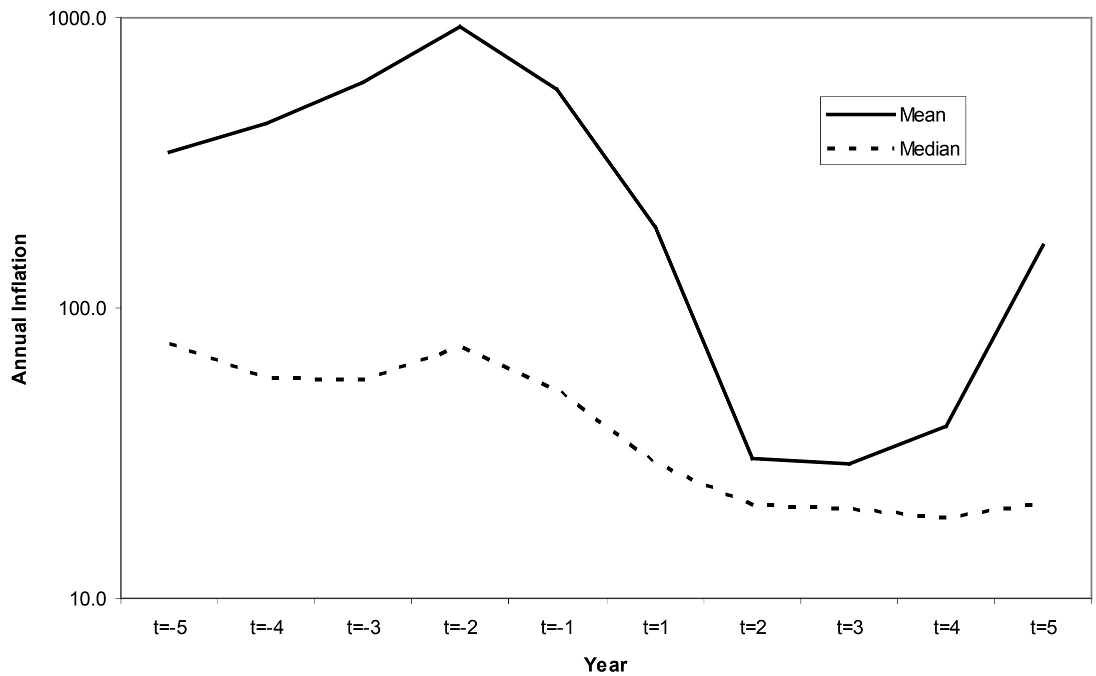
complete list with all exchange rate-based stabilization programs that took place over the period is presented in the appendix (Table A1).

1.3 Data Description and Summary Statistics

The dataset for exchange rate classifications is from Reinhart and Rogoff (2004). This dataset classifies exchange rates arrangements for 153 countries for the period 1946-2001. The measure of inflation we use is CPI percentage change from the *International Financial Statistics* (IFS) of the IMF. Data on output, per capita output, consumption, investment, trade balance, foreign direct investment and foreign reserves are from the IFS and *World Development Indicators* (WDI) of the World Bank. Terms of Trade data for Latin American countries is taken from the United Nations *Economic Commission for Latin America and the Caribbean* (CEPAL). For the remaining countries, is taken from the IFS. We prefer the CEPAL data for Latin American countries, since this database cover a larger period. Data on several US interest rates as well as on the SP500 stock market index is from *Global Insight.*

Exchange rate-based stabilization programs are associated with output expansions and decreasing rates of inflation, at least initially. Figures 1.1 and 1.2 make this point clear. Figure 1.2 shows the median and mean inflation rates in the sample before and after an ERBS program began. The median inflation rate declines from a peak of 74% two years before a program started, to a low of about 19% by year 4. The mean inflation goes from almost 1,000% to 29%.[6] However, by year 4, mean inflation was again on its way up.

Figure 1.1: Annual inflation before and after an ERBS plan was started

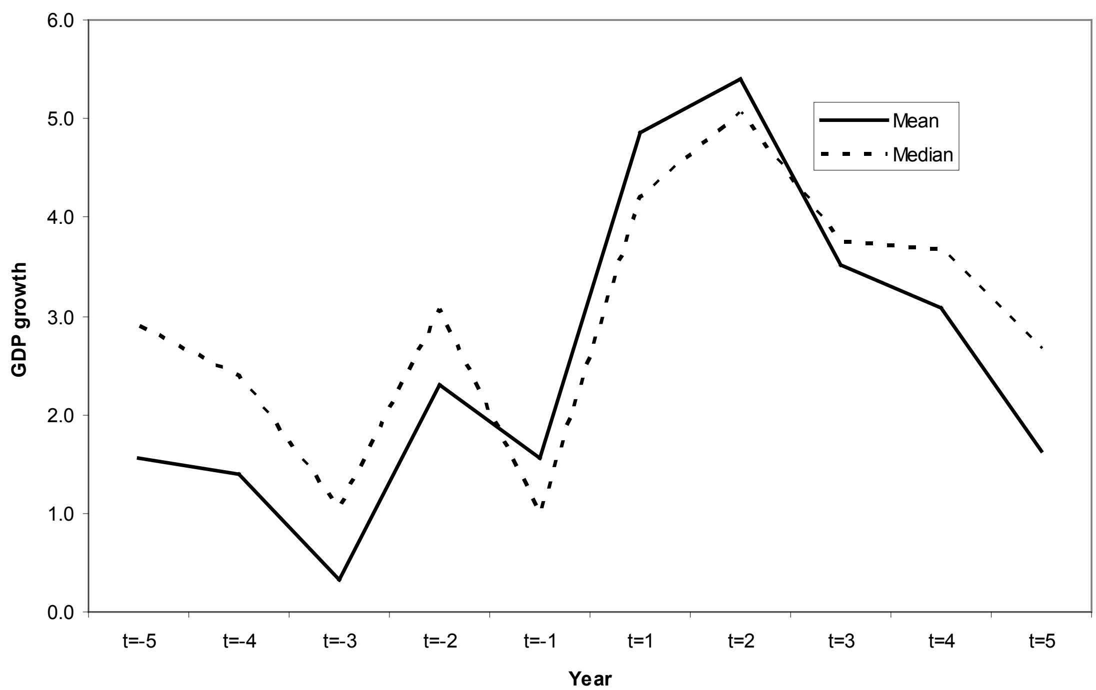


Note: Year 1 is the year in which an ERBS program started.

Figure 1.2 shows the median and mean real GDP growth rates before and after an ERBS program starts. GDP growth is around 2% during the earlier years before a program begins, and sharply increases to between around 5% for the first two years of the ERBS program. By the fourth year, real GDP growth is again around its pre-program levels, suggesting that the programs where only successful in the short term.

[6] Mean rates are higher because the distribution of inflation has a well-known skewness to the right.

Figure 1.2: Real GDP growth before and after an ERBS plan was started.



Note: Year 0 is the year in which an ERBS program started.

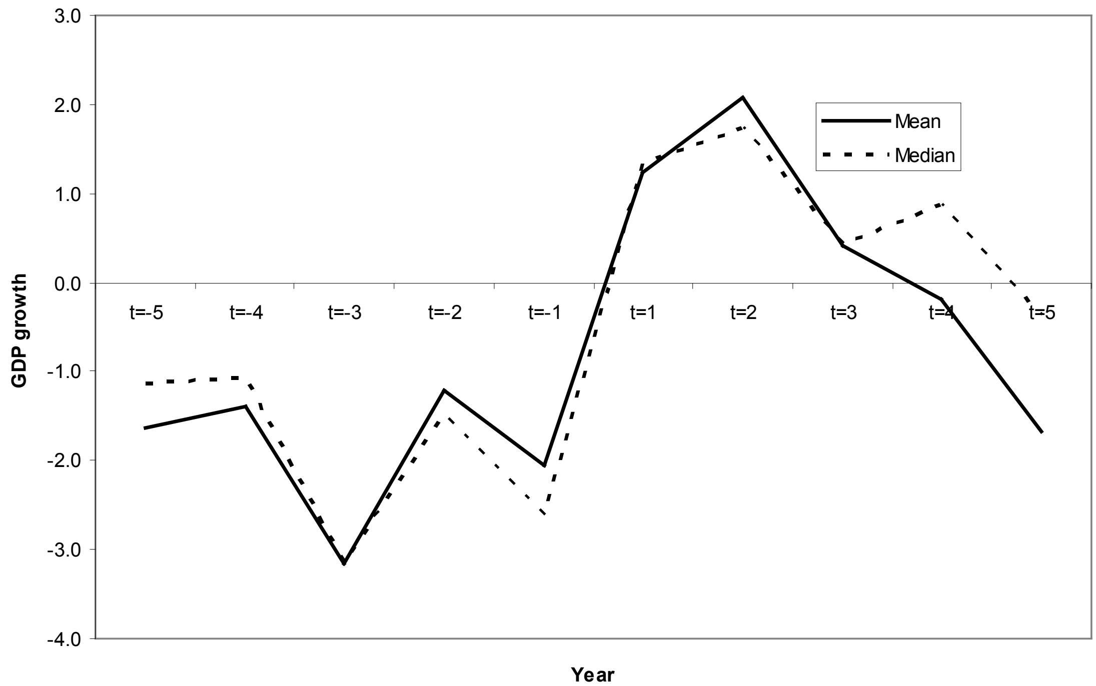
The previous two graphs seem to confirm the idea that exchange rate-based stabilizations are in fact expansionary in their early stages. However, correlation between ERBS programs and early output expansions does not necessarily mean that the stabilization programs "caused" the expansions. For example, other variables may explain both, the output performance and the ERBS programs. One simple way to check this is to see if output growth in countries under a stabilization plan was not only high, but also high relative to world output performance. Letting g_{it} denote real output growth in country *i* in year *t* and y_t denote world growth in that year, then the following measures output growth in each country relative to world output growth.

$$g_{it}^{d} = g_{it} - y_t \tag{1.1}$$

Figure 1.3 plots the average and median output growth relative to world growth. Looking at output growth relative to the world growth is relevant since the causality of stabilization programs on output would be less likely if a country is booming at the same time that most of the rest of the world is. Growth is below world growth on each of the previous five years prior to an ERBS program. Once an ERBS starts, growth is above world growth and remains that way for the first four years after the ERBS started.[7]

[7] Median growth is above world growth during the first four years after the start of an ERBS program. Mean growth is above world growth only the first three years.

Figure 1.3: Real GDP growth before and after an ERBS plan started relative to world growth.



Note: Year 0 is the year in which an ERBS program started.

In Tables 1.2 and 1.3 we test the significance of this "before and after" effects for a series of macroeconomic variables. We calculate sample averages for each of the four years preceding and ERBS and for the four years following the start of an ERBS program. Most of the expansionary effects of stabilization occur in the first two years. If we look at GDP growth, per capita output growth and differential growth (domestic growth above world growth), we observe always the same picture: very poor performance during the years preceding an ERBS stabilization program, followed by a period of two years of exceptionally good performance and later a return to more modest numbers. For example, output growth during these two years is 4.8 and 5.5 percent, respectively, above to what it was in the pre-ERBS years or to what it will be in years 3 and 4. Per capita output growth present a similar picture, with growth rates above 3 percent in years 1 and 2, well above to preceding years. In addition, growth above international growth is only significantly positive in years 1 and 2.

It is also of interest to see if the effects of stabilization on consumption and investment are similar to that on output growth. In both cases, the higher growth rates are observed in years 1 and 2. In particular, investment growth is exceptionally high on those tow years (14.9 and 13.2 percent respectively) as opposed to any of the previous four years of an ERBS, in which it was not significantly different from zero. The trade balance and current account balance, both measured as a percentage of GDP, also behave as expected. They go from small deficits to more pronounced deficits in years 2, 3 and 4 as absorption increases at a faster rate than output.

Table 1.2: Average statistics before and after stabilizations

	GDP growth		Per capita growth		Growth differential		Consumption		Investment	
Stabilization years	*x%*	*t*	*x%*	*t*	*x%*	*t*	*x%*	*t*	*x%*	*t*
-4	1.4	1.6	-0.4	-0.5	-1.4	-1.6	2.4	2.2	1.1	0.3
-3	0.3	0.3	-1.5	-1.3	-3.2	-3.0	-2.2	-1.4	0.3	0.1
-2	2.3	2.7	0.5	0.6	-1.2	-1.4	2.3	1.9	-0.6	-0.2
-1	1.4	1.5	-0.4	-0.4	-2.2	-2.5	2.0	1.7	1.6	0.6
1	4.8	5.2	3.0	3.2	1.2	1.3	5.4	5.3	14.9	3.1
2	5.5	8.2	3.6	5.0	2.1	3.1	6.6	7.5	13.2	6.3
3	3.5	4.5	1.7	2.3	0.4	0.6	2.9	3.5	5.9	2.7
4	3.2	3.5	1.4	1.7	-0.1	-0.1	3.3	3.2	5.3	2.5

Notes: x% are sample averages in percent, t are heteroskedasticity-robust t-statistics. Growth differential is country GDP growth minus world output growth. Investment is measured as gross fixed capital formation growth.

Table 1.3: Average statistics before and after stabilizations

	Trade balance		Current account		Fiscal balance		FDI	
Stabilization years	*x%*	*t*	*x%*	*t*	*x%*	*t*	*x%*	*t*
-4	-0.7	-0.9	-5.8	-4.5	-4.1	-3.5	0.6	4.3
-3	-0.7	-0.4	-4.8	-3.0	-4.3	-2.4	0.8	4.3
-2	-0.1	-0.1	-4.0	-1.9	-3.8	-1.9	0.9	4.3
-1	-0.4	-0.3	-2.6	-1.3	-1.3	-2.1	1.4	4.9
1	-1.6	-1.1	-3.2	-2.7	0.2	0.3	2.2	4.6
2	-4.0	-2.5	-6.4	-3.1	-1.0	-2.3	1.9	4.8
3	-3.1	-2.4	-4.7	-2.8	-0.6	-1.3	1.6	4.6
4	-2.4	-1.9	-4.1	-2.4	-1.4	-2.2	1.7	5.5

Notes: x% are sample averages in percent, t are heteroskedasticity-robust t-statistics. Trade balance, current account, fiscal balance and FDI are all percentages of GDP.

1.4 Likelihood of Stabilization Plans

The previous section presented some basic statistics that seem to support the hypothesis that exchange rate-based stabilization plans are expansionary, at least during the early stages. This simple evidence is, however, far from conclusive. One should take into account that the political decision to start a stabilization plan is not entirely exogenous. For example, Echenique and Forteza (2000) argue that governments are more likely to launch a plan when international conditions are favorable. Starting a stabilization plan when the international economic environment is good might reduce the costs associated with stabilization. Their work provides evidence that favorable international conditions, and not the stabilization plans, are the main reason of the initial boom observed during stabilization.

The purpose of this section is to run a probit model similar to theirs. Echenique and Forteza (2000) run a probit model using panel data for five Latin American countries that implemented ERBS programs during the period 1964-1995. The dependent variable is a dummy variable that takes the value one if and ERBS program started in the country in that year, and zero otherwise. The independent variables they use are different domestic and international variables that may explain the initiation of an ERBS program. We run a similar regression with two modifications.

Firstly, we update the data set in order to include recent years. Thus, our sample period is 1960-2005. This will allow us to include in our estimation the crises that several South-American countries suffered at the beginning of the present decade. For example, real GDP declined by roughly 11 percent in Argentina and Uruguay in 2002. These recessions were preceded by abandonment of the stabilization plans that were initiated in both countries in the early 90's. In December 2001, Argentina ended the Convertibility Plan that was introduced in 1991, and the exchange rate was depreciated by almost 200 percent in the following months. In the case of Uruguay, the country was under a stabilization plan based on crawling bands introduced in December 1990. On January 2002, the band was widened and the pace of depreciation was accelerated. By June 2002, the system of bands was abandoned altogether and the exchange rate was allowed to float.

Secondly, we update the list of stabilization programs using the Reinhart-Rogoff (2004) algorithm, as was discussed in the previous section. After this, we end up with a bigger list of ERBS programs across 23 different emerging economies.[8] Table A2 in the Appendix, lists the stabilization programs along with their dates.

In order to study the determinants of the decision to start a stabilization program, first we create a binary variable for ERBS plans: *E* equals 1 when a ERBS plan is started in a country in year *t* and zero otherwise. As in Echenique and Forteza (2000), we assume that the probability of starting an inflation stabilization plan is a function of domestic variables, *X*, and external variables, *Z*, that affect the decision of the policymakers. We then estimate a probit regression of the likelihood of starting an exchange rate-based stabilization plan. The specifications estimated are of the form:

$$P(E = 1 | X, Z) = G(bX + dZ) \tag{1.2}$$

where *ERBS* is a binary variable that takes a value equal to 1 if country *i* started an exchange rate-based stabilization plan in year *t* and 0 otherwise. *X* is an array of domestic explanatory variables that influence the decision of starting a stabilization plan. This may contain contemporaneous as well as lagged variables. *Z* is an array of international

[8] The number of programs that we detect depends upon the cutoff level of inflation. With a 40% cutoff, we detect 25 stabilization episodes, with a 20% cutoff we detect 34 episodes, and with a 10% cutoff we detect 41 episodes.

variables that influence the decision to start a plan. It may also contain contemporaneous as well as lagged variables. The function *G* is the standard normal cumulative distribution function (cdf) for the probit model.

Table 1.4 shows the results using panel data for the countries that implemented ERBS. The dependent variable is a dummy variable that takes the value one if and ERBS program started in the country in that year, and zero otherwise. The domestic explanatory variables of the reported regression are the log of inflation, the fiscal balance as share of output, the log of the international reserves to GDP ratio, the trade balance and the terms of trade, all lagged one year. The international explanatory variables are the world growth rate of GDP, the percent increase in the S&P 500 return index (SP500) and the lagged Federal Funds rate. [9]

In both models, the coefficient for the lagged inflation rate is statistically significant at one percent and exhibits the correct sign. Stabilization programs are more likely to be implemented when the inflation rate in the previous year was higher. The coefficient for the fiscal balance is positive and significant. The coefficient for the international reserves to GDP ratio is also significant and shows a positive sign. Governments prefer to launch stabilization plans when they have more reserves and are running fiscal surpluses (or smaller deficits). The trade balance and terms of trade were not statistically significant in either model. As for the external variables, only the world output growth, with a positive estimate, proves to be statistically significant. The likelihood that a country will launch a stabilization plan is higher if the world economy is

[9] Several international interest rates were used in the regressions yielding similar results.

growing at a faster rate, which translates into a "favorable" international environment. The remaining two variables, international interest rates and the SP500 return, are not statistically significant.

Our results are thus not conclusive as to whether ERBS programs are started when international conditions are favorable. The domestic inflation environment seems to be the determinant condition for starting a stabilization program. International conditions play a role, at least in our estimated regressions, only to the extent that high growth in the world economy creates a favorable environment in which the decision to start a plan may involve less domestic costs.

1.5 Empirical evidence on the real effects of stabilization

In the past, it was thought that stopping inflation was costly, in the sense that it would bring sharp declines in output growth. Okun (1978) estimate for the US economy the sacrifice ratio of disinflation, that is, the percent output loss per percentage point reduction in inflation. Even for the small open economy, this view was thought to apply, as was argued by Fischer (1986). Disinflation is expected to cause a recession, regardless of the nominal anchor used. This view is very much related to the Phillips-curve literature on the output-inflation trade-off.

However, the conventional wisdom was challenged by the stabilization episodes in the southern-cone of Latin America of the seventies. These programs used the exchange rate as an anchor in order to stop inflation, and contradicting the initial view, they were associated with strong initial expansions in consumption and output, despite the real appreciation of the exchange rate. Several studies have documented this empirical regularity, with Kiguel and Liviatan (1992), Reinhart and Végh (1994) and Calvo and Végh (1999) among them.

For example, Reinhart and Végh (1994) perform regression analysis using panel data on seven countries that implemented stabilization programs during 1964-1993. In their regressions, the growth rate of real GDP is the dependent variable, and several dummies designed to capture different stages of the stabilization programs are the independent variables. They find that the early stages of stabilization are associated with output expansions while the late stages are associated with recessions. This is the typical "early expansion – late recession" hypothesis that has been ascribed with exchange rate-based stabilization.

1.5.1 Empirical Methodology and Results

To test the effects of exchange rate-based inflation stabilization, we estimate panel regressions of the effects of ERBS programs on output, per capita output, consumption and investment growth as follows:

$$y_{i,t} = \beta_1 E1_t + \beta_2 E2_t + \beta_3 E3_t + \beta_4 E4_t + X'b + Z'd + \gamma\, y_{i,t-1} + \alpha_i + \varepsilon_{it} \qquad (1.3)$$

where y_{it} represents the dependent variable of interest (output, per capita output consumption, investment) for country i in year t. The variables E1, E2, E3 and E4 are dummy variables meant to capture the different stages of the stabilization period. E1 is a variable that takes the value of 1 if country i is in year t in the first year of an ERBS program. E2 takes value of 1 if the country is in its second year of an ERBS program, and E3 and E4 are defined analogously. X is a set of domestic control variables and Z a set of external control variables. The α_i are country fixed effects to account for any differences by country.

It is important to notice that in equation 1.3 we include as a right hand side variable the lagged dependent variable, $y_{i,t-1}$. Adding dynamics in this fashion is a major change in the model. In this case, the usual approach to estimating a fixed-effects model, the least squares dummy variable estimator (LSDV), generates a biased estimate of the coefficients, since now we have in the equation, the entire history of the right-hand side variables. To solve this problem, we use the Arellano-Bond dynamic panel estimator, proposed by Arellano and Bond (1991). This technique relies on a GMM procedure for looking at efficient instrumental variables for dynamic panel data models.

The results of the panel regressions are reported in Tables 1.5-1.9. Columns 1-2 in these tables are fixed and random effects estimators using only the dummy variables for the first 4 years of stabilization. These are similar to the regressions reported on Reinhart and Végh (1994) and the results yield similar conclusion. For output growth, per-capita output growth, consumption and investment growth, the first year of ERBS plans are associated with expansions in these variables. For the trade balance to output ratio, the results are significant for the second year, with a drop in the trade balance, as would be expected from an economic expansion.

Since our interest is in investigating whether this expansionary effect is a result of stabilization or external conditions, we include a set of external control variables. The chosen variables are world GDP growth, the SP500 stock market return, the yield on 10yr US Treasury bonds and the terms of trade for each country.[10] Columns 3 and 4 in Tables 5-9 show the results when international variables are included. The coefficient on world growth is positive and significant at the 1 percent level in all specifications with the exception of the equation for investment growth, for which is significant only at the 10 percent level. This is the expected result, implying that increases in the domestic variables are more likely when the world output is also increasing. The coefficient on the US Treasury yield is negative and significant at the 1 percent level in all specifications, with the exception for the trade-balance to output equation. This result is also as expected, since lower international interest rates are favorable for emerging economies. The estimates on the SP500 return index and the terms of trade are not statistically significant. The interesting result is that, even after including external control variables, the estimates on the first year dummy, *E1*, are still positive and significant.

Columns 5-7 of Tables 1.5-1.9 summarize the results when the lagged dependent variable is included as a regressor, which should improve the efficiency of the estimation. Columns 5 and 6 are the fixed and random effects, respectively, and column 7 is the

[10] Several different international interest rates were used yielding similar results.

Arellano-Bond estimates. The inclusion of the lagged dependent variable in the fixed and random effects models do not significantly alter the results. The coefficients on the first year dummy, *E1*, remain positive and statistically significant. As an example, output growth is 2.2 percent higher during the first year of stabilization, consumption growth is 2.7 percent higher, and investment growth is 10.9 percent higher.[11] The Arellano-Bond estimates also provide support that stabilization cause increases in output, consumption and investment, during the first year of the programs.

1.6 Robustness checks

To check the robustness of our results, we estimate the panel regression with alternative definitions of ERBS programs. The results of the previous sections are derived from ERBS programs that were defined using a 20 percent cut-off inflation rate. We estimate the models using different cut-offs of the inflation rate. In particular, we use a 10 percent cutoff (which increases the number of identified programs from 34 to 41) and a 40 percent cutoff (which reduces the number of identified programs from 34 to 25).

The results are summarized in Tables 1.10 and 1.11. Table 1.10 shows the results for the 25 ERBS plans detected using a 40 percent inflation cut-off. The point estimates on the first year dummies remain positive and statistically significant at the one percent

[11] These are the results for the fixed effects equations. Fixed effects estimates are always consistent but random effects may be more efficient. However, the Hausman test rejects the null hypothesis that the coefficients are the same under both methods for almost all specifications, so random effects are not consistent.

level for the equations for output, consumption and investment growth. In some cases, the positive effect of stabilization is also seen in later years. For example, using Arellano-Bond estimators, consumption is significantly higher during the first four years of stabilization. Table 1.11 shows identical results, when the criteria for detecting ERBS programs is a 10 percent inflation rate, which results in 41 programs being identified. Again, the point estimates on the first year dummies are positive and statistically significant at the one percent level for all specifications.

1.7 Conclusions

The empirical evidence presented in this paper, cannot reject the notion that exchange rate based stabilization programs are expansionary during the early phases. Using a new list of stabilization programs for emerging economies and data from recent years, we conclude that stabilization programs that use the exchange rate as a nominal anchor, lead to initial real GDP expansions, even when account is taken of international conditions. The expansionary effects are not exclusive of output. Real consumption and investment also tend to be higher during the early stages of stabilization, whereas the trade balance to output tends to be lower, as absorption increases with the economic boom.

We derive a new list of stabilization programs using the Reinhart-Rogoff's (2002) extensive country chronologies of exchange rate arrangements. Until very recently, most of the empirical literature dealing with exchange rates used the official classification published in the IMF's *Annual Report on Exchange Rate Arrangements and Exchange Restrictions*. Yet, a closer look at the experience suggests that these official classifications often fail to describe actual country monetary policy. After using the Reinhart-Rogoff new country chronologies, we detect new exchange rate based stabilization programs that were omitted on previous work.

Our probit model, although not conclusive, suggest that the starting of a stabilization program is more likely when the region faces favorable international conditions. However, this does not imply that the effects of stabilization programs should be dismissed. In particular, our panel regressions provide some evidence that the initial phases of an ERBS program, leads to an initial boom in output, even after controlling for external variables.

It is interesting to notice that one would also like to control for other effects, such as domestic reforms. Many of the stabilization programs studied in this paper, have been accompanied with trade and financial liberalization and structural reforms. It remains an issue for future research to take account of this, maybe by constructing a "liberalization index" along the lines of work by De Melo, Denizer and Gelb (1996) for transition economies.

Table 1.4: Probit Model. Dependent variable is E1 (dummy for first year of ERBS)

Explanatory Variables	*Model 1*	*Model 2*
Log Inflation $_{i,t-1}$	0.419***	0.782***
	(4.88)	(4.95)
Reserves $_{i,t-1}$	0.031*	0.062*
	(1.68)	(1.74)
Fiscal Balance $_{i,t-1}$	0.071**	0.145*
	(2.02)	(1.89)
Trade Balance $_{i,t-1}$	0.007	0.023
	(0.37)	(0.62)
Terms of Trade $_{i,t-1}$	-0.002	-0.003
	(-0.55)	(-0.39)
World Growth $_{t}$	0.276**	0.578**
	(2.32)	(2.37)
S&P500 $_{t}$	0.009	0.020
	(0.97)	(1.15)
Federal Funds $_{t-1}$	-0.005	-0.001
	(-0.10)	(-0.00)
Constant	-4.204	-8.241
	(-4.51)	(-4.27)
Number of obs	456	456
McFadden R-sq	0.21	0.2

Note: Significance at the 10, 5 and 1 percent level is indicated by one, two and three stars, respectively. For Model 1 an inflation rate of 20% was used as a cut-off for identifying the ERBS plans. For Model 2 an inflation rate of 40% was used.

Table 1.5: Panel regression. Dependent variable: Real GDP growth

	-1	*-2*	*-3*	*-4*	*-5*	*-6*	*-7*
Estimation Method	*Fixed effects*	*Random effects*	*Fixed effects*	*Random effects*	*Fixed effects*	*Random effects*	*Arellano-Bond*
E1	1.463*	1.392*	1.743**	1.586**	2.201***	1.979***	3.143***
	(1.79)	(1.71)	(2.13)	(1.95)	(2.79)	(2.54)	(3.38)
E2	1.087	1.014	1.442*	1.282	0.958	0.553	2.165**
	(1.23)	(1.15)	(1.61)	(1.44)	(1.09)	(0.63)	(2.04)
E3	0.977	0.939	1.38	1.221	1.046	0.701	2.430**
	(1.02)	(0.99)	(1.45)	(1.28)	(1.14)	(0.78)	(2.21)
E4	0.166	0.106	0.645	0.486	0.377	0.057	1.61
	(0.16)	(0.10)	(0.63)	(0.47)	(0.38)	(0.06)	(1.34)
World GDP			0.622***	0.618***	0.566***	0.538***	0.513***
			(5.77)	(5.83)	(5.43)	(5.33)	(3.94)
SP500			-0.011	-0.01	-0.008	-0.006	-0.01
			(-1.16)	(-1.06)	(-0.92)	(-0.76)	(-1.07)
10YRBOND			-0.31***	-0.29***	-0.23***	-0.20***	-0.258**
			(-4.85)	(-4.75)	(-3.66)	(-3.42)	(-1.91)
TOT			0.002	0.001	0.001	0.001	0.012
			(0.56)	(0.36)	(0.16)	(0.22)	(1.24)
GPD_{t-1}					0.286***	0.327***	0.262***
					(8.78)	(10.30)	(6.09)
Constant	3.626***	3.606***	3.379***	3.458***	2.154***	2.107**	0.006
	(24.25)	(13.84)	(4.64)	(4.78)	(3.01)	(3.08)	(0.20)
Observations	1006	1006	857	857	841	841	817
Adj R-sq	0.04	0.02	0.12	0.11	0.2	0.16	
Hausman	Chi (4) = 1.36		Chi (8) = 3.56		Chi (9) = 32.82		
Test	P-value = 0.85		P-value = 0.89		P-value = 0.00		

Notes: t-statistics in parentheses. One, two and three stars denote significance at 10, 5 and 1 percent respectively. Stabilization plans are identified using a cutoff 20% inflation rate. Sample period: 1960 to 2005.

Table 1.6: Panel regression. Dependent variable: Per-capita GDP

	-1	*-2*	*-3*	*-4*	*-5*	*-6*	*-7*
Estimation Method	*Fixed effects*	*Random effects*	*Fixed effects*	*Random effects*	*Fixed effects*	*Random effects*	*Arellano-Bond*
E1	1.599**	1.587**	1.875**	1.814**	2.258***	2.190***	3.142***
	(2.02)	(2.02)	(2.36)	(2.30)	(2.94)	(2.88)	(3.47)
E2	1.195	1.166	1.539*	1.445*	1.093	0.766	2.261**
	(1.40)	(1.37)	(1.78)	(1.67)	(1.27)	(0.90)	(2.19)
E3	1.139	1.129	1.512	1.407	1.16	0.892	2.523**
	(1.23)	(1.23)	(1.63)	(1.53)	(1.30)	(1.00)	(2.36)
E4	0.385	0.34	0.823	0.714	0.515	0.251	1.626
	(0.38)	(0.34)	(0.82)	(0.72)	(0.53)	(0.26)	(1.39)
World GDP			0.511***	0.485***	0.482***	0.435***	0.542***
			(4.88)	(4.72)	(4.77)	(4.41)	(4.16)
SP500			-0.01	-0.01	-0.007	-0.006	-0.011
			(-1.21)	(-1.15)	(-0.91)	(-0.75)	(-1.17)
10YRBOND			-0.32***	-0.32***	-0.25***	-0.24***	-0.208
			(-5.21)	(-5.31)	(-4.06)	(-4.01)	(-1.43)
TOT			-0.001	-0.001	-0.001	-0.001	0.012
			(-0.40)	(-0.26)	(0.49)	(-0.27)	(1.28)
$PGDP_{t-1}$					0.264***	0.310***	0.244***
					(8.03)	(9.67)	(5.69)
Constant	1.568***	1.561***	2.222***	2.303***	1.434**	1.353**	0.028
	(10.83)	(6.72)	(3.14)	(3.28)	(2.07)	(2.04)	(0.95)
Observations	1006	1006	857	857	841	841	817
Adj R-sq	0.03	0.01	0.12	0.1	0.19	0.17	
Hausman	Chi (4) = 0.50		Chi (8) = 21.49		Chi (9) = 39.30		
Test	P-value = 0.97		P-value = 0.01		P-value = 0.00		

Notes: t-statistics in parentheses. One, two and three stars denote significance at 10, 5 and 1 percent respectively. Stabilization plans are identified using a cutoff 20% inflation rate. Sample period: 1960 to 2005.

Table 1.7: Panel regression. Dependent variable: Consumption

	-1	*-2*	*-3*	*-4*	*-5*	*-6*	*-7*
Estimation Method	*Fixed effects*	*Random effects*	*Fixed effects*	*Random effects*	*Fixed effects*	*Random effects*	*Arellano-Bond*
E1	2.019**	1.903**	2.554**	2.023*	2.723**	2.193**	3.973***
	(1.88)	(1.79)	(2.33)	(1.86)	(2.52)	(2.05)	(3.19)
E2	1.841	1.741	2.913**	2.386**	2.596**	1.872	4.817***
	(1.57)	(1.50)	(2.42)	(1.99)	(2.14)	(1.56)	(3.38)
E3	0.228	0.131	1.003	0.481	0.839	0.193	3.630**
	(0.18)	(0.11)	(0.78)	(0.38)	(0.66)	(0.15)	(2.44)
E4	1.859	1.751	2.052	1.521	2.066	1.46	4.415***
	(1.35)	(1.28)	(1.47)	(1.09)	(1.50)	(1.07)	(2.71)
World GDP			0.463***	0.460***	0.498***	0.496***	0.350*
			(2.97)	(3.02)	(3.23)	(3.32)	(1.86)
SP500			-0.017	-0.01	-0.019	-0.019	-0.02
			(-1.39)	(-1.36)	(-1.56)	(-1.52)	(-1.51)
10YRBOND			-0.27***	-0.24***	-0.25***	-0.216**	-0.459**
			(-3.10)	(-2.84)	(-2.79)	(-2.47)	(-2.30)
TOT			0.011**	0.006*	0.009**	0.004	0.047***
			(2.37)	(1.68)	(2.02)	(1.20)	(3.57)
CON_{t-1}					0.103***	0.136***	0.071*
					(2.84)	(3.82)	(1.61)
Constant	3.734***	3.709***	2.562**	3.096***	2.083**	2.478***	-0.029
	(17.93)	(12.10)	(2.53)	(3.16)	(2.07)	(2.56)	(-0.68)
Observations	818	818	743	743	727	727	706
Adj R-sq	0.01	0.01	0.06	0.06	0.07	0.08	
Hausman	Chi (4) = 0.79		Chi (8) = 16.58		Chi (9) = 34.59		
Test	P-value = 0.94		P-value = 0.03		P-value = 0.00		

Notes: t-statistics in parentheses. One, two and three stars denote significance at 10, 5 and 1 percent respectively. Stabilization plans are identified using a cutoff 20% inflation rate. Sample period: 1960 to 2005.

Table 1.8: Panel regression. Dependent variable: Investment

	-1	-2	-3	-4	-5	-6	-7
Estimation Method	*Fixed effects*	*Random effects*	*Fixed effects*	*Random effects*	*Fixed effects*	*Random effects*	*Arellano-Bond*
E1	9.467***	8.279***	10.480***	9.402***	10.953***	9.931***	13.778***
	(2.92)	(2.61)	(3.33)	(3.06)	(3.52)	(3.27)	(3.67)
E2	5.938*	4.861	6.717*	5.860*	5.707	4.713	8.874**
	(1.66)	(1.38)	(1.94)	(1.73)	(1.62)	(1.36)	(2.05)
E3	2.503	1.371	3.171	2.329	1.804	0.992	6.719
	(0.67)	(0.37)	(0.87)	(0.66)	(0.49)	(0.27)	(1.48)
E4	4.141	2.998	5.138	4.225	4.892	3.972	10.129**
	(1.02)	(0.75)	(1.31)	(1.09)	(1.26)	(1.04)	(2.08)
World GDP			0.688*	0.736*	0.747*	0.808**	0.592
			(1.63)	(1.81)	(1.78)	(2.01)	(1.08)
SP500			0.001	0.001	0.004	0.004	-0.017
			(0.02)	(0.03)	(0.13)	(0.12)	(-0.44)
10YRBOND			-0.839***	-0.79***	-0.773***	-0.72***	-0.094
			(-3.39)	(-3.33)	(-3.10)	(-3.01)	(-0.15)
TOT			0.011	0.004	0.01	0.002	0.083**
			(0.80)	(0.44)	(0.74)	(0.29)	(2.13)
INV_{t-1}					0.162***	0.169***	0.211***
					(4.49)	(4.75)	(1.61)
Constant	4.686***	4.798***	6.391**	6.829**	5.145*	5.548**	0.149
	(7.97)	(8.24)	(2.29)	(2.57)	(1.85)	(2.09)	(1.10)
Observations	829	829	771	771	755	755	734
Adj R-sq	0.01	0.01	0.01	0.04	0.04	0.07	
Hausman	Chi (4) = 4.00		Chi (8) = 2.79		Chi (9) = 3.39		
Test	P-value = 0.41		P-value = 0.94		P-value = 0.94		

Notes: t-statistics in parentheses. One, two and three stars denote significance at 10, 5 and 1 percent respectively. Stabilization plans are identified using a cutoff 20% inflation rate. Sample period: 1960 to 2005.

Table 1.9: Panel regression. Dependent variable: Trade balance

	-1	-2	-3	-4	-5	-6	-7
Estimation Method	*Fixed effects*	*Random effects*	*Fixed effects*	*Random effects*	*Fixed effects*	*Random effects*	*Arellano-Bond*
E1	-0.781	-0.716	-0.532	-0.479	-0.949	-0.665	-0.534
	(-0.79)	(-0.72)	(-0.52)	(-0.47)	(-1.25)	(-0.85)	(-0.68)
E2	-3.0***	-2.99***	-3.18***	-3.12***	-2.64***	-2.11**	-2.341***
	(-2.79)	(-2.74)	(-2.86)	(-2.80)	(-3.19)	(-2.45)	(-2.69)
E3	-1.879	-1.821	-1.704	-1.645	0.268	1.179	-0.308
	(-1.59)	(-1.54)	(-1.44)	(-1.38)	(0.30)	(1.28)	(-0.33)
E4	-1.98	-1.925	-1.734	-1.672	-0.573	0.143	-0.302
	(-1.53)	(-1.49)	(-1.35)	(-1.30)	(-0.60)	(0.14)	(-0.30)
World GDP			0.631***	0.642***	0.333***	0.253**	0.450***
			(4.66)	(4.72)	(3.28)	(2.46)	(3.95)
SP500			0.001	0.001	0.005	0.009	0.009
			(0.05)	(0.15)	(0.64)	(1.02)	(1.15)
10YRBOND			0.102	0.113	0.566	0.056	0.055
			(1.28)	(1.42)	(0.96)	(0.94)	(0.44)
TOT			0.001	0.001	0.001	0.002	0.028***
			(0.19)	(0.31)	(0.06)	(1.07)	(3.30)
TBY_{t-1}					0.665***	0858***	0.384***
					(25.58)	(45.03)	(7.93)
Constant	-3.3***	-3.30***	-6.43***	-7.69***	-2.78***	-2.24***	0.029
	(-18.18)	(-3.35)	(-7.09)	(-5.19)	(-4.02)	(-3.25)	(1.13)
Observations	1040	1040	848	848	847	847	823
Adj R-sq	0.04	0.01	0.05	0.04	0.07	0.04	
Hausman	Chi (4) = 22.29		Chi (8) = 2.79		Chi (9) = 118.96		
Test	P-value = 0.00		P-value = 0.94		P-value = 0.00		

Notes: t-statistics in parentheses. One, two and three stars denote significance at 10, 5 and 1 percent respectively. Stabilization plans are identified using a cutoff 20% inflation rate. Sample period: 1960 to 2005.

Table 1.10: Panel regression. Alternative ERBS identification

Dependent Var	*GDP growth*		*Consumption*		*Investment*	
	-1	*-2*	*-3*	*-4*	*-5*	*-6*
Estimation Method	*Fixed effects*	*Arellano-Bond*	*Fixed effects*	*Arellano-Bond*	*Fixed effects*	*Arellano-Bond*
E1	2.669***	4.041***	3.869***	5.340***	10.869***	13.275***
	(2.95)	(3.77)	(3.09)	(3.69)	(3.06)	(3.07)
E2	0.962	2.748**	2.473*	5.242***	5.526	7.954
	(0.93)	(2.21)	(1.72)	(3.09)	(1.35)	(1.58)
E3	0.272	2.327*	0.568	4.190**	0.234	5.008
	(0.26)	(1.85)	(0.39)	(2.43)	(0.06)	(0.98)
E4	0.73	2.154	2.433	5.868***	5.124	12.364**
	(0.06)	(1.57)	(1.54)	(3.12)	(1.14)	(2.20)
World GDP	0.565***	0.509***	0.504***	0.342*	0.770*	0.62
	(5.45)	(3.92)	(3.28)	(1.83)	(1.83)	(1.13)
SP500	-0.008	-0.011	-0.021*	-0.022	0.005	-0.016
	(-0.95)	(-1.22)	(-1.66)	(-1.64)	(0.14)	(-0.41)
10YRBOND	-0.227***	-0.282**	-0.249***	-0.487**	-0.760***	-0.173
	(-3.62)	(-2.09)	(-2.79)	(-2.44)	(-3.04)	(-0.28)
TOT	0.001	0.011	0.009**	0.047***	0.009	0.081**
	(0.10)	(1.22)	(2.03)	(3.56)	(0.67)	(2.08)
Lagged Depvar	0.286***	0.256***	0.106***	0.073*	0.162***	0.217***
	(8.79)	(5.95)	(2.93)	(1.67)	(4.49)	(4.91)
Constant	2.196***	0.003	2.081**	-0.032	5.265*	0.13
	(3.06)	(0.14)	(2.07)	(-0.74)	(1.88)	(0.97)
Observations	841	817	727	706	755	734
Adj R-sq	0.2		0.07		0.04	

Notes: t-statistics in parentheses. One, two and three stars denote significance at 10, 5 and 1 percent respectively. Stabilization plans are identified using a cutoff 40% inflation rate. Sample period: 1960 to 2005.

Table 1.11: Panel regression. Alternative ERBS identification

Dependent Var	*GDP growth*		*Consumption*		*Investment*	
	-1	*-2*	*-3*	*-4*	*-5*	*-6*
Estimation Method	*Fixed effects*	*Arellano-Bond*	*Fixed effects*	*Arellano-Bond*	*Fixed effects*	*Arellano-Bond*
E1	2.101***	2.898***	2.942***	3.913***	9.500***	12.311***
	(2.90)	(3.38)	(2.93)	(3.37)	(3.34)	(3.57)
E2	1.279	2.222**	2.782**	4.373***	7.573**	10.517***
	(1.61)	(2.33)	(2.51)	(3.36)	(2.40)	(2.72)
E3	1.051	2.017**	1.247	3.197**	2.327	5.714
	(1.28)	(2.06)	(1.09)	(2.38)	(0.71)	(1.43)
E4	1.148	1.758*	2.762**	4.011***	4.578	7.041*
	(1.32)	(1.66)	(2.25)	(2.75)	(1.35)	(1.66)
World GDP	0.569***	0.517***	0.516***	0.360*	0.776*	0.625
	(5.50)	(3.97)	(3.36)	(1.92)	(1.85)	(1.14)
SP500	-0.008	-0.009	-0.02	-0.019	0.003	-0.017
	(-0.94)	(-1.00)	(-1.61)	(-1.48)	(0.09)	(-0.44)
10YRBOND	-0.239***	-0.258*	-0.259***	-0.449**	-0.800***	-0.073
	(-3.80)	(-1.91)	(-2.91)	(-2.25)	(-3.21)	(-0.12)
TOT	0.001	0.013	0.010**	0.048***	0.011	0.089**
	(0.28)	(1.35)	(2.12)	(3.63)	(0.81)	(2.28)
Lagged Depvar	0.282***	0.260***	0.099***	0.069	0.159***	0.208***
	(8.68)	(6.06)	(2.74)	(1.58)	(4.40)	(4.73)
Constant	2.106***	0.006	1.952*	-0.027	4.983*	0.154
	(2.95)	(0.22)	(1.95)	(-0.63)	(1.79)	(1.14)
Observations	841	817	727	706	755	734
Adj R-sq	0.2		0.08		0.05	

Notes: t-statistics in parentheses. One, two and three stars denote significance at 10, 5 and 1 percent respectively. Stabilization plans are identified using a cutoff 10% inflation rate. Sample period: 1960 to 2005.

Chapter 2

Business Cycles in Emerging Markets and Implications for the Real Exchange Rate

2.1 Introduction

The last ten years have been exceptionally good for many emerging economies. The share of world output of emerging and developing countries has risen from about 37 percent in 2000 to 47 percent by 2009 and is expected to represent more than half of total world output by 2013 according to the IMF.[12] Countries are different to each other and individual characteristics should be taken into account, but a quick list of the main drivers of this development would surely put a growth-friendly economic and financial global environment among the top. Commodity prices, of which emerging economies are big producers, have seen an extraordinarily boom and world interest rates were, for the most of the decade, at record lows.

The first question we aim to answer in this paper is how much of the business cycle in emerging economies can be attributable to these external conditions. One strand

[12] Data from the IMF, World Economic Outlook Database of January 2010.

of the literature on business cycles in small open economies has focused on the role played by terms-of-trade in driving economic fluctuations. For example, Mendoza (1995) finds that terms-of-trade shocks explain about half of output variability in developing countries. Another strand of the literature has focused instead on the role of interest rates. Two main works on this area are Neumeyer and Perry (2005) and Uribe and Yue (2006), who find that foreign interest rates and country risk premiums, are the main drivers of business cycles in emerging economies.

In this paper we develop an empirical model that measures the relative importance of several sources of fluctuations. Specifically, we estimate a structural VAR for 15 emerging economies over the last 16 years that includes 8 key macroeconomic variables. We find that country spreads shocks explain about 12% of output variability. Shocks to foreign interest rates account for an additional 7% and terms-of-trade shocks explain around 5% of GDP fluctuations. We also find that the terms-of-trade are of virtually no importance in explaining real exchange rates, while country risk premiums explain almost a quarter of real exchange rate variations.

A second objective of our work is to investigate how well a real business cycle model can fit the observed empirical regularities. In this regard, we find that a benchmark small open RBC model does a well job in explaining the effects of foreign interest rates and country spreads, but it overestimates the importance of the terms-of-trade.

Our work builds on the literature of business cycles for small open economies. A seminal paper in this area is Mendoza (1991), which develops a one-good small open economy with productivity and foreign interest rate shocks that closely replicates the

Canadian business fluctuations. Mendoza (1995) analyzes the effects of the terms-of-trade in a three-good economy. He finds that terms-of-trade shocks account for 50% of GDP volatility and generates real appreciations. Additional business cycle regularities are provided in Backus, Kehoe and Kydland (1992) and Correia, Neves and Rebelo (1995) among others. They all find that private consumption in emerging countries is procyclical and more volatile than output and real net exports are countercyclical. All these models however do not show interest rates disturbances playing a significant role in driving the business cycles. The role of interest rates in emerging economies is analyzed in Neumeyer and Perry (2005), which adds a country risk (or country spread), to the foreign interest rate. The country risk component is affected by fundamentals (expected productivity) and through the presence of a working capital constraint foreign interest rate shocks are amplified. They find that eliminating the country risk component lowers output volatility by 27% while stabilizing international rates lowers it by 3%. Uribe and Yue (2006) also investigate the countercyclical behavior of country spreads in emerging economies. They find that country spreads further exacerbate the effects of foreign interest rates on economic aggregates. Since macro fundamentals also affect country spreads, they try to disentangle this endogeneity by estimating a structural VAR were it is assumed that interest rates affect resource allocations with a lag.

Another line of research related to our work, though one which we do not attempt to develop further theoretically, is the one of sovereign default. The most direct and clear reason for why interest rate in emerging countries are higher than comparable rates in industrial countries concerns the risk of default. Developing countries are charged a higher rate in capital markets because investors assign a higher probability of default. A classic paper on the microfundations of default is Eaton and Gersovitz (1981). New models of endogenous defaults can be found in Aguiar and Gopinath (2006) and Arellano (2008). These models generally predict that default incentives are higher during recessions and that prior to default, the economy experiences higher interest rate premia, capital outflows, real exchange depreciation and a collapse in private consumption.

In this paper we construct a DSGE model for a small open economy. We consider three sectors in the model economy – exportables, importables and nontradables. Home production takes place in the exportable and nontraded sectors. Capital stock is sector specific and labor is freely mobile. We assume that domestic firms face a working capital constraint, which forces them to borrow funds from international capital markets if domestic savings are not enough to cover domestic investment. The interest rate at which firms borrow is assumed to depend on both, foreign rates and country spreads. We then subject the model economy to shocks to productivity, terms-of-trade, foreign rates and country spreads. In analyzing the economy, we address in particular how macroeconomic variables such as output, consumption, investment, the trade balance and real exchange rates respond to changes in the exogenous variables.

The remainder of the paper is organized as follows. In section 2.2 we present some statistics summarizing the business cycles in 15 emerging economies and we estimate the empirical model, identify the shocks to the terms-of-trade, foreign interest rates and country spreads, and analyze the corresponding business cycle properties. In section 2.3 we develop the theoretical model. In section 2.4, we estimate the model using

Bayesian techniques. We discuss which parameters we choose to calibrate, and the prior distributions for the parameters we choose to estimate, and we report our estimation results. In section 2.5 we solve the model using numerical methods and we compare the properties of the theoretical model with those of the empirical model through impulse response functions. Finally, section 2.6 offers some conclusions.

2.2 Empirical Regularities

The purpose of this section is to document a few empirical regularities about business cycles in emerging economies. Our focus is in the relationships between macro fundamentals, real interest rates, real exchange rates and the terms-of-trade. We compute business cycle statistics for a set of 15 countries since 1994 and establish some stylized facts. We find that interest rates are countercyclical whereas real exchange rates and the terms-of-trade are pro-cyclical in emerging economies. Since our focus is on understanding the causal relationship between these variables, we proceed to estimate a structural VAR model that includes world interest rates, country spreads, real exchange rates, the terms-of-trade and domestic macro fundamentals.

2.2.1 Data description

The data we use to compute business cycle statistics consists of quarterly series on output, investment (gross fixed capital formation), consumption (private consumption) and the trade balance (net exports over output). National account series were obtained from the IMF *International Financial Statistics* (IFS). Real effective exchange rates (REER) are trade-weighted exchange rate indices computed by JPMorgan. We use as our measure of real interest rates the real yields on dollar-denominated bonds issued in international capital markets. We construct real interest rates for each country by adding JPMorgan's EMBI+ stripped spread to the US real interest rate. We measure US real interest rates as the 3-month gross Treasury bill rate divided by the average gross US inflation over the past four quarters. Finally, the terms-of-trade are the ratio of export prices to import prices and for each country these are taken from domestic central banks or domestic statistical agencies.[13]

We limit our analysis for the fifteen countries for which we were able to obtain all comparable data. These countries are: Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Peru, Uruguay, Venezuela, Indonesia, Malaysia, Philippines, Russia, Turkey and South Africa. The sample has a quarterly frequency, starts in the first quarter of 1994 and ends in the second quarter of 2009. All national account series have been seasonally adjusted using the Census Bureau's X-11 method. Moments reported correspond to cyclical components of Hodrick-Prescott (HP) filtered data.

[13] See the Data Appendix for a detailed list of sources and explanations.

2.2.2 Business cycle statistics

Business cycles in emerging markets are highly (inversely) correlated with the interest rate that these countries face in international capital markets. Periods of low interest rates tend to be associated with periods of high output growth, and vice versa. Figure 2.1, which shows detrended output and the country interest rate for five selected countries between 1994q1 and 2009q2 illustrates this negative comovement in emerging economies. Business cycles in emerging markets are also highly (positively) correlated with real exchange rates. Periods of high real exchange rates tend to be associated with periods of high output levels, and vice versa. Figure 2.2 which shows detrended output and real effective exchange rates for the same five countries illustrates this positive comovement. Figure 2.3 plots country interest rate and real effective exchange rates, showing a negative correlation between the two variables.

Tables 2.1-2.3 provide more detailed business cycle statistics for the sample economies. Table 1 lists volatilities for all the series we consider. All standard deviations are computed for Hodrick-Prescott filtered data and are in percentage points. Some interesting regularities emerge. On average, private consumption is slightly more volatile than output. The average volatility in output is 2.65 while the average volatility in consumption is 2.85, about 7.5% percent higher. This is a well documented empirical fact for developing economies. Neumeyer and Perry (2005) and Prasad et al. (2003) also report that consumption is more volatile than output in developing economies. This seems to be at odds with the "permanent income hypothesis" of Friedman (1957) which predicts that individuals will smooth consumption relative to income. By contrast, in industrialized countries consumption is less volatile than output, as predicted by standard theory. Kydland and Prescott (1982) find that over the period 1950-1980, consumption in the US is 0.72 times as volatile as output, while Raffo (2008) estimates that in the European Union consumption is 0.85 times as volatile as output.

Table 2.1 also shows that investment is, on average, about 3.5 times as volatile as output, another well documented regularity for both emerging and industrial countries. The average standard deviation in real interest rates is 2.83 which is in line with that reported by Neumeyer and Perry (2005) for a set of 5 emerging countries (2.32%) and higher than the one they report for a set of 5 industrialized countries (1.66%). Real exchange rates and terms-of-trade display much higher variability than interest rates with average standard deviations of 7.87 and 7.25, respectively. Not surprisingly, oil-dependent countries like Ecuador, Venezuela and Russia display the highest volatilities in the terms-of-trade, while countries that experienced sharp devaluations over the sample period (Argentina, Indonesia and Russia) have highly volatile real exchange rates.

We also look at the correlations between variables. Table 2.2 shows the contemporaneous correlations with GDP. Private consumption and investment are, as expected, highly correlated with GDP.[14] The trade balance (the ratio of net exports to output) is negatively correlated with output in all cases except for Philippines. The average correlation coefficient is quite substantial at -0.55. Strong countercyclical net exports are a striking feature in international economies, as noted by Backus and Kehoe

[14] The case of private consumption in Indonesia is an odd one. We actually find a negative correlation with output. Because we were only able to get reliable data for national accounts since 2000, this might be a consequence of small sample size.

(1992) and even more pronounced in emerging economies. Aguiar and Gopinath (2006) also find a strong negative correlation for emerging economies between net exports and output. This implies that countries borrow when income is high and save when income is low, an observations that seems to contradict also the theory of consumption smoothing. Table 2 also shows that real interest rates are countercyclical in all fifteen economies in the sample. The simple average correlation is -0.48. Neumeyer and Perry (2005) also find that real interest rates are countercyclical and moreover, that they lead the cycle. This is an important feature of business cycles in emerging economies since it is in sharp contrast with what it is observed in industrial economies (they find a positive correlation of 0.20 on average between real interest rates and output in 5 developed countries). Finally, real exchange rates and terms-of-trade are procyclical with simple average correlations of 0.36 and 0.17 respectively.

Table 2.3 reports other business cycles statistics of interest. The average correlation between real exchange rates (REER) and net exports (NX) is -0.37 implying that countries run higher trade balance surpluses (or smaller deficits) when the domestic currency is cheaper in real trade-weighted terms. Real interest rates and real exchange rates are negatively correlated with the mean correlation being -0.34. High real interest rates reflect a large probability of a real depreciation so this negative correlation is what we should expect to see.

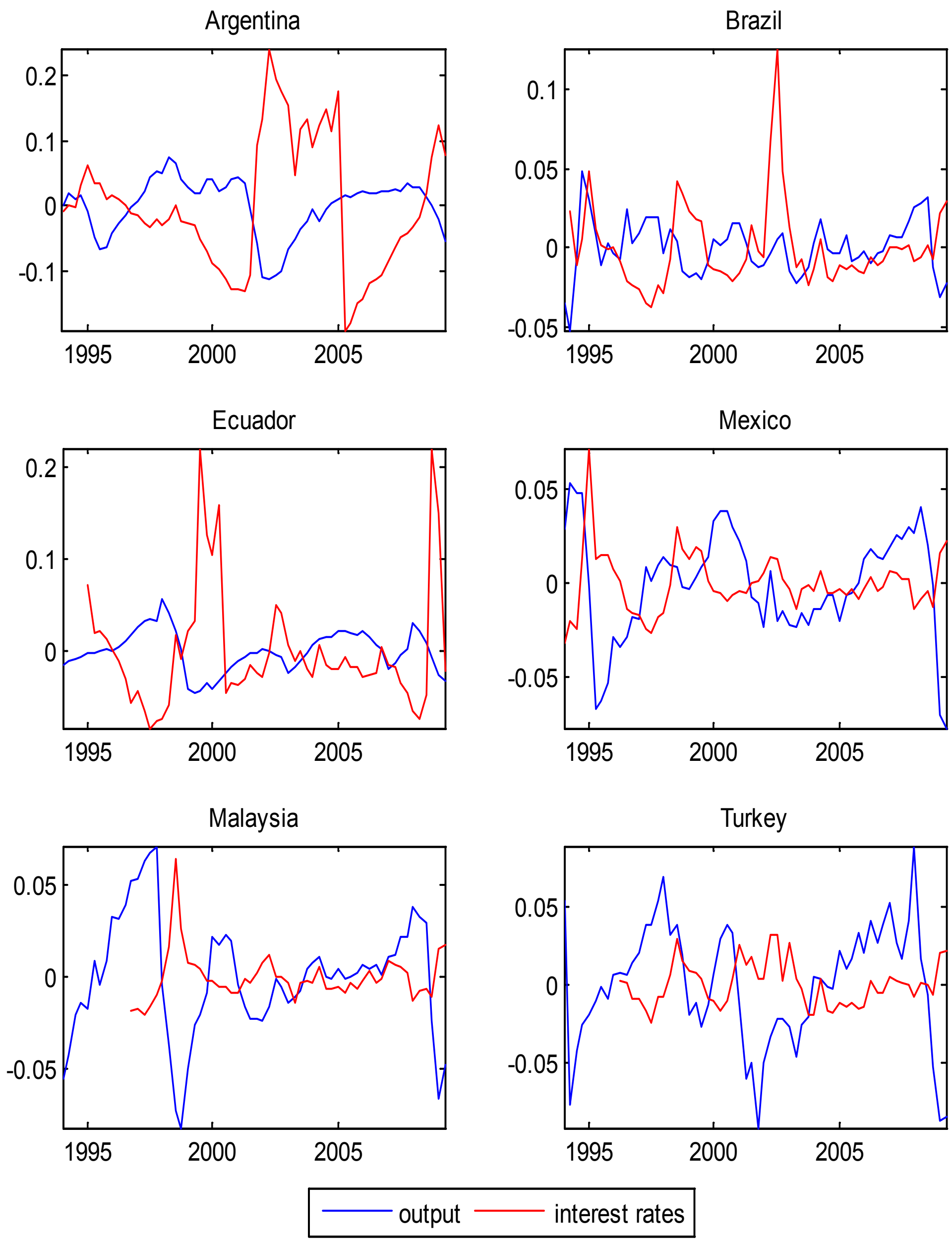


Figure 2.1: Output and interest rates in emerging economies. Output is the HP filtered (λ = 1600) component of the log of the seasonally adjusted GPD series. Country interest rates are real yields on dollar denominated bonds issued in international capital markets. Sources: IFS, EMBI+.

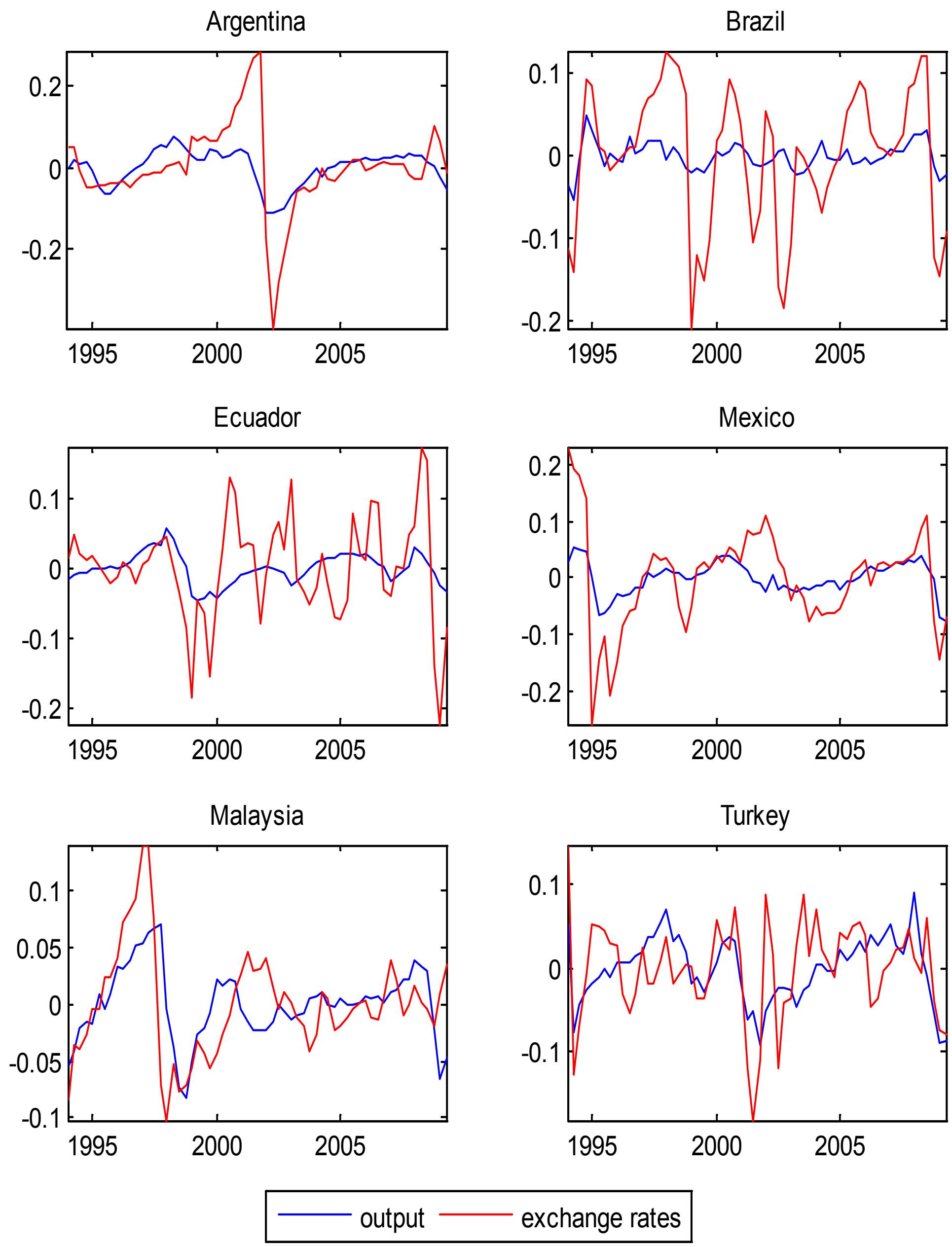


Figure 2.2: Output and exchange rates in emerging economies. Output is the HP filtered (λ = 1600) component of the log of the seasonally adjusted GPD series. Real Effective Exchange Rates are HP detrended (λ = 1600) series of the logged real effective exchange rate. Sources: IFS, JPMorgan.

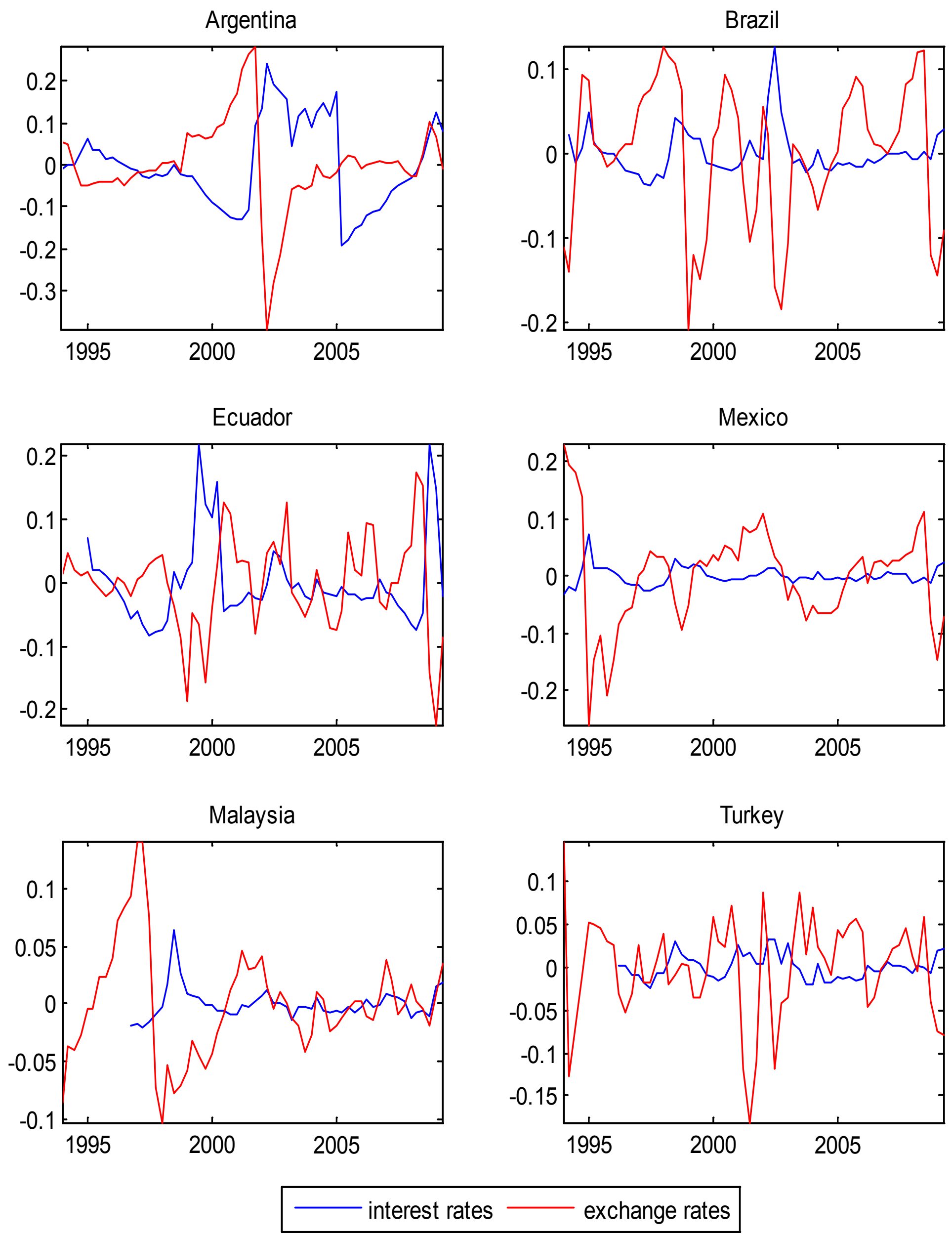


Figure 2.3: Real exchange rates and interest rates in emerging economies. Real Effective Exchange Rates are HP detrended ($\lambda = 1600$) series of the logged real effective exchange rate. Country interest rates are real yields on dollar denominated bonds issued in international capital markets. Sources: IFS, JPMorgan.

Table 2.1: Business cycles statistics

Volatilities	Standard deviations, in percentages						
	GDP	PC	INV	NX	R	REER	TOT
Argentina	4.34	4.99	14.76	1.70	10.00	10.52	4.42
	(0.45)	(0.47)	(1.90)	(0.19)	(0.79)	(1.62)	(0.34)
Brazil	1.73	2.29	5.75	1.91	2.65	8.47	3.82
	(0.19)	(0.26)	(0.46)	(0.14)	(0.52)	(0.64)	(0.33)
Chile	1.83	2.09	7.01	2.17	0.70	3.84	9.34
	(0.17)	(0.20)	(0.64)	(0.24)	(0.09)	(0.31)	(1.01)
Colombia	1.97	2.03	10.21	1.57	1.31	5.49	5.89
	(0.15)	(0.15)	(1.11)	(0.18)	(0.19)	(0.39)	(0.62)
Ecuador	2.19	2.77	10.16	4.05	6.55	7.35	16.11
	(0.20)	(0.31)	(1.22)	(0.49)	(0.98)	(0.89)	(2.36)
Mexico	2.88	3.41	8.88	1.25	1.57	8.83	4.31
	(0.29)	(0.28)	(0.98)	(0.15)	(0.25)	(0.93)	(0.59)
Peru	2.03	1.88	7.14	1.60	1.09	2.55	7.38
	(0.17)	(0.18)	(0.90)	(0.15)	(0.13)	(0.24)	(0.85)
Uruguay	3.09	3.62	8.37	1.50	2.58	6.81	5.12
	(0.25)	(0.22)	(0.70)	(0.24)	(0.48)	(0.72)	(0.55)
Venezuela	6.08	5.58	18.03	4.44	2.83	8.61	22.07
	(1.43)	(0.55)	(2.95)	(0.50)	(0.23)	(0.72)	(3.38)
Indonesia	0.67	0.53	3.54	1.67	0.88	15.60	2.88
	(0.10)	(0.06)	(0.37)	(0.24)	(0.18)	(2.75)	(0.30)
Malaysia	3.19	3.82	13.68	4.73	1.32	4.72	3.95
	(0.30)	(0.33)	(1.51)	(0.62)	(0.31)	(0.57)	(0.69)
Philippines	1.27	0.76	7.22	3.01	0.87	7.18	6.15
	(0.12)	(0.08)	(0.52)	(0.28)	(0.16)	(0.54)	(0.60)
Russia	3.38	3.49	9.59	4.52	7.65	14.42	11.02
	(0.50)	(0.42)	(1.32)	(0.46)	(1.33)	(1.39)	(1.23)
Turkey	3.88	3.82	12.37	2.03	1.42	5.77	3.52
	(0.34)	(0.27)	(1.01)	(0.17)	(0.13)	(0.60)	(0.41)
South Africa	1.18	1.73	3.08	1.29	0.99	7.83	2.79
	(0.16)	(0.20)	(0.24)	(0.10)	(0.09)	(0.92)	(0.28)
Average	2.65	2.85	9.32	2.50	2.83	7.87	7.25

Note: GDP is gross domestic output, PC is private consumption, INV is gross fixed capital formation, NX is net exports over GDP, R is the country interest rate, REER is the real effective exchange rate and TOT is the terms-of-trade. R is the US real interest rate plus the EMBI spread. All series except NX are in logs. All series were filtered with the Hodrick-Prescott filter with a smoothing parameter of 1600. Numbers in parentheses are standard errors obtained from 300 bootstrap samples.

Table 2.2: Business cycles statistics

Correlations with GDP	PC	INV	NX	R	REER	TOT
Argentina	0.99	0.97	-0.92	-0.69	0.56	0.06
	(0.00)	(0.01)	(0.02)	(0.06)	(0.14)	(0.12)
Brazil	0.75	0.83	-0.50	-0.14	0.59	0.59
	(0.06)	(0.03)	(0.09)	(0.13)	(0.08)	(0.08)
Chile	0.94	0.82	-0.72	-0.30	0.36	0.41
	(0.01)	(0.05)	(0.08)	(0.19)	(0.08)	(0.11)
Colombia	0.93	0.85	-0.75	-0.41	0.46	0.19
	(0.02)	(0.04)	(0.07)	(0.13)	(0.10)	(0.11)
Ecuador	0.91	0.83	-0.64	-0.61	0.32	-0.14
	(0.03)	(0.05)	(0.10)	(0.08)	(0.12)	(0.16)
Mexico	0.95	0.91	-0.77	-0.32	0.69	0.45
	(0.01)	(0.02)	(0.06)	(0.11)	(0.07)	(0.12)
Peru	0.73	0.82	-0.51	-0.34	0.13	0.43
	(0.06)	(0.04)	(0.10)	(0.13)	(0.13)	(0.09)
Uruguay	0.87	0.89	-0.48	-0.58	0.34	-0.04
	(0.03)	(0.02)	(0.08)	(0.10)	(0.18)	(0.14)
Venezuela	0.85	0.89	-0.46	-0.52	0.30	0.21
	(0.04)	(0.04)	(0.22)	(0.09)	(0.22)	(0.08)
Indonesia	-0.16	0.36	-0.35	-0.64	0.03	0.09
	(0.13)	(0.14)	(0.21)	(0.11)	(0.14)	(0.18)
Malaysia	0.89	0.85	-0.58	-0.74	0.53	0.06
	(0.03)	(0.04)	(0.14)	(0.07)	(0.14)	(0.21)
Philippines	0.69	0.57	0.19	-0.43	0.29	-0.49
	(0.09)	(0.09)	(0.11)	(0.13)	(0.13)	(0.10)
Russia	0.72	0.83	-0.68	-0.55	0.26	0.69
	(0.12)	(0.05)	(0.10)	(0.13)	(0.15)	(0.09)
Turkey	0.92	0.91	-0.68	-0.42	0.50	0.21
	(0.02)	(0.02)	(0.07)	(0.10)	(0.10)	(0.11)
South Africa	0.88	0.48	-0.33	-0.51	0.05	-0.13
	(0.04)	(0.13)	(0.15)	(0.10)	(0.10)	(0.14)
Average	0.79	0.79	-0.55	-0.48	0.36	0.17

Note: GDP is gross domestic output, PC is private consumption, INV is gross fixed capital formation, NX is net exports over GDP, R is the country interest rate, REER is the real effective exchange rate and TOT is the terms-of-trade. R is the US real interest rate plus the EMBI spread. All series except NX are in logs. All series were filtered with the Hodrick-Prescott filter with a smoothing parameter of 1600. Numbers in parentheses are standard errors obtained from 300 bootstrap samples.

Table 2.3: Business cycles statistics

Other correlations	ρ(R,REER)	ρ(TOT,REER)	ρ(R,NX)	ρ(TOT,NX)	ρ(REER,NX)
Argentina	-0.58	-0.01	0.66	-0.15	-0.68
	(0.11)	(0.13)	(0.07)	(0.13)	(0.10)
Brazil	-0.43	0.67	0.10	-0.62	-0.48
	(0.12)	(0.06)	(0.15)	(0.07)	(0.10)
Chile	-0.08	0.44	0.38	-0.24	-0.26
	(0.14)	(0.10)	(0.14)	(0.15)	(0.09)
Colombia	-0.22	0.02	0.30	-0.20	-0.35
	(0.16)	(0.12)	(0.17)	(0.13)	(0.10)
Ecuador	-0.50	0.33	0.42	0.37	-0.30
	(0.11)	(0.25)	(0.12)	(0.14)	(0.11)
Mexico	-0.55	0.22	0.38	-0.05	-0.88
	(0.12)	(0.15)	(0.11)	(0.12)	(0.03)
Peru	0.07	-0.17	0.09	-0.43	-0.36
	(0.13)	(0.12)	(0.13)	(0.10)	(0.13)
Uruguay	-0.41	-0.13	0.36	-0.20	-0.43
	(0.16)	(0.13)	(0.13)	(0.13)	(0.11)
Venezuela	0.39	-0.22	0.28	-0.30	-0.09
	(0.14)	(0.08)	(0.10)	(0.09)	(0.16)
Indonesia	-0.59	-0.35	0.07	-0.24	0.37
	(0.08)	(0.15)	(0.13)	(0.19)	(0.13)
Malaysia	-0.44	0.41	0.52	-0.57	-0.86
	(0.13)	(0.14)	(0.11)	(0.13)	(0.05)
Philippines	-0.27	-0.18	-0.15	-0.41	0.22
	(0.17)	(0.11)	(0.17)	(0.13)	(0.11)
Russia	-0.67	0.22	0.57	-0.60	-0.67
	(0.17)	(0.14)	(0.08)	(0.12)	(0.08)
Turkey	-0.45	0.22	0.56	-0.25	-0.62
	(0.10)	(0.14)	(0.07)	(0.13)	(0.10)
South Africa	-0.39	0.04	0.09	-0.36	-0.16
	(0.09)	(0.10)	(0.17)	(0.11)	(0.09)
Average	-0.34	0.10	0.31	-0.28	-0.37

Note: GDP is gross domestic output, PC is private consumption, INV is gross fixed capital formation, NX is net exports over GDP, R is the country interest rate, REER is the real effective exchange rate and TOT is the terms-of-trade. R is the US real interest rate plus the EMBI spread. All series except NX are in logs. All series were filtered with the Hodrick-Prescott filter with a smoothing parameter of 1600. Numbers in parentheses are standard errors obtained from 300 bootstrap samples. Average is the simple average of the 15 countries

In summary, we confirm well-known patterns in aggregate data for emerging economies. First, consumption and investment are highly volatile relative to output. Second, net exports are countercyclical, suggesting that emerging countries borrow during expansions and save during recessions. Third, real interest rates are countercyclical. And forth, real exchange rates and terms-of-trade are procyclical.

2.2.3 Estimation of the VAR system

In this section we estimate a first-order recursive VAR system using panel data on the 15 emerging countries for the period 1994:Q1-2009:Q2. We estimate a panel VAR instead of individual country VARs because using a panel-modeling framework substantially increases the efficiency and the power of the analysis. Estimating one VAR for each country would suffer from too few degrees of freedom.

Our objective is to identify shocks to country spreads, the foreign interest rate and the terms-of-trade and assess their impact on fundamental macroeconomic variables in emerging markets. There are two main reasons why we choose to follow this approach. First, a recursive VAR can be used to trace through the dynamic effects of shocks to country spreads, foreign interest rates and terms-of-trade on such variables as output, the trade balance and real exchange rates. And secondly, it allows us to relax the assumption that small open economies take the interest rate at which they can borrow as a given in the theoretical model to be developed later. By making the country spread a function of domestic fundamental variables, more realistic dynamics can be established.

The identification strategy we employ follows the approach taken by Uribe and Yue (2006). In order to identify the exogenous shocks, we impose a simple recursive structure on the system. Specifically, the recursive VAR model takes the following form:

$$A \begin{bmatrix} \hat{y}_t \\ \hat{c}_t \\ \hat{i}_t \\ nx_t \\ \hat{tot}_t \\ \hat{R}_t^{us} \\ \hat{R}_t^{embi} \\ \hat{rer}_t \end{bmatrix} = B \begin{bmatrix} \hat{y}_{t-1} \\ \hat{c}_{t-1} \\ \hat{i}_{t-1} \\ nx_{t-1} \\ \hat{tot}_{t-1} \\ \hat{R}_{t-1}^{us} \\ \hat{R}_{t-1}^{embi} \\ \hat{rer}_{t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_t^{y} \\ \varepsilon_t^{c} \\ \varepsilon_t^{i} \\ \varepsilon_t^{nx} \\ \varepsilon_t^{tot} \\ \varepsilon_t^{rus} \\ \varepsilon_t^{embi} \\ \varepsilon_t^{rer} \end{bmatrix} \tag{2.1}$$

where y denotes real output, c denotes real private consumption, i denotes real investment, nx denotes the net exports to output ratio, tot denotes the terms-of-trade, rer denotes the real effective exchange rate, R^{us} denotes the gross real US interest rate and R^{embi} denotes the emerging country gross real domestic interest rate. All variables are measured as log-deviations from a HP trend with the exception of nx which is a ratio instead of a log. The gross real US interest rate is measured as the gross yield of 10yr Treasury bonds divided by the average gross Personal Consumption Expenditure (PCE) inflation over the previous four quarters. The country interest rate is measured as the gross US rate times the gross EMBI+ stripped spread.

To identify the model we impose the restriction that the matrix A is lower-triangular with unit diagonal elements. This implies that shocks to *price* variables, (i.e.

shocks to the US interest rate ε^{rus}, shocks to country spreads ε^{embi}, shocks to real exchange rates ε^{rer}, and shocks to the terms-of-trade ε^{tot}) affect domestic real variables with a one-period lag. On the contrary, shocks to real domestic variables (ε^{y}, ε^{c}, ε^{i} and ε^{nx}) have a contemporaneously effect on interest rates and exchange rates. Since investment and consumption decisions on durable goods take time to plan and implement whereas financial markets react to new information almost instantaneously, these appears to be plausible assumptions. The proposed identification scheme is identical to that of Uribe and Yue (2006) with the difference that our model also accounts for terms-of-trade and real exchange rates shocks.

Shocks to the terms-of-trade and US interest rate (ε^{tot} and ε^{rus}) are assumed to be completely exogenous and to follow each an AR(1) process. This translates into imposing the additional restrictions $A_{5i} = B_{5i} = 0$ for all $i \neq 5$, and $A_{6j} = B_{6j} = 0$ for all $j \neq 6$. We impose these restrictions because it is safe to assume that developments in small emerging economies do not affect the interest rate in US or the price of commodities traded in international markets.

We estimate model (2.1) by equation-by-equation OLS. We should note that one problem with dynamic panel data models is that they are subject to Hurwicz-type bias. The main problem is that the fixed-effects OLS estimator does not provide a consistent estimate as the number of cross-sections increases for a given number of time observations. The estimator, however, is consistent as the number of observations per unit increases for a given number of cross-sections and is asymptotically equivalent to the maximum likelihood estimator.[15] Because panel data econometrics is usually characterized by a large number of cross-sections and a small number of time-series observations, this bias problem has received considerable attention.

To overcome this problem, a number of alternative estimators have been proposed in the literature which are based on instrumental variables (Anderson and Hsiao, 1981) or GMM (Arellano and Bond, 1991). We nevertheless choose to use the fixed-effects OLS estimator for two reasons. First, our dataset consists of a relatively small number of cross-sections (15 countries) and of a large number of time-series observations for each country (62 quarterly observations). Since the size of the OLS bias depends negatively on the number of time-series observations in the panel, it is of limited importance in our analysis. And secondly, instrumental variable estimators tend to produce estimates with larger variance and are thus less efficient than OLS. This drawback can outweigh the bias of OLS estimator in empirical macroeconomics when the time dimension of the model is large enough. Judson and Owen (1999) compare the performance of the fixed-effects OLS estimator with the Anderson-Hsiao and Arellano-Bond estimators in terms of bias and root mean squared error (RMSE) of the coefficient estimates via Monte-Carlo experiments. They conclude that, even for time-series sample sizes of 30, the fixed-effects OLS performs better than the alternative IV estimators.

We estimate the VAR system equation-by-equation by FE-OLS. In determining the appropriate lag length we use the Akaike information criterion. The estimated

[15] See Holtz-Eakin, Newey and Rosen (1988) and Nickell (1981). In particular, Nickell demonstrates that the bias is of order 1/T.

coefficients are reported in Table 4. Because of the complicated dynamics intrinsic to a VAR system with 8 variables, we analyze the results via impulse response functions and variance decompositions.

2.2.4 Impulse response functions

The model dynamics can be studied by computing impulse response functions. We report plots of responses to innovations to output, the terms of trade, the US interest rate and the country spread in Figures 2.4-2.7, respectively.

Table 2.4: Parameter estimates of VAR model

Indep variable	Dependent variable $\hat{y}_t$	$\hat{c}_t$	$\hat{i}_t$	nx_t	$\hat{tot}_t$	$\hat{R}_t^{us}$	$\hat{R}_t^{embi}$	$\hat{rer}_t$
$\hat{y}_t$		0.651	2.050	0.483			-0.345	-0.037
		(27.34)	(17.28)	(7.76)			(-3.36)	(-0.20)
$\hat{y}_{t-1}$	0.588	-0.215	-0.529	-0.333			0.119	0.341
	(9.90)	(-5.35)	(-3.70)	(-5.23)			(1.17)	(1.91)
$\hat{c}_t$			0.350	-0.571			0.088	0.358
			(2.69)	(-9.89)			(0.91)	(2.08)
$\hat{c}_{t-1}$	0.139	0.446	-0.262	0.358			-0.032	-0.297
	(2.70)	(13.52)	(-2.04)	(6.29)			(-0.35)	(-1.83)
$\hat{i}_t$				-0.123			-0.016	0.084
				(-7.48)			(-0.61)	(1.75)
$\hat{i}_{t-1}$	-0.001	0.015	0.487	0.076			-0.008	-0.173
	(-0.06)	(1.59)	(14.60)	(4.55)			(-0.33)	(-3.69)
nx_t							0.099	-0.115
							(1.67)	(-1.10)
nx_{t-1}	-0.026	-0.083	-0.205	0.500			-0.078	-0.004
	(-0.78)	(-3.85)	(-2.70)	-14.84			(-1.30)	(-0.04)
$\hat{tot}_t$							-0.067	0.039
							(-4.33)	-1.41
$\hat{tot}_{t-1}$	0.025	0.003	0.004	-0.013	0.678		0.063	-0.040
	(3.12)	(0.58)	(0.24)	(-1.73)	(27.1		(4.04)	(-1.43)
$\hat{R}_t^{us}$							0.129	0.659
							(0.91)	(2.62)
$\hat{R}_{t-1}^{us}$	-0.143	-0.046	0.191	0.119		0.777	0.204	-0.571
	(-1.73)	(-0.88)	(1.04)	(1.47)		(9.37)	(1.29)	(-2.04)
$\hat{R}_t^{embi}$								-0.375
								(5.67)
$\hat{R}_{t-1}^{embi}$	-0.115	-0.026	-0.008	0.042			0.678	-0.060
	(-6.59)	(-2.33)	(-0.20)	(2.40)			(22.92)	(-0.88)
$\hat{rer}_{t-1}$	-0.018	0.023	0.002	-0.005			0.059	0.643
	(-1.82)	(3.71)	(0.11)	(-0.51)			(3.76)	(22.87)
R^2	0.630	0.868	0.849	0.615	0.458	0.600	0.565	0.611
S.E.	0.018	0.011	0.04	0.018	0.066	0.007	0.028	0.049
Obs.	723	723	723	723	875	61	723	723

Note: t-statistics in parenthesis. The system was estimated equation by equation by instrumental variables, except for the US rate equation which was estimated by OLS. The sample consists of panel data from Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Peru, Uruguay, Venezuela, Indonesia, Malaysia, Philippines, Russia, Turkey and South Africa, over the period 1994q1 to 2009q2.

An increase in output deteriorates the trade balance, reduces the country interest rate (by reducing the risk-premium) and appreciates the currency in real terms. These are all standard responses for an emerging economy. The deterioration of the trade balance is explained by a substantial increase in investment. A 1.7 percent increase in output reduces the interest rate by about 0.6 percentage points on impact. The interest rate continues to decline for two quarters before mean reverting. Figure 2.5 shows the time paths in response to a one standard deviation increase in the terms-of-trade. This positive shock raises output and consumption by about 0.3% and investment by 1%. These peaks are observed in the fourth quarter. The higher increase in investment again causes the trade balance to deteriorate. The improvement in the terms-of-trade also reduces on impact the country spread and raises the real exchange rate, although the effect on real exchange rates is very imprecisely measured, as seen by the wide confidence intervals.

Figure 2.6 displays the response of the variables to an increase in the US interest rate. This pushes the economy into a recession: output, consumption and investment decreases, while the trade balance improves. These effects are quite persistent. For example output continues to decline for almost two years, before recovering. The behavior of country interest rates deserves some comments. As might be expected, the increase in foreign interest rates causes country interest rates to rise on impact. Interest rates then continue to rise in emerging economies, even as US rates revert to their long-run mean. This delayed effect on interest rates was already detected by Uribe and Yue (2006) and Eichengreen and Mody (2000). However, in our sample emerging markets interest rates never increase by the full amount of the US rate increase, meaning that country risk actually goes down. This is observed by looking the respective panels of Figure 2.6. US rates increase by 0.7 percent (one standard deviation) at the time of the innovation and then gradually mean-revert. On impact, rates in emerging economies go up by only 15 basis points, meaning that the country spread decreases by about 55 basis points. Interest rates continue to rise in these economies, peaking a year later at about 45 basis points, still less than the 70 basis points increase in US rates. This incomplete pass-through from US rates to emerging markets rates is behind our finding that US rates explain less of the business cycles (about 7%) than Uribe and Yue (2006), who find that US rate shocks explain 20% of aggregate activity, mainly by the delayed effect on country spreads. One likely explanation of why US rate increases do not fully propagate to emerging markets is because US rates might be increased by the Fed when the US economy is booming and concerns are centered on high inflation. To the extent that a booming US economy is positively correlated with world overall demand, US rates will be higher when the world economy is doing well, and in particular, when demand for goods produced by emerging economies is high.

The results of a shock to country spreads are shown in Figure 2.7. In response to an unanticipated one standard deviation (2.8%) increase in the risk premium, output falls by around half of a percentage point. Consumption and investment fall as well and the trade balance improves. Although the real exchange rate appreciates slightly on impact, it quickly moves into negative territory. By the fourth quarter, real exchange rates are 2 percent below their steady state levels. This is not surprising, since increases in risk should be associated with a weaker nominal exchange rate as investors switch to safer currencies. The effects of country spreads on aggregate activity we found are qualitatively similar to those in Uribe and Yue (2006). As an example, they report that a one percent increase in country spreads reduces output by almost 0.2 percent by the third quarter. It should be noted that we report responses of variables to one standard deviation, instead of to a one percent innovation. For a given size of the innovation in spreads, the behavior of output is quantitatively similar.

Figure 2.4: Impulse Response to an Output Innovation

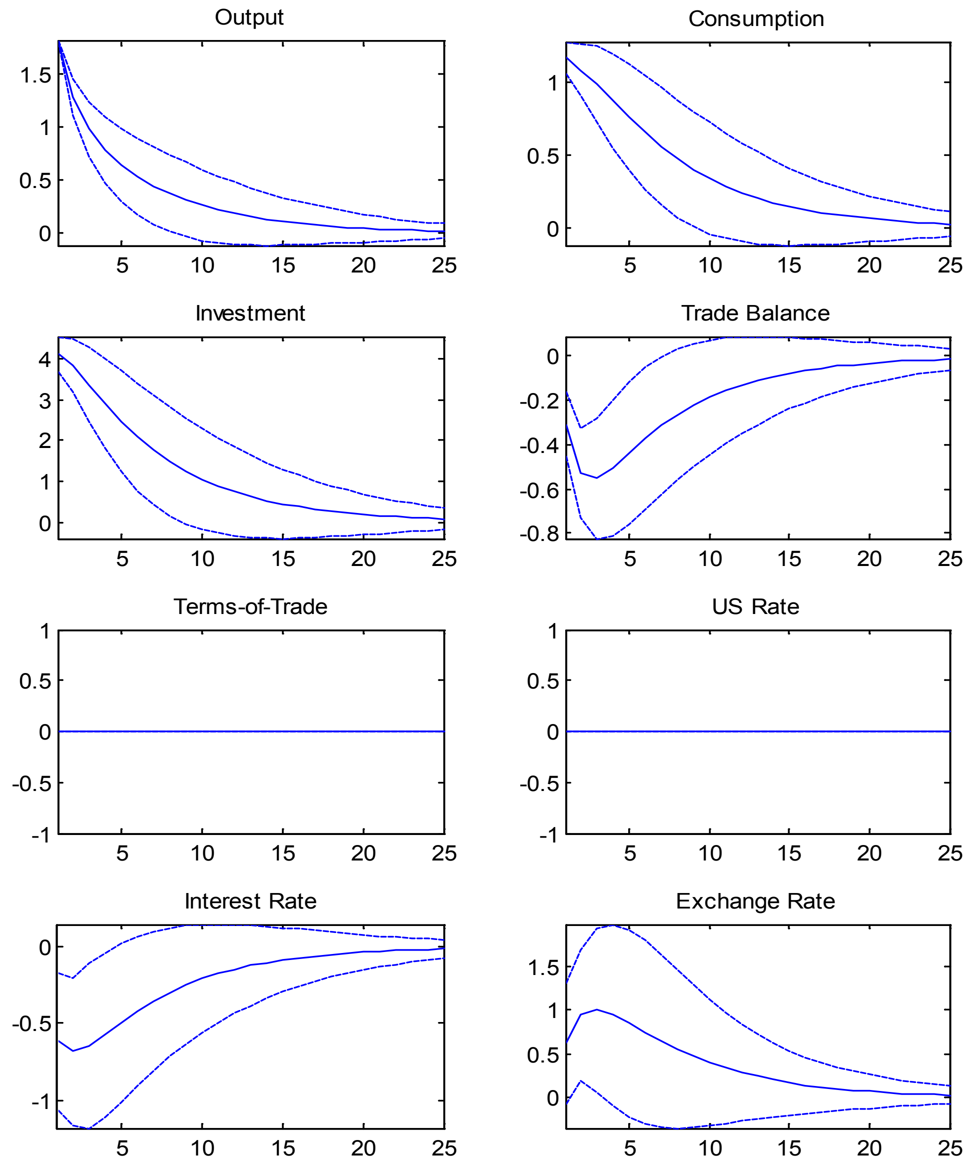


Figure 2.4: Impulse response functions to a 1 standard deviation output shock. All variables except for the trade balance and interest rates are expressed in percent deviations from a HP trend. The trade balance and interest rates are expressed in percentage point's deviations. The 95% confidence intervals are computed by the delta method.

Figure 2.5. Impulse Response to a Terms-of-Trade Innovation

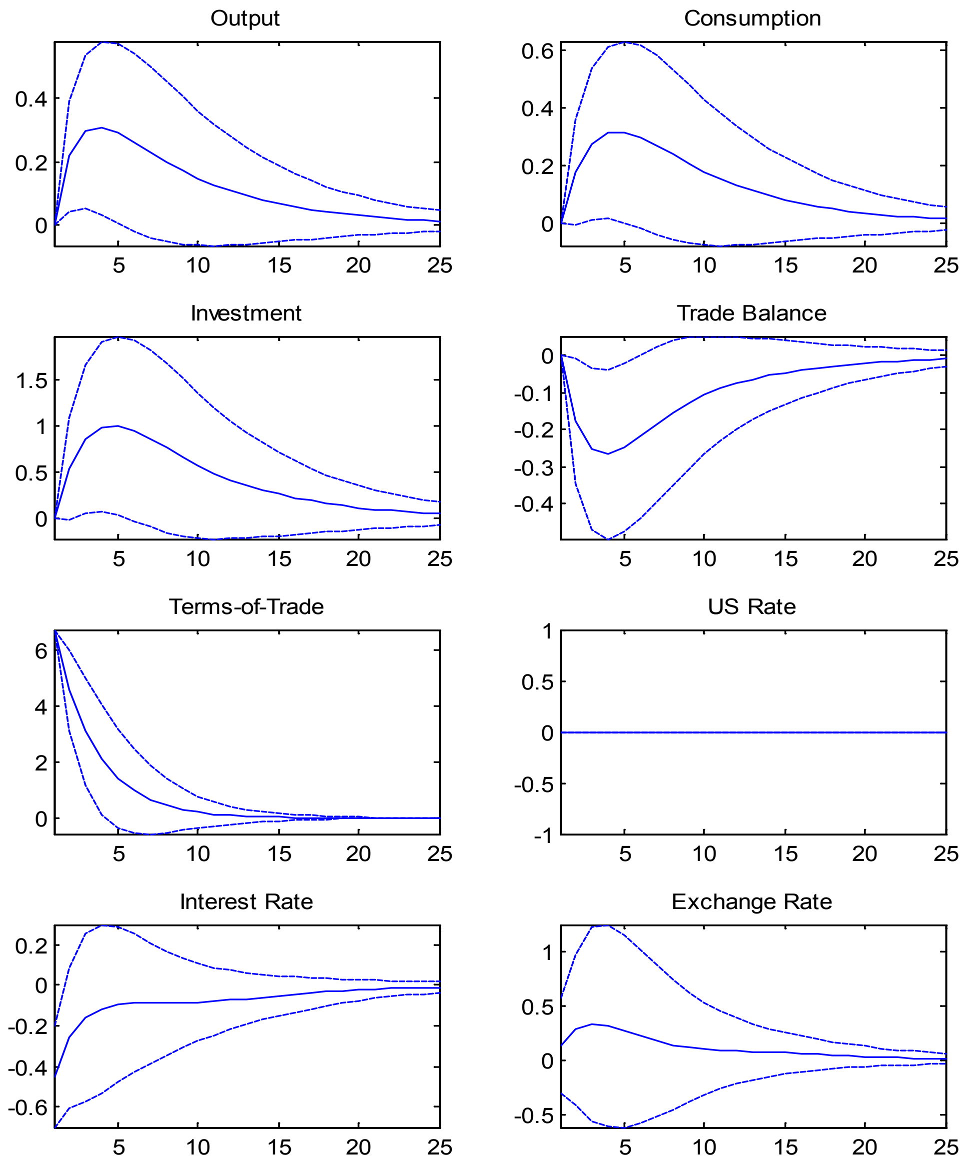


Figure 2.5: Impulse response functions to a 1 standard deviation terms-of-trade shock. All variables except for the trade balance and interest rates are expressed in percent deviations from a HP trend. The trade balance and interest rates are expressed in percentage point's deviations. The 95% confidence intervals are computed by the delta method.

Figure 2.6. Impulse Response to a US Rate Innovation

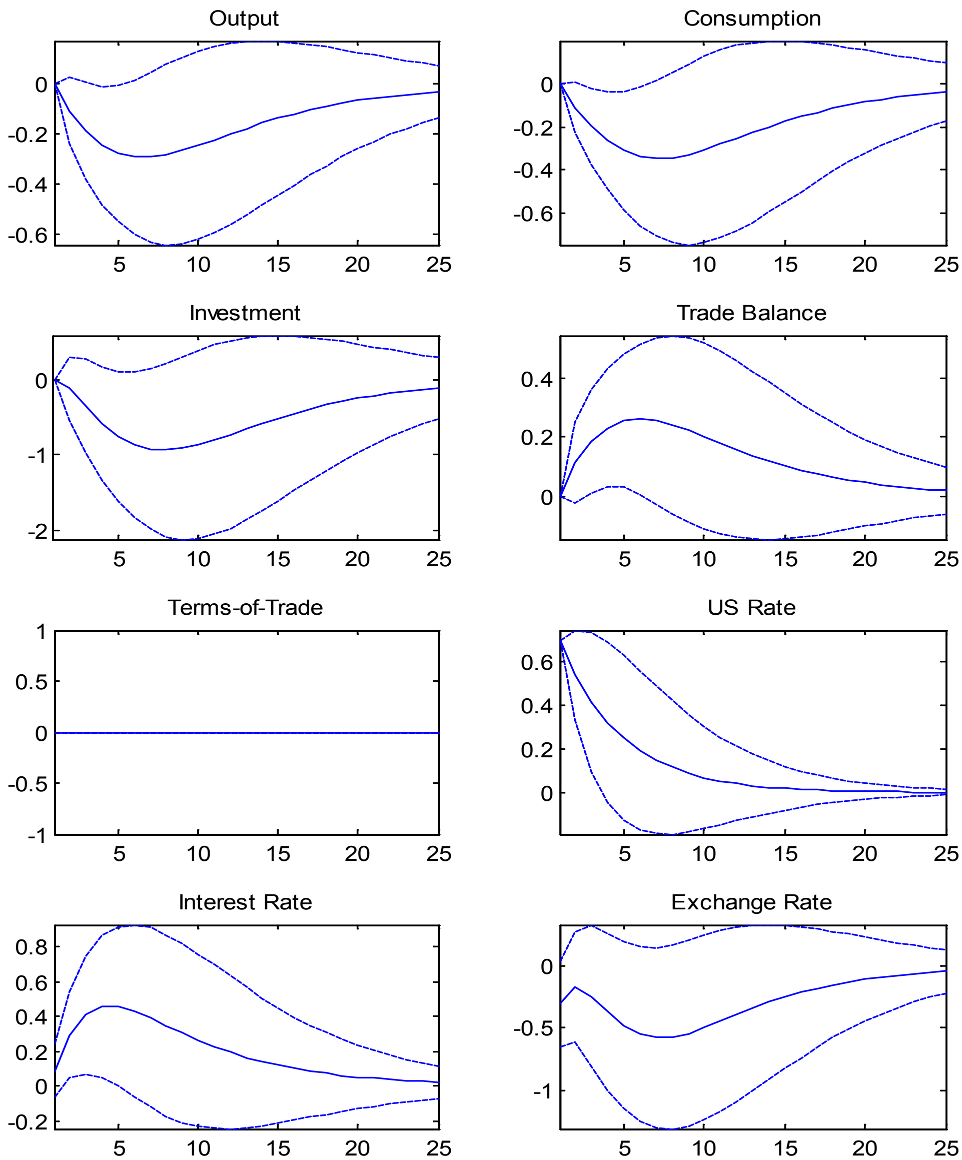


Figure 2.6. Impulse response functions to a 1 standard deviation US rate shock. All variables except for the trade balance and interest rates are expressed in percent deviations from a HP trend. The trade balance and interest rates are expressed in percentage point's deviations. The 95% confidence intervals are computed by the delta method.

Figure 2.7. Impulse Response to a Country Spread Innovation

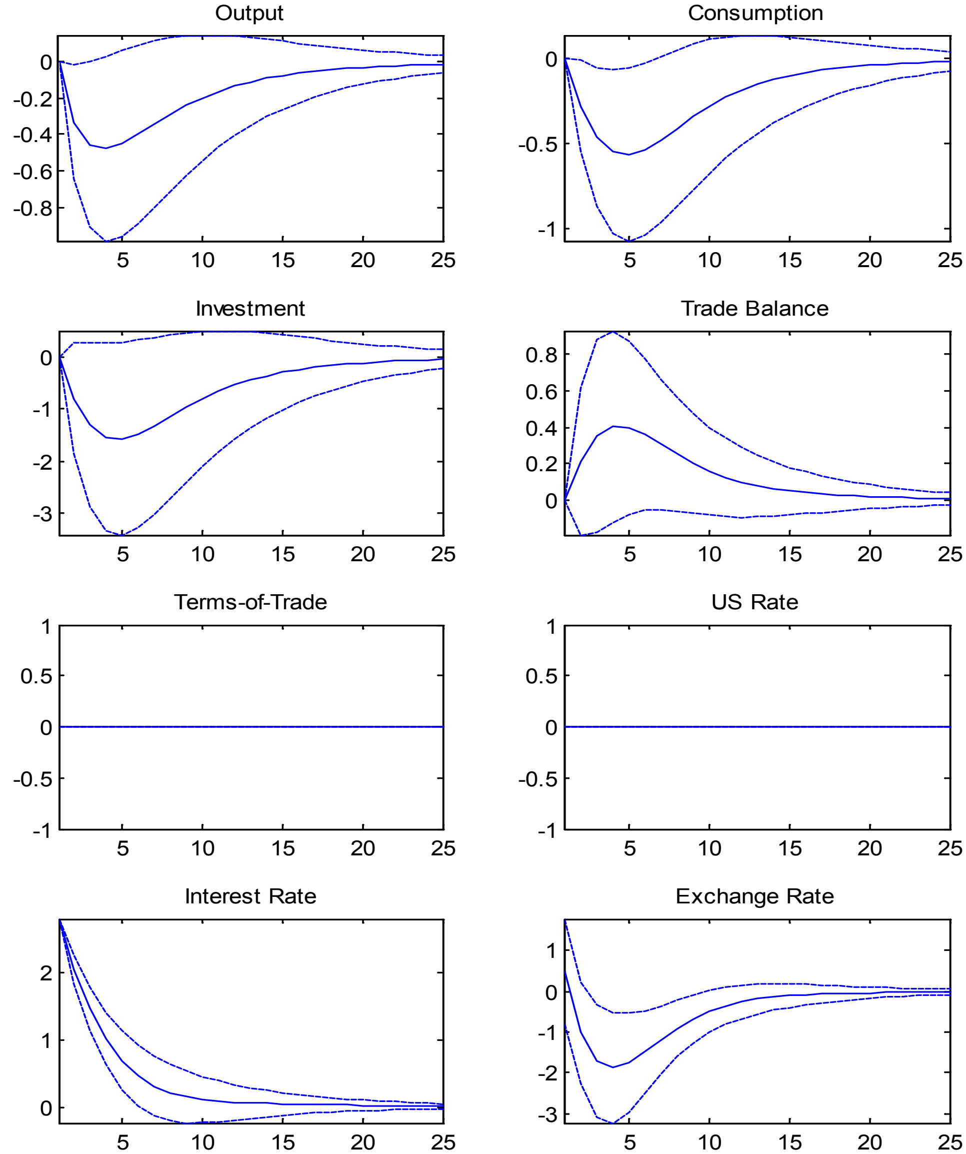


Figure 2.7. Impulse response functions to a 1 standard deviation country spread shock. All variables except for the trade balance and interest rates are expressed in percent deviations from a HP trend. The trade balance and interest rates are expressed in percentage point's deviations. The 95% confidence intervals are computed by the delta method.

2.2.5 Variance decompositions

In order to answer our original question of how important are terms-of-trade and interest rate shocks in emerging economies, we compute variance decompositions of the estimated VAR model. This allows us to measure the fraction of the variance in one variable of the model (at a given horizon) that is attributable to the structural innovation in another variable. These decompositions are shown in Table 2.5. Overall, country spread shocks are of more significance than foreign interest rates and terms-of-trade shocks. At a frequency of 20 quarters, the contribution of country spread innovations is about 12% while that of US interest rates of 7%. The contribution of term-of-trades innovations is about 5%. Similar contributions are observed for consumption, investment and the trade balance. About a quarter of movements in real exchange rates are explained by country risk innovations.

In contrast with previous studies, we find that the terms of trade have only a minor role. They explain at most 5% of output variability, and just 1% of real exchange rate movements. This stands in sharp contrast with Mendoza (1995) and Kose (2002) who find large effects of the terms-of-trade on output fluctuations. However, it is worth pointing out that they do not account for country risk shocks. Mendoza (1995) treats the interest rate as a constant while Kose (2002) estimates a VAR with shocks to the foreign interest rate, but not to country spreads. On the other hand, Uribe and Yue (2006) estimate a VAR with foreign and country spread shocks, but without terms-of-trade innovations. They find almost identical contributions of country spread shocks on output to ours (12% in both cases) but a much larger effect of US rate shocks (20% in their work versus 7% in ours). Given that their dataset stops on 2002, one may interpret the lower contribution we find of foreign interest rates as further evidence of the “decoupling” of emerging economies from rich economies. Our main contribution in this section is to show that country spreads are the most relevant shock in explaining the business cycle.

Table 2.5: Variance decompositions

Horizon	Forecast SE	*tot*	*rus*	*rir*	*rer*
		Percentage of the variance of GDP explained by:			
4	2.74	3	1	7	1
12	3.27	5	6	12	2
20	3.31	5	7	12	2
		Percentage of the variance of CON explained by:			
Horizon	Forecast SE	*tot*	*rus*	*rir*	*rer*
4	2.71	3	2	8	0
12	3.49	5	7	15	1
20	3.56	5	9	15	1
		Percentage of the variance of INV explained by:			
Horizon	Forecast SE	*tot*	*rus*	*rir*	*rer*
4	9.14	2	1	6	0
12	11.3	5	5	11	2
20	11.5	5	6	12	2
		Percentage of the variance of NX explained by:			
Horizon	Forecast SE	*tot*	*rus*	*rir*	*rer*
4	2.71	2	1	5	0
12	3.05	4	6	9	1
20	3.08	4	6	9	1
		Percentage of the variance of RIR explained by:			
Horizon	Forecast SE	*tot*	*rus*	*rir*	*rer*
4	4.27	2	3	83	3
12	4.64	2	7	75	5
20	4.66	2	7	74	5
		Percentage of the variance of RER explained by:			
Horizon	Forecast SE	*tot*	*rus*	*rir*	*rer*
4	7.27	1	1	15	75
12	8.18	1	4	24	60
20	8.23	1	4	24	59

Notes: tot denotes the terms-of-trade, rus the US interest rate, rir the country interest rate (US rate plus EMBI spread) and rer the real exchange rate. Forecast horizons are in quarters. Variance decompositions are expressed as percentage points.

2.3 The Theoretical Model

In this section we develop a theoretical model of a small open economy in which the empirical regularities established in the preceding section can be interpreted as the equilibrium of an economy subject to terms-of-trade and interest rate shocks. The basis of the model is the standard neoclassical growth model for a small open economy. We disaggregate the economy into three sectors: exportables, importables and nontradables so as to capture variability in the terms of trade as a source of macroeconomic risk. Households consume all three types of goods but domestic firms produce only exportables and nontradables. Capital is sector specific and investment in both producing sectors takes place using importable goods. The model economy displays frictions in its investment process (both to reduce investment variability and to generate the observed hump-shaped response in the data), a bond-holding adjustment cost function (to eliminate the unit root process otherwise present in small open economies of this sort) and a working capital constraint so as to induce effects of interest rate shocks. The need to finance a fraction of the wage bill by holding non-interest bearing financial assets means that changes in the interest rate will affect production decisions and have a direct effect on output. Our model is closely related to Neumeyer and Perry (2005) and Uribe and Yue (2006), extending their models to a multi-sector framework to capture real exchange rate effects.

2.3.1 Households

Consider a small open economy populated by a large number of infinitely lived households where the representative household maximizes a lifetime utility function of the form,

$$E_t \sum_{t=0}^{\infty} \beta^t u(c_t, h_t) \tag{2.2}$$

where c_t is a consumption index in period t, h_t is hours worked in period t, the parameter β is the subjective discount factor and the period utility function u is assumed to be increasing in c, decreasing in h, concave and smooth.

The consumption index c_t, is an homogenous function of exportables c^X, importables c^M and nontradables c^N. In particular, we consider the CES aggregator,

$$c_t = \Omega(c_t^X, c_t^M, c_t^N) = \left[\left(\gamma^X\right)^{\frac{1}{\theta}} \left(c_t^X\right)^{\frac{\theta-1}{\theta}} + \left(\gamma^M\right)^{\frac{1}{\theta}} \left(c_t^M\right)^{\frac{\theta-1}{\theta}} + \left(\gamma^N\right)^{\frac{1}{\theta}} \left(c_t^N\right)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}, \quad \theta > 0 \tag{2.3}$$

where the parameter θ represents the elasticity of substitution between goods, with γ^i being their shares in total consumption, for i=*X,M,N*. Total expenditure on consumption is the sum of expenditure on each good,

$$p_t^c c_t = p_t^X c_t^X + c_t^M + p_t^N c_t^N , \tag{2.4}$$

where p^c is the price of the consumption composite good. We let the price of importable goods to serve as the numeraire, which means that p^X is the price of exportables in terms of importables, or the terms-of-trade. Minimizing total expenditures subject to the constraint of attaining consumption level of c, yields the equilibrium relative demands for each consumption good,

$$c^X = \gamma^X \left(\frac{p^X}{p^c} \right)^{-\theta} c \tag{2.5}$$

$$c^M = \gamma^M \left(\frac{1}{p^c} \right)^{-\theta} c \tag{2.6}$$

$$c^N = \gamma^N \left(\frac{p^N}{p^c} \right)^{-\theta} c \tag{2.7}$$

The associated consumption-based price index p^c is then given by,

$$p_t^c = \left[\gamma^X (p_t^X)^{1-\theta} + \gamma^M + \gamma^N (p_t^N)^{1-\theta} \right]^{\frac{1}{1-\theta}} , \tag{2.8}$$

Since this is a small open economy that cannot affect international prices, the terms-of-trades are exogenous and taken as given by the economy. Households offer labor services for a wage w_t and own the capital stock in producing sectors, k^X and k^N, which they rent at the rental rate, r^X and r^N, respectively. The capital stock evolves according to the following law of motion,

$$k_{t+1}^{j} = (1-\delta)\,k_t^{j} + \left(1 - \frac{\kappa}{2}\left(\frac{i_t^{j}}{i_{t-1}^{j}} - 1\right)^2\right) i_t^{j} \tag{2.9}$$

for $j = X,N$, where i_t is gross investment in period t and the parameter δ is the depreciation rate. Following standard practice in the international business cycle literature, we introduce adjustment costs in the capital accumulation process. This is a convenient way to reduce excessive investment volatility. The way adjustment costs are written here, replacing depreciated capital does not generate adjustment costs.[16] As mentioned before, we will assume that the investment good is an importable good. Although a strong assumption, De Bock (2008) shows that emerging economies import a substantial part of their equipment and capital goods. The period budget constraint for the household is,

$$b_{t+1} = R_t^f b_t - \Psi(b_{t+1}) + w_t h_t + r_t^X k_t^X + r_t^N k_t^N - i_t^X - i_t^N - p_t^c c_t \tag{2.10}$$

where b_t is the amount of international bonds denominated in units of importables at the beginning of period t and R^f the gross interest rate on foreign bonds. It is important to

[16] Adjustment costs in capital accumulation help reduce excessive investment volatility. The functional form we use here is identical to the one use by Fernandez-Villaverde et al (2009).

note that we do not assume that the interest rate is constant or that it is solely a function of the US interest rate. On the contrary, the interest rate on foreign bonds will be modeled as a stochastic process depending on both, shocks to US rates and shocks to a country spread term. Furthermore, the country spread is also a function of domestic fundamentals, allowing us to capture the feedback mechanism between interest rates and macroeconomic fundamentals. In the next section we make this point clear by defining the stochastic process. We assume that there are costs of holding bonds, represented here by the convex function $\psi(.)$.[17] The relative prices p^c, w, r^X and r^N, are denominated in units of importables. To prevent households from borrowing an ever-growing amount of debt from international markets, we impose a no-Ponzi constraint of the form,

$$\lim_{j\to\infty} E_t \frac{b_{t+j+1}}{\prod_{s=0}^{j} R^f_{t+s}} \geq 0 \tag{2.11}$$

2.3.2 Timing of events

In order to keep consistency with our maintained assumptions in the empirical model of the previous section, we also impose the constraint in the theoretical model that household decisions must be made one period in advance. This means that unanticipated innovations to the interest rate or the terms-of-trade will have real effects on resource

[17] Bond holding costs are also expressed in real amount, that is, in terms of the numeraire good. Bond holding costs are needed to avoid the unit root process of small open economies. See Schmitt-Grohé and Uribe (2003) for other ways of closing small open economies.

allocations only after one period, as was the case in our empirical exercise. Specifically, a representative household must choose labor supply, consumption and investment one period in advance, before observing the interest rate or export price realization.

Households then choose at time *t* contingent plans $\{c_{t+1}, h_{t+1}, i^X_{t+1}, i^N_{t+1}, b_{t+1}\}_{t=0}^{\infty}$ so as to maximize the utility function (2.2) subject to the sequence of capital accumulation constraints (2.9), the budget constraint (2.10) and the no-Ponzi game condition (2.11) for given values of initial conditions of $\{c_t, h_t, i^X_t, i^N_t, k^X_t, k^N_t b_t\}$ and for the given sequences of prices $\{w_t, r^X_t, r^N_t, R^f_t, p^c_t, p^x_t, p^n_t\}$. Letting μ^j_t denote the respective multiplier on (2.9), and λ_t denote the Lagrange multiplier on (2.10), the first-order conditions are,

$$0 = u_c(c_{t+1}, h_{t+1}) - E_t \lambda_{t+1} p^c_{t+1} \tag{2.12}$$

$$0 = u_h(c_{t+1}, h_{t+!}) + E_t \lambda_{t+1} w_{t+1} \tag{2.13}$$

$$0 = -\lambda_t [1 + \psi'(b_{t+1})] + \beta E_t [\lambda_{t+1} R^f_{t+1}] \tag{2.14}$$

$$0 = -\mu^X_t + \beta E_t \mu^X_{t+1}(1-\delta) + \beta E_t \lambda_{t+1} r^X_{t+1} \tag{2.15}$$

$$0 = -\mu^N_t + \beta E_t \mu^N_{t+1}(1-\delta) + \beta E_t \lambda_{t+1} r^N_{t+1} \tag{2.16}$$

$$0 = -E_t\lambda_{t+1} + E_t\mu_{t+1}^X\left[1-\frac{\kappa}{2}\left(\frac{i_{t+1}^X}{i_t^X}-1\right)^2 - \kappa\frac{i_{t+1}^X}{i_t^X}\left(\frac{i_{t+1}^X}{i_t^X}-1\right)\right] + \beta E_t\mu_{t+2}^X\left[\kappa\left(\frac{i_{t+2}^X}{i_{t+1}^X}\right)^2\left(\frac{i_{t+2}^X}{i_{t+1}^X}-1\right)\right] \qquad (2.17)$$

$$0 = -E_t\lambda_{t+1} + E_t\mu_{t+1}^N\left[1-\frac{\kappa}{2}\left(\frac{i_{t+1}^N}{i_t^N}-1\right)^2 - \kappa\frac{i_{t+1}^N}{i_t^N}\left(\frac{i_{t+1}^N}{i_t^N}-1\right)\right] + \beta E_t\mu_{t+2}^N\left[\kappa\left(\frac{i_{t+2}^N}{i_{t+1}^N}\right)^2\left(\frac{i_{t+2}^N}{i_{t+1}^N}-1\right)\right] \qquad (2.18)$$

2.3.3 Firms

Firms produce two goods, exportable and nontradable goods, using capital and labor as inputs, which they hire from households. The production technologies in both sectors are Cobb-Douglas and are given by,

$$y_t^X = e^{\lambda_t^X}(k_t^X)^{\alpha^X}(h_t^X)^{1-\alpha^X} \qquad (2.18)$$

$$y_t^N = e^{\lambda_t^N}(k_t^N)^{\alpha^N}(h_t^N)^{1-\alpha^N} \qquad (2.19)$$

where λ^i is a random productivity shock, k^i is the capital stock and h^i are total hours worked for sectors $i = X, N$. Productivity shocks are assumed to follow a first-order autoregressive process,

$$\lambda_{t+1}^X = \rho^X\lambda_t^X + \varepsilon_{t+1}^X \qquad with \quad \varepsilon^X \sim N\left(0,\sigma_X^2\right) \qquad (2.20)$$

$$\lambda_{t+1}^N = \rho^N\lambda_t^N + \varepsilon_{t+1}^N \qquad with \quad \varepsilon^N \sim N\left(0,\sigma_N^2\right) \qquad (2.21)$$

with $0<\rho^i<1$, $\varepsilon^i>0$, for i = X,N. These assumptions imply that the unconditional expectation of the productivity level is one or $E[e^{\lambda}] =1$ in both sectors.

Firms in both sectors are subject to a working capital constraint. Firms need to pay for labor services before output is sold, so firms need to borrow to cover a fraction of the wage bill. Firms choose labor and capital for each sector so as to maximize profits which are given by,

$$p_t^X y_t^X + p_t^N y_t^N - w_t(h_t^X + h_t^N) - r_t^X k_t^X + r_t^N k_t^N - \left(R_t^f - 1\right)\eta\, w_t(h_t^X + h_t^N) \tag{2.22}$$

where the last term represents the cost associated with the loans used by the firms to pay for the wage bill. The parameter η denotes the fraction of the wage bill that has to be paid in advance. The first order conditions associated with this problem are,

$$r_t^X = \alpha^X p_t^X \lambda_t^X (k_t^X)^{\alpha^X - 1} (h_t^X)^{1-\alpha^X} \tag{2.23}$$

$$w_t(1 + r_t^f \eta) = (1-\alpha^X) p_t^X \lambda_t^X (k_t^X)^{\alpha^X} (h_t^X)^{-\alpha^X} \tag{2.24}$$

$$r_t^N = \alpha^N p_t^N \lambda_t^N (k_t^N)^{\alpha^N - 1} (h_t^N)^{1-\alpha^N} \tag{2.25}$$

$$w_t(1 + r_t^f \eta) = (1-\alpha^N) p_t^N \lambda_t^N (k_t^N)^{\alpha^N} (h_t^N)^{-\alpha^N} \tag{2.26}$$

2.3.4 Competitive Equilibrium

In equilibrium the markets for capital, labor, and nontradable goods must clear,[18]

$$k_t^{X(s)} = k_t^{X(d)} \tag{2.27}$$

$$k_t^{N(s)} = k_t^{N(d)} \tag{2.28}$$

$$h_t = h_t^X + h_t^N \tag{2.29}$$

$$c_t^N = y_t^N \tag{2.30}$$

The foreign market has in each period a clearing condition given by,

$$NX_t = p_t^X\left(y_t^X - c_t^X\right) - c_t^M - i_t^X - i_t^N, \tag{2.31}$$

where NX_t are net exports in period t. This simply states that net exports are equal to the goods produced in the country that are not spent in consumption, investment and bond holding costs.

A *competitive equilibrium* corresponds to sequences of household's allocations $\left\{c_t^X, c_t^M, c_t^N, h_t^{X(s)}, h_t^{N(s)}, i_t^X, i_t^N, k_{t+1}^{X(s)}, k_{t+1}^{N(s)}, b_{t+1}\right\}_{t=0}^{\infty}$, domestic producer firms' allocations $\left\{h_t^{X(d)}, h_t^{N(d)}, k_{t+1}^{X(d)}, k_{t+1}^{N(d)}\right\}_{t=0}^{\infty}$, equilibrium prices $\left\{p_t^C, p_t^N, r_t^X, r_t^N, w_t\right\}_{t=0}^{\infty}$, initial conditions $k_0^X, k_0^N, b_0, h_0, c_0, i_0$, and shock processes for $\left\{\lambda_t^X, \lambda_t^N, p_t^X, R_t^f, R_t^x\right\}_{t=0}^{\infty}$, such that:

[18] We use the superscript s to indicate quantities supplied by households who own the factors of production, and the superscript d to indicate quantities demanded by firms.

- Given prices, initial conditions and shock processes, the household's allocations solve the household problem given by equations (2.4)-(2.17)
- Given prices and shock processes, the firms allocations solve the firms problem given by equations (2.22)-(2.26)
- Markets clear, equation (2.27)-(2.30)
- The resource constraint given by equation (2.31) is satisfied

2.3.5 Shock processes and functional forms

We proceed now to characterize the stochastic processes that govern all exogenous shocks and the functional forms for the utility function and adjustment-costs introduced in the model.

Productivity shocks

The productivity process for both sectors is assumed to follow an *AR(1)* process as described by equations (2.20)-(2.21). Moreover, we assume a persistence of 0.95 which is standard in the real business cycle literature (see Neumeyer and Perri, 2005). Productivity is affected by normally distributed shocks and in the simulations we set their standard deviation so as to much the average output volatility seen in our data sample.

Terms-of-Trade shocks

As noted earlier, the external price of importables is normalized to one, which implies that the price of exportables p^X, is the terms-of-trade. We assume this price evolves stochastically according to

$$\log p_t^X = \rho^{tot} \log p_{t-1}^X + \varepsilon_t^{tot} \qquad with\ \varepsilon_t^{tot} \sim N(0, \sigma_{\varepsilon^{tot}}^2)$$

The parameters ρ^{tot} and σ^2 are those corresponding to the fifth equation in the empirical VAR of section 2, $\rho^{tot} = 0.678$ and $\sigma^2 = 6.6\%$.

Interest Rate and Country spread shocks

Emerging economies can borrow capital from foreign investors. However, we do not assume that they can borrow freely at the international interest rate. Because domestic residents can default on their foreign debt, they need to pay a premium above risk-free international interest rates to compensate for default risk. We therefore assume this default risk, or country spread, is a function of domestic macro variables as estimated in the VAR model of section 2.2. We would like to mention that this is still and ad-hoc formulation of how country spreads behave. A nice improvement would be to model country spreads “inside” the model. Arellano (2008) develops such a model, although output is given exogenously in her work. The process for the international interest rate at which emerging economies can borrow is then given by the seventh equation of the VAR system

$$\hat{R}_t = 0.678\hat{R}_{t-1} + 0.129\hat{R}_t^{us} - 0.204\hat{R}_{t-1}^{us} - 0.345\hat{y}_t + 0.119\hat{y}_{t-1} + 0.088\hat{c}_t - 0.032\hat{c}_{t-1} - 0.016\hat{i}_t$$
$$- 0.008\hat{i}_{t-1} + 0.099tby_t - 0.078tby_{t-1} - 0.067t\hat{o}t_t + 0.063t\hat{o}t_{t-1} + 0.059r\hat{e}r_{t-1} + \varepsilon_t^r$$
$$with\ \varepsilon_t^r \sim N(0, \sigma^2_{\varepsilon^r})$$

The estimated standard deviation of innovations to country interest rates is 2.8%. The foreign interest rate, here assumed for simplicity to be the US interest rate, evolves according to the sixth equation in the VAR system,

$$\hat{R}_t^{us} = \rho^{rus}\hat{R}_{t-1}^{us} + \varepsilon_t^{rus} \qquad with\ \varepsilon_t^{rus} \sim N(0, \sigma^2_{\varepsilon^{rus}})$$

with a persistence coefficient estimated at ρ^{rus} = 0.777, and an estimated standard deviation of σ^2 = 0.7%. As noted by Uribe and Yue (2006), the country interest rate shock, ε_t^r, can equivalently be interpreted as a country spread shock. To see this, define country spreads as the difference between country interest rates and US rates, $\hat{S}_t = \hat{R}_t - \hat{R}_t^{us}$. Then, since $\hat{R}_t^{us}$ appears as a regressor in the country interest rate equation, the estimated residuals are exactly the same whether we use $\hat{R}_t$ or $\hat{S}_t$ as the dependent variable.

Functional Forms

The period utility function is assumed to take the following form,

$$u(c,h) = \frac{1}{1-\sigma}\left[c - \frac{h^{v}}{v}\right]^{1-\sigma}, \qquad v > 0$$

These preferences were first introduced in the macro literature by Greenwood, Hercovitz and Huffman (1988) and are widely used in small open economy models. They have the property that the intertemporal substitution of leisure is zero, implying that labor supply depends only on wages and not on consumption.

We adopt a standard functional form for bond holding costs,

$$\Psi(b_{t+1}) = \frac{\varphi}{2}(b_{t+1} - b)^{2}, \qquad \varphi > 0$$

where φ is a constant to be calibrated determining the size of the bond holding costs, and b is the steady-state level of bond holdings. This functional form implies that no holding costs are present on the steady-state.

2.3.6 The Real Exchange Rate

Since this is a non-monetary model, it is not straightforward how to define the real exchange rate. Ostry (1988) defines the real exchange rate as p^N weighted by the share of nontradables in total expenditures. On the other hand, Greenwood (1984) and Mendoza (1995) use p^c as equivalent to the real exchange rate. They argue that in three-good models that explicitly examine terms-of-trade effects, the real exchange rate is better measured using the domestic relative price of aggregate consumption, which is a function of both p^N and p^X. In the exercises we perform we use the latter definition for the real exchange rate. This also ensures consistency with our dataset since our empirical series is constructed by using CPI indexes for most countries.[19]

2.4. Estimation

We estimate the model using Bayesian techniques. Bayesian inference starts out from a prior distribution that describes the information prior to observing the data used in the estimation. The observed data is then used to update the priors via Bayes' law, to the posterior distribution of the model's parameters. The posterior distribution can then be summarized with usual measures of location (mode, mean) and dispersion (standard deviation and confidence intervals).

[19] We use the inverse so that an increase in p^c corresponds to a real appreciation of the domestic country, as is the case in our econometric model of section 2.

2.4.1 Calibration and Bayesian estimation

In calibrating the model, we choose fairly standard values for the taste and technology parameters. We set the inverse of the intertemporal elasticity of substitution σ to 2 and the labor curvature parameter for the GHH specification v to 1.6 as in Neumeyer and Perry (2005) and Uribe and Yue (2006). The depreciation rate of capital is set to 0.025 at a quarterly frequency, also standard in the literature. The discount factor β is set to 0.98 to match the average real interest rate in our sample, which is 8% annually. The steady state level of bond holdings b is chosen such that the steady-state average trade balance-to-output ratio equals about 0.5% which is the average in our dataset. Following Mendoza (1995) we set the capital share for the nontraded goods sector $\alpha^N = 0.36$ and $\alpha^X = 0.49$. Using a dataset for 13 developing countries, Ostry and Reinhart (1992) estimate the intratemporal elasticity of substitution between goods to lie in the 1.22-1.27 range. Accordingly, we set this parameter to $\theta = 1.25$.

Three parameters remain to be set. These are the bond-holdings cost parameter ψ, the capital adjustment parameter κ, and the parameter representing the fraction of the wage bill that needs to be paid in advance η. We proceed to estimate these parameters with Bayesian techniques using four key macroeconomic series from the dataset used in section 2 as observables: real GDP, real consumption, real investment and the trade balance-to-output ratio.

The estimation is performed in the following way. First, we estimate the mode of the posterior distribution my maximizing the log posterior function, which combines the prior information of the parameters with the likelihood of the data. In a second step, the

Metropolis-Hastings algorithm is used to get a complete picture of the posterior distribution and to evaluate the marginal likelihood of the model.[20]

2.4.2 *Priors and Posterior Estimates*

The prior on the bond-holdings cost parameter is assumed to be beta distributed with mean 0.001 and standard deviation 0.0005. This represents a fairly low holding cost of adjusting bond (or debt) positions. For example, Uribe and Yue (2006) estimate this parameter to be 0.00042. A gamma distribution with mean 20 and standard deviation 10 is assumed for the capital adjustment parameter. Because different researchers have used widely different values for this parameter, we wanted to choose a rather loose prior for this parameter. Uribe and Yue estimate this parameter at 72.8 whereas Neumeyer and Perry (2005) use different values in different experiments, ranging from as low as 8 to 40. Finally, the prior distribution for the working capital constraint parameter is assumed to be gamma with mean 1 and standard deviation 0.5. Uribe and Yue estimate this parameter at 1.20 while Neumeyer and Perry calibrate it to 1.

Table 2.6 gives the calibration and priors of all parameters along with the mode, the mean, and the 5 and 95 percentiles of the posterior distribution of the parameters estimated by the Metropolis-Hastings algorithm. The bond-holdings cost parameter is estimated at 0.0005 which is in line with previous papers and represents a very small cost

[20] The estimation was carried out using Dynare. A sample of 100,000 draws was created (neglecting the first 20,000 draws). The Hessian resulting from the optimization procedure was used for defining the transition probability function that generates the new proposed draw. A step size of 0.3 resulted in a rejection rate of 0.80.

with changing the stock of debt. The capital adjustment costs are estimated at 17.9. The posterior mean of the fraction of the wage bill paid in advance is 0.62. Figures 8 and 9 provide graphical representations of the priors and posteriors for each parameter of interest.

Table 2.6: Parameter values

Panel A: calibrated parameters

Discount factor	β	0.98	Capital share in X-sector	α^X	0.49
Utility curvature	σ	2	Capital share in N-sector	α^N	0.36
Labor curvature	υ	1.6	Depreciation rate	δ	0.025
Intratemporal elasticity	θ	1.25	AR(1) in X-sector shock	ρ^X	0.95
Exportables share	γ^X	0.15	AR(1) in N-sector shock	ρ^N	0.95
Importable share	γ^M	0.15			
Nontradable share	γ^N	0.7			

Panel B: estimated parameters

	Prior distribution			Posterior distribution			
	Distr.	Mean	St. Dev.	Mode	Mean	5 percent	95 percent
Bond holding costs φ	Beta	0.001	0.0005	0.0005	0.0005	0.0005	0.0006
Capital adjustment κ	Gamma	20	10	20	17.9	16.3	19.9
Working capital η	Gamma	1	0.5	0.99	0.62	0.36	0.89

Note: The posterior distribution is obtained using the Metropolis-Hastings algorithm. A sample of 100,000 draws was created, dropping the first 20,000 before using posterior simulations. A scale of 0.2 was used for the jumping distribution in MH algorithm, resulting in an acceptance rate of 20%.

Figure 2.8.:Priors distribution

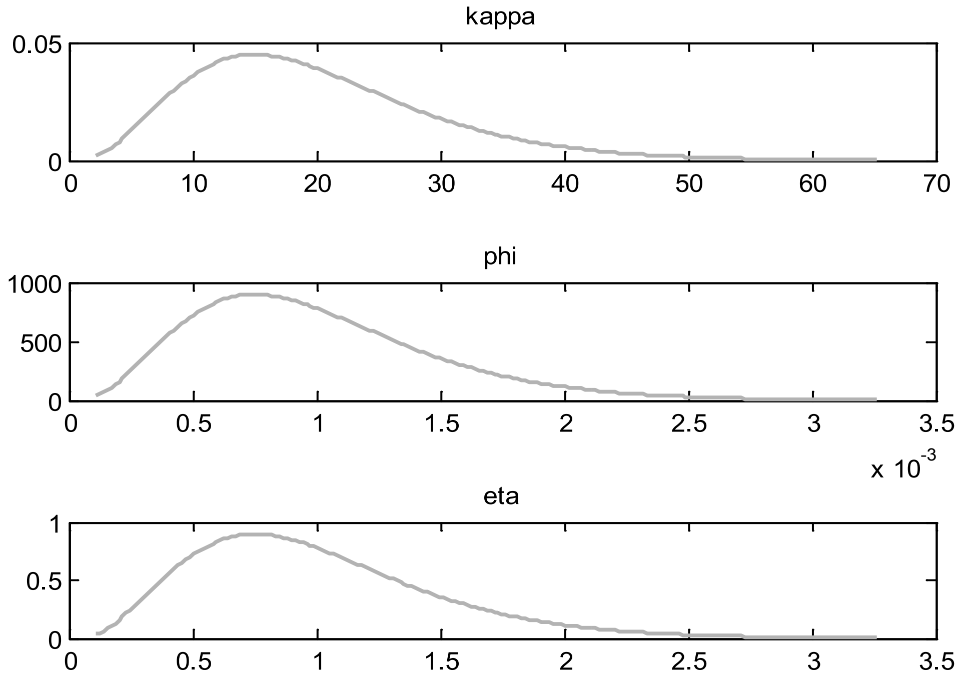


Figure 2.8. Prior distributions for estimated parameters. Kappa is the parameter of the capital adjustment costs. Phi is the parameter for the bond-holding cost function. Eta is the parameter of the working capital constraint.

Figure 2.9: Priors and Posteriors

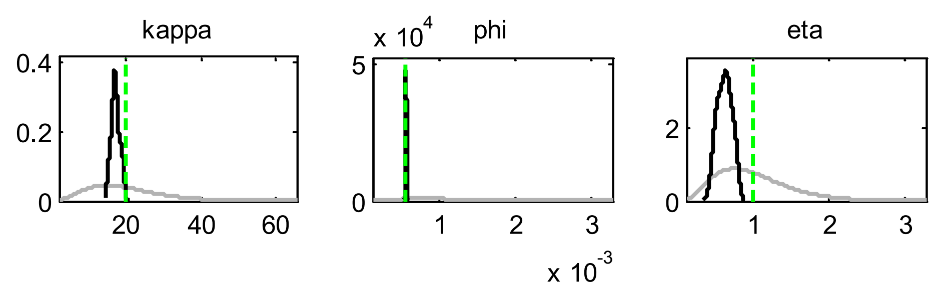


Figure 2.9. Priors and posteriors of estimated parameters. Comparison of the posterior (black lines) to the prior distribution (grey lines). Green lines are the posterior modes. The posterior distribution is obtained using the Metropolis-Hastings algorithm. A sample of 100,000 draws was created, dropping the first 20,000 before using posterior simulations. A scale of 0.2 was used for the jumping distribution in MH algorithm, resulting in an acceptance rate of 20%.

2.5 Model solution

The theoretical model of the previous section cannot be solved analytically so we use numerical methods instead. We first computed the deterministic steady-state by turning-off all stochastic shocks. Then we log-linearize the system of equations characterizing the solution of the model around its steady-state. Finally, we solve the resulting system of stochastic difference equations using the method of undetermined coefficients as described by Uhlig (1999).

2.5.1 Impulse responses

We compare the results obtained from the theoretical model to those obtained from the empirical model by studying the impulse responses of macroeconomic aggregates induced by productivity, terms-of-trade and interest rates shocks. As Sims (1980) suggests in his seminal paper, VAR models can be applied to actual observed data and to the model-generated data, and compare the impulse-response paths of both. If the impulse-response generated by the theoretical model falls within the confidence bands of those generated by actual data, then we have some evidence that the DSGE model captures some features of actual economies.

Figure 2.10 reports the impulse response functions to a one standard deviation increase in the US interest rate. The model (red lines) does a good job in predicting the responses of output, consumption, investment and the trade balance. This can be appreciated by noting that the model-implied responses lie within the 95% confidence bands of the data-implied responses (blue lines). The behavior of the real exchange rate implied by the model is not as good, but it gets the direction right. That is, upon an increase in the US interest rate, the model predicts a real exchange rate depreciation which continues for 3 quarters before reverting to the mean. The mechanism through which the real exchange rate depreciates in the model is via a fall in the price of nontradables due to the fall in aggregate demand. The real exchange rate however returns to its long-run average more quickly in the model that in the data.

Figure 2.11 plots the responses to a country spread increase of one standard deviation. The model overestimates the initial responses of output, consumption and the trade balance relative to the actual responses seen in the data, and fails to generate a hump-shaped response. For example, the model predicts a fall of about 1% in output after an increase of 2.8 percentage points in the country risk premium. The fall estimated in the empirical model is, on the other hand, of about 0.5%. Nevertheless, after a few quarters all predicted responses lie inside the confidence intervals from the empirical responses. In the figure, we also see that after an unanticipated increase in risk spreads, the real exchange rate jumps down (i.e., depreciates) and then returns to zero from below. The size of the real depreciation in the model is of about 1%, whereas in the data, a real depreciation of 2% (by the fourth quarter) is observed.

Figure 2.12 reports the impulse response functions to a one standard deviation terms-of-trade innovation. The model performance is not as good as it was in the case of

US and country interest rate shocks. Mainly, it overstates the effects of terms-of-trade shocks on all variables. The model predicts a positive effect on output of almost 0.6% when the peak effect observed in the data is of about 0.3%. It also overestimates the effects on consumption and investment. Because of our maintained assumption that absorption decisions are taken one period in advance, the trade balance improves upon an increase in the terms-of-trade since no quantity effect can happen at the time of the shock to offset the value-effect of higher export prices. But by the third quarter, the increases in consumption and investment are enough to move the trade balance into negative territory. The negative correlation between the terms-of-trade and the trade balance (albeit delayed, not contemporaneous, in our model) is know as the Obstfeld-Razin-Svensson effect. Finally, the model correctly predicts a real appreciation (on impact, the export price jumps, and starting in the second quarter, the price of nontradables also increases) although the effect is also greatly overstated.

Figure 2.10. Impulse Responses to a US Rate shock

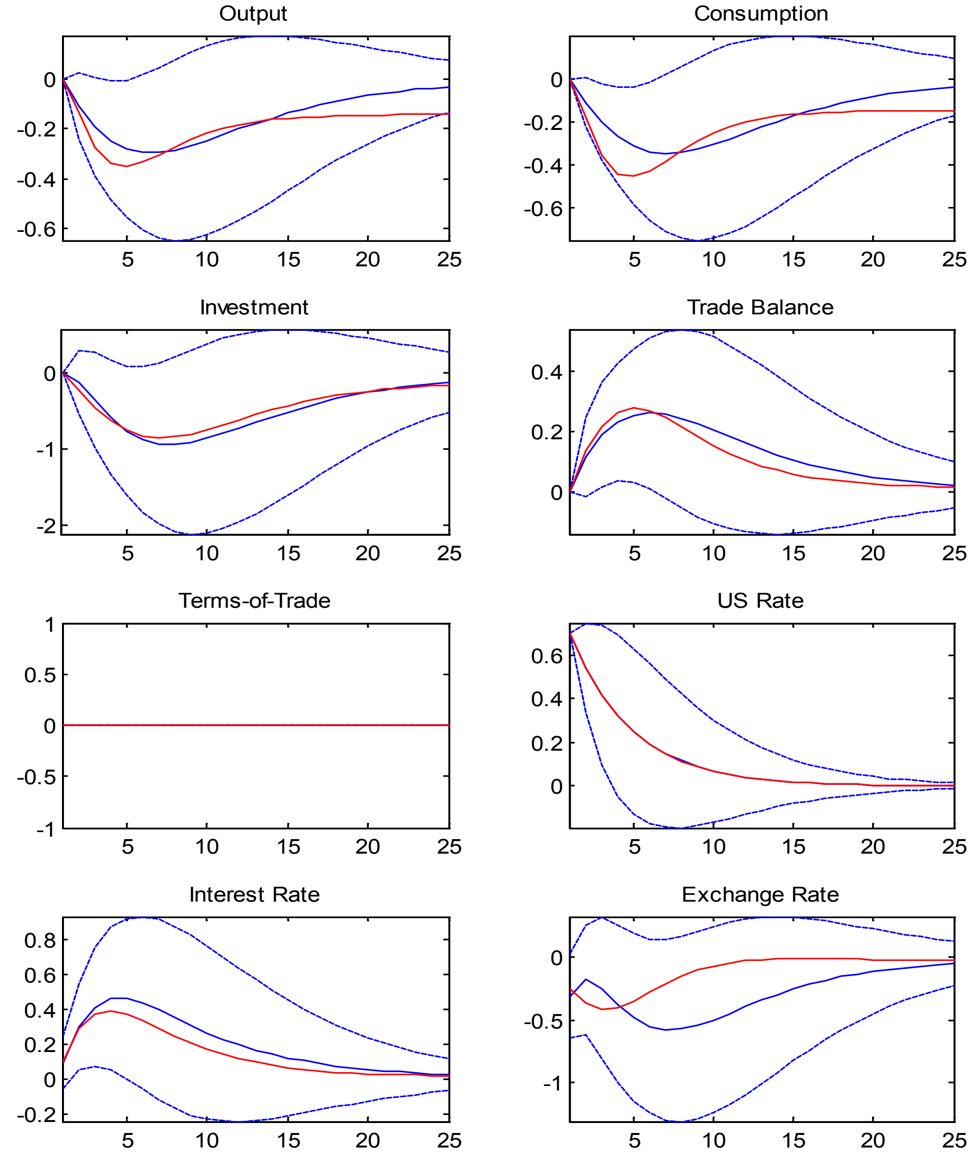


Figure 2.10. Impulse response functions to a 1 standard deviation US rate shock. Blue lines are empirical impulse responses with 95% error bands computed with the delta method. Red lines are impulse responses from the theoretical model.

Figure 2.11. Impulse Response to a Country Spread shock

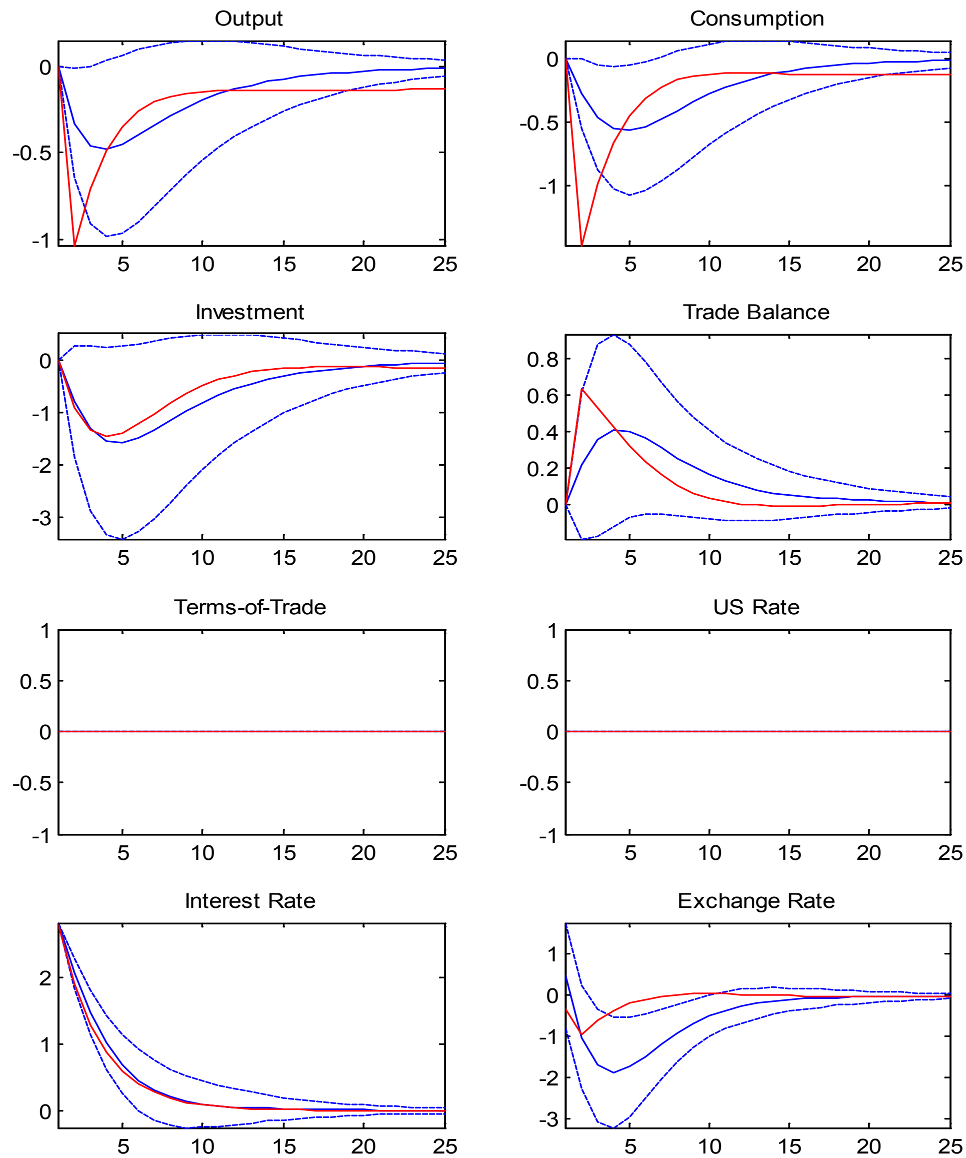


Figure 2.11. Impulse response functions to a 1 standard deviation Country Spread shock. Blue lines are empirical impulse responses with 95% error bands computed with the delta method. Red lines are impulse responses from the theoretical model.

Figure 2.12. Impulse Response to a TOT shock

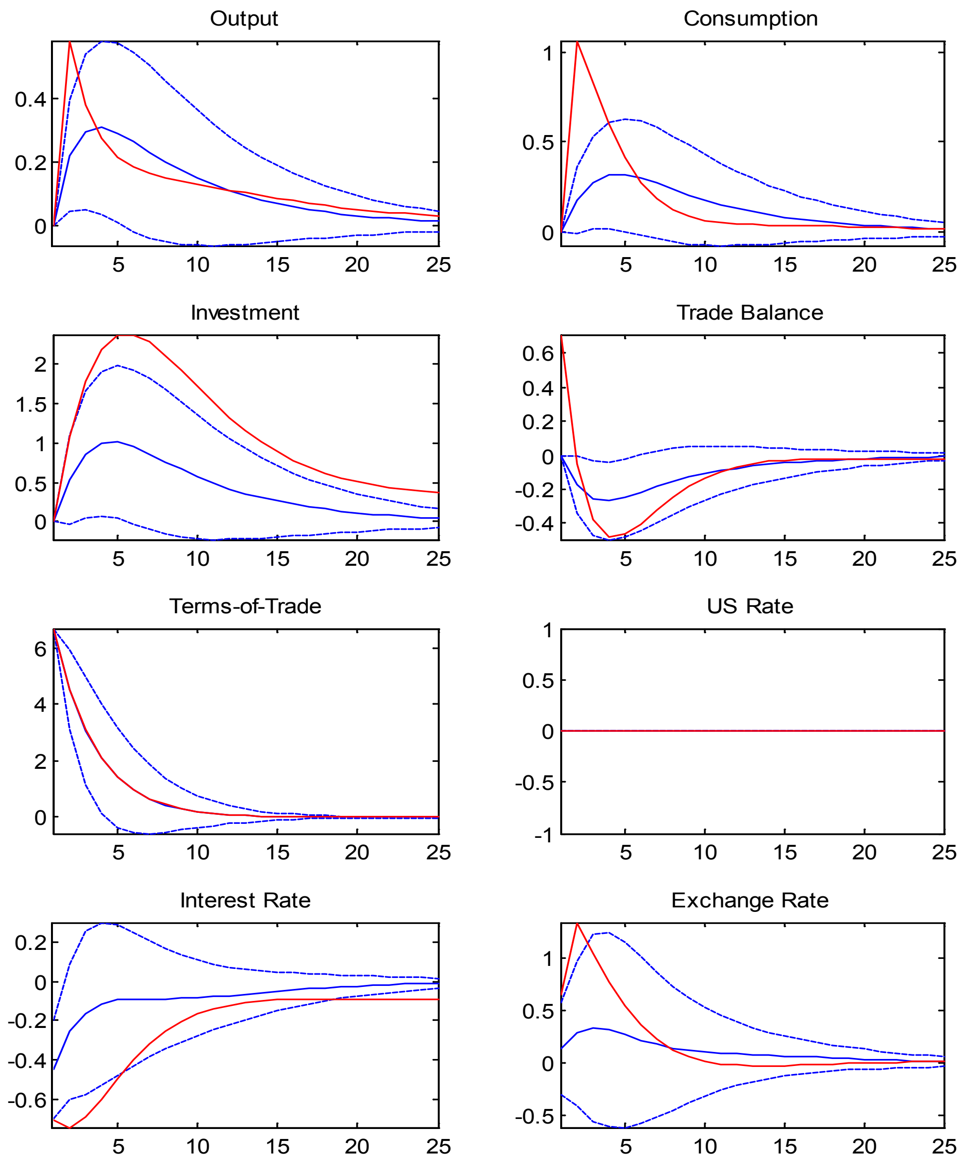


Figure 2.12. Impulse response functions to a 1 standard deviation TOT shock. Blue lines are empirical impulse responses with 95% error bands computed with the delta method. Red lines are impulse responses from the theoretical model.

2.6 Conclusions

In this paper, we find that interest rate shocks are more important than terms-of-trade shocks in driving the business cycle and in explaining the real exchange rate. Country spreads explain about 12 percent of movements in domestic output, US interest rates explain and additional 7 percent and terms-of-trade explain in turn 5 percent of output variability. We also find that in the data, real exchange rates are mainly driven by shocks to the country spreads and not by innovations to the terms-of-trade.

We study the plausibility of these effects by extending the models described in Uribe and Yue (2006) and Neumeyer and Perry (2005), to a three-sector environment, thus allowing us to study interest rates, terms-of-trade and real exchange rates all in one single model. Our theoretical model does a reasonable good job in analyzing the effects of foreign interest rate and country spread shocks. We find that bond-holding costs, investment adjustment costs and working capital constraints are needed in order to generate plausible propagation mechanisms.

An important shortcoming of our model is that it overpredicts the effects of terms-of-trade shocks on domestic macro aggregates relative to the data. It also underestimates the effects of country spreads on real exchange rates by around 50% and it overestimates the effects of terms-of-trade on real exchange rates.

Our empirical finding that terms-of-trade are of minor importance in driving business cycles is in sharp contrast with Mendoza (1995). We believe that this is the result of different approaches. Whereas Mendoza measures the contribution of terms-of-trade shocks as a driving force of business cycles via simulations of his theoretical model, we measure the contribution of terms-of-trade shocks by means of variance decompositions using actual data on 15 emerging countries.

A natural extension of this paper would be to model nominal prices. Given that our model does a good job qualitatively, but not quantitatively, in explaining the real exchange rate, suggests that nominal rigidities might be needed to better model real exchange rates.

Chapter 3

The Carry Trade in the FX Market

3.1 Introduction

This paper studies one of the most popular strategies for currency investors, the *carry trade*, the effect that volatility in the foreign exchange market has on the carry trade and it develops three new trading rules that aim at improving the risk-return profile of the carry trade. Uncovered interest parity (UIP) implies that currencies with high interest rates are expected to depreciate, while currencies with low interest rates are expected to appreciate. Therefore, expected exchange rate changes would offset interest rate differentials, leaving risk-neutral investors indifferent. In fact, there is a large literature showing that the opposite tends to be true: high interest rate currencies actually are more likely to appreciate against low interest rate currencies. This violation of UIP is at the heart of the carry trade. By buying high interest rate currencies and shorting low interest rate currencies, the carry trade strategy not only earns the positive interest rate differential, the *carry*, it also profits from expected exchange rate changes.

A large body of evidence exists documenting the failure of UIP, or equivalently, the *forward-premium puzzle*, starting with Hansen and Hodrick (1980) and Fama (1984).

One of the most convincing explanations for the failure of UIP (and therefore, for the excess returns of the carry trade) is the consideration of a time-varying risk premium (Engel, 1984; Fama, 1984). If investors are holding more risk by buying high interest rate currencies, then they are just being compensated for that additional risk. And indeed, carry trade profits tend to unwind sharply when volatility increases (Brunnermeier et al., 2008; Clarida et al., 2009).

In this study, we investigate the relation between volatility and exchange rates, and propose three trading rules for investing in foreign currencies. The first model we study is based on Markov-switching forecasts of exchange rate changes. Markov-switching models were first developed by Hamilton (1989, 1990) and introduced in the exchange rate literature by Engel and Hamilton (1990) and Engel (1994). Under the Markov-switching approach, the universe of possible outcomes is split into several states of the world corresponding to different *regimes*. The exchange rate then switches between regimes according to some unobservable variable. Engel and Hamilton (1990) and Engel (1994) estimate a two-state Markov-switching model for several industrialized currencies and find no evidence that it produces superior forecasts than the benchmark random-walk model. Although the forecast success of Markov-switching models were modest at best in earlier work, Clarida et al (2003) show that the term-structure of forward rates contains valuable information for forecasting future spot rates. In particular, they estimate a regime-switching vector equilibrium correction model (VECM) that significantly outperforms the random walk model out-of sample. The other two trading strategies we analyze are based on more direct measures of currency volatility. In one of them, we estimate currency volatility with an exponentially-weighted moving average model (EWMA). In the third model, we use implied volatilities which are derived from the FX Options market.

Our main contribution is to show that currency strategies that use FX volatility measures as a decision variable provide better risk-adjusted returns than the standard carry trade. The mechanisms by which this is achieved, is by exiting the carry trade and in fact, doing the exact opposite, whenever volatility is above a specified threshold. A second contribution is to show that currency investing, as defined by the carry trade and our proposed strategies, deliver higher Sharpe ratios than a benchmark bond and stock portfolio, even when one includes the recent global financial crises, a period in which carry trade profits declined sharply.

The remainder of the paper is organized as follows. Section 3.2 discusses the relationship between volatility and carry trade profits. Section 3.3 describes the three different currency strategies we propose as alternatives to the carry trade. Section 3.4 describes the dataset and sample used. Section 3.5 reports the results, by looking at cumulative and average returns, Sharpe ratios and CAPM-style regressions. Finally, section 3.6 concludes the paper.

3.2 Volatility and Carry trades

The relationship between volatility and FX returns has been studied in detail by some researchers recently. Brunnermeier et al (2008) and Clarida et al (2009) find that higher volatility is associated with carry trade losses. Working with data on the G10 currencies, Clarida et al. first divide the data sample into two volatility regimes (high and low) and then proceed to estimate Fama-type regressions. They show that the widely documented negative slope coefficient in these regressions is an artefact of the volatility regime. Running Fama-regressions conditional on volatility regime, they find a positive coefficient greater than unity in high volatility regimes. That is, in high volatility regimes, high interest rate currencies tend to depreciate significantly. Melvin and Taylor (2009) is another paper that focuses on volatility and the foreign exchange market. They analyze in detail the events of the recent global financial crisis and their implication for foreign exchanges. Using monthly data, they construct a *global financial stress index* (FSI), basically a composite of several market indicators meant to capture large shifts in asset prices, increases in risk and uncertainty and shifts in liquidity. They then simulate the returns that a currency investor would earn from investing in the Deutsche Bank Carry Return Index in normal periods and close out the position in stressful periods, as measured by the FSI. They find that such an investor would have significantly outperformed a standard carry trade investor by avoiding sharp losses associated with the recent global financial crisis.

A few differences separate our work from that of Melvin and Taylor (2009). The dataset we use is longer and it uses weekly observations rather than monthly. We also take into account transaction costs, whereas they do not. And we proceed in different ways in measuring volatility. We also do not simply assume that the investor exits the carry trade and does nothing when volatility is high, but rather propose that the investor should actually do the opposite to the carry trade: invest in low-yielding currencies while shorting high-yielding currencies. The rationale for this can be found in one of the main results of Clarida et al (2009), the significantly positive and greater than unity coefficient of Fama regressions.

3.3 Three models for currency trading

3.3.1. Markov regime switching model

The first strategy we analyze is based on assuming that currencies follow a two state Markov regime-switching process. This type of model was introduced in the exchange rate literature by Engel and Hamilton (1990). Under the Markov-switching approach, the universe of possible occurrences is split into *m* different states and exchange rates switch between regimes according to some unobserved variable. Because exchange rates tend to exhibit long swings (movements in one direction for long periods of time), a Markov-switching model is a natural specification to test.

We restrict ourselves to a two-state model in the mean and variance. In other words, exchange rates follow a two-state Random Walk with drift process, where the drift coefficient and the standard deviation are allowed to change between states. Let e_t *(t = 1,2,…,T)* be the natural logarithm of the exchange rate (foreign currency per USD) and y_t the first difference of *e* (i.e. $y_t = e_t - e_{t-1}$). Then the Markov-switching model for a particular exchange rate is:

$$y_t = \mu_{s_t} + \varepsilon_t, \qquad \varepsilon_t \sim N\left(0, \sigma_{s_t}^2\right) \tag{3.1}$$

where s_t is an unobserved state variable that takes on values in the set {1,2}, and ε_t is a normally-distributed error term with a variance that also switches between states. Thus, equation 2 allows for different means and variances across regimes.

The state variable s_t is assumed to follow a Markov-chain with stationary transition probability matrix:

$$P = \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix} \tag{3.2}$$

where $p_{ij} = \Pr(s_t = j \mid s_{t-1} = i)$, for $i,j = 1,2$, and where $\sum_j p_{ij} = 1$. A vector of current state probabilities is then defined as $\pi_t = [\pi_1 \; \pi_2]$ where π_i is the probability that the variable y is currently in state i. Given π_i and P, the probability that the variable y will be in a given regime next period can be forecasted using,

$$\pi_{t+1} = \pi_t \mathbf{P} \tag{3.3}$$

and the one-period ahead forecast of y_{t+1}, based on time-t information is,

$$\hat{y}_{t+\frac{1}{t}} = E(y_{t+1}|y_1, y_2, \ldots, y_t) = \pi_{t+1}\mu_S \tag{3.4}$$

where E denotes the rational expectations operator and $\mu_S = [\mu_1 \ \ \mu_2]'$ is the vector of state means. These forecasts are nonlinear since the estimates of the states probabilities are produced by a nonlinear filter.

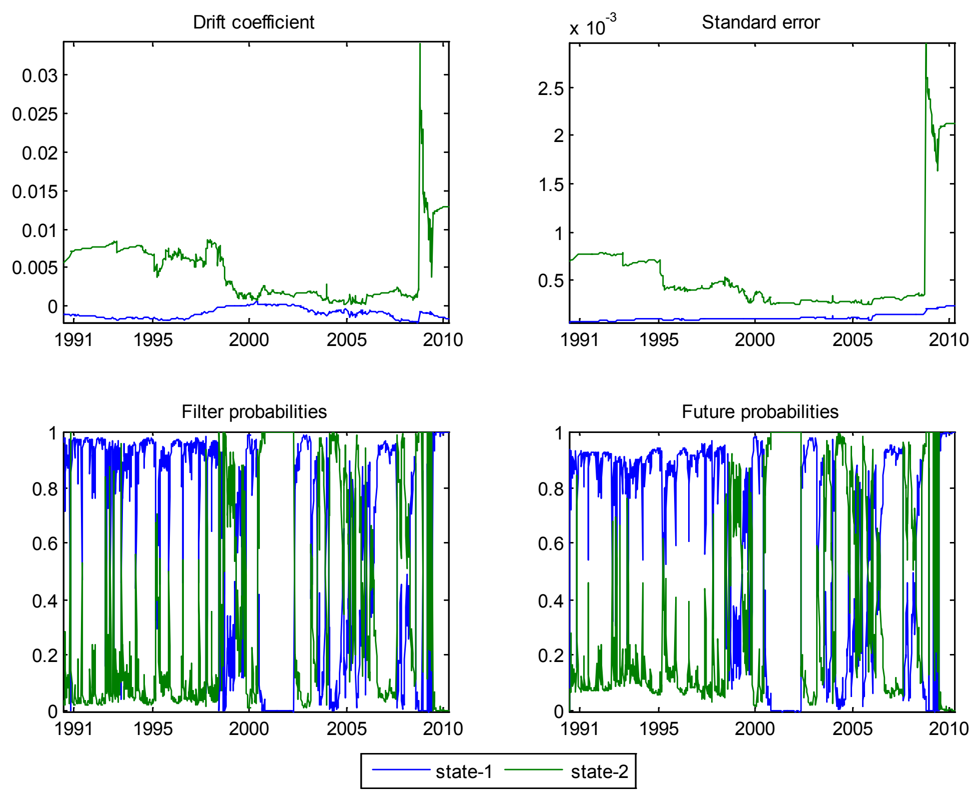
We estimate the means (μ_1, μ_2), variances (σ_1^2, σ_2^2), and the transition probabilities ($p_{11}, p_{12}, p_{21}, p_{22}$) via Maximum likelihood via the EM algorithm which is a method of maximizing the sample likelihood function by iterating on the normal equations (Hamilton 1990). Forecasts for the logarithm of the spot rate are then computed by,

$$\hat{e}_{t+\frac{1}{t}} = e_t + \hat{y}_{t+\frac{1}{t}} \tag{3.5}$$

Forecasts are computed through rolling estimation with fixed windows of the model. That is, the first forecast is obtained with a sub-sample of fixed size n. The next period, the model is re-estimated by adding the next available observation and dropping the first observation used in the previous period, keeping the sub-sample with fixed size n.

We report the results for the Australian dollar as an example in Figure 3.1. The top two panels show the state-dependent estimates of the drift coefficient and of the standard error in equation (1). In state 1, the Australian dollar tends to appreciate against the US dollar (negative drift) and displays relatively low volatility. On the other hand, state 2 is characterized by depreciation (positive drift) and high volatility of the Australian dollar. The bottom panels show the filtered current-state probabilities and the next-period state probabilities. For most of the sample period, the Australian dollar has been on state 1.

Figure 3.1: An example of the Markov-switching estimation model for the AUD



Notes: Maximum likelihood rolling estimates for the Australian dollar against the US dollar. The size of the sub-sample in each estimation is 5 years. The estimations were done in Matlab using the EM algorithm of Hamilton (1990).

Trading rule from the Markov-switching model

Single crosses

A trading rule maps an information set to a binary variable, z_t, which takes the value +1 for a long position in the foreign exchange at time t and -1 for a short position. A natural approach in our case would be to go long the foreign currency if the expected appreciation derived from the Markov-switching model is enough to compensate for interest rate differentials, and go short otherwise. For currency pairs involving the USD, the strategy would be,

$$\begin{aligned} z_t &= +1 \quad if \quad \hat{e}_{t+\frac{1}{t}} - e_t < i_t^* - i_t \\ z_t &= -1 \quad if \quad \hat{e}_{t+\frac{1}{t}} - e_t \geq i_t^* - i_t \end{aligned} \tag{3.6}$$

where i_t^* is the one-period foreign (from the perspective of a US investor) interest rate, and i_t is the one-period US interest rate. As an example, an investor would borrow USD (paying the interest rate, i_t) and invest the proceeds in AUD (earning the interest rate, i_t^*) as long as the AUD is expected to appreciate against the USD (or depreciate by less than the interest rate differential).

One problem with such a trading rule is that it might generate large transaction costs by trading each time it predicts even a small net positive return. Following Dueker & Neely (2007), we require then that the expected return exceed a threshold filter before changing currency positions. We can also back out the interest rate differential for any currency pair from the current spot and the forward rate using covered interest parity,

$$i_t^* - i_t = f_t - e_t \tag{3.7}$$

where f_t is the one-period ahead (log) forward exchange rate.[21] Then, trading rules with threshold filters to avoid excessive trading can be described by the following set of equations,

$$\begin{array}{llll} if\ z_{t-1}=+1, & z_t=+1 & if & \hat{e}_{t+1|t} < f_t + x \\ & z_t=-1 & if & \hat{e}_{t+1|t} \geq f_t + x \\ if\ z_{t-1}=-1, & z_t=+1 & if & \hat{e}_{t+1|t} < f_t - x \\ & z_t=-1 & if & \hat{e}_{t+1|t} \geq f_t - x \end{array} \tag{3.8}$$

where x is the threshold filter that determines when a change in positions actually occurs.

Portfolios 3v3

For portfolios of G10 currencies, the approach involves sorting currencies by expected carry returns and then placing long positions in the three currencies with highest expected returns and short positions in the three currencies with lowest expected returns. A rolling Markov-switching model is estimated each period for each currency pair against the USD. The currencies are then sorted by expected *carry returns*, which are defined as follows,

$$E\left[r^i_{(t+1|t)}\right] = -\left(\hat{e}_{(t+1|t)} - e_t\right) + i^i_t - i_t \tag{3.9}$$

[21] There is an extensive literature showing that covered interest parity holds at almost all times. See for example Clinton (1988) and Taylor (1987).

where $E\left[r^i_{(t+1|t)}\right]$ is the expected carry return for currency *i* at time *t+1* conditional on information known at time *t*. The investment strategy proposed is similar to the standard carry trade. The difference is that while the standard carry trade implicitly assumes that expected exchange rate changes are zero, the Markov-switching strategy allows for expected changes in exchange rates over the investment period.

3.3.2. Exponentially weighted moving average model

As discussed in the introduction, several authors have provided evidence that carry trade returns are systematically correlated with exchange rate volatility. Clarida et al (2009) show that carry trade strategies generate persistent excess returns that unwind sharply when volatility increases. During periods of low volatility, high-interest rate currencies tend to appreciate, providing an additional source of profits to the carry trade. However, when volatility increases, high-interest currencies tend to depreciate sharply, significantly affecting carry trade returns. It is natural then to investigate the returns obtained from investment strategies that explicitly take into account exchange rate volatility.

The second model we investigate is based in using an exponential weighted moving average (EWMA) historical measure of volatility as the key deciding variable for trading currencies. In particular, the proposed strategy involves doing the standard carry trade when volatility is below some threshold level, and doing a "reverse" carry trade when volatility is above that threshold. Since high (low)-interest rate currencies tend to depreciate (appreciate) when volatility is high, taking a long position in low-yielding currencies and a short position in high-yielding currencies should improve returns. Of course, one needs to first forecast when volatility will be high to take the corresponding position in advance. Otherwise, by the time one switches from high-yielding to low-yielding currencies, substantial losses will have been incurred already.

We forecast next-period exchange rate volatility with an exponentially weighted moving average (EWMA) model. EWMA models allow more recent observations to have stronger impact on the forecast of volatility than older data points. This is an advantage over simple historical models, since volatility is in practice likely to be affected more by recent events that events further in the past. We can express the EWMA model for each currency as follows[22],

$$\sigma_t^2 = (1 - \lambda) \sum_{j=0}^{T} \lambda^j \left(e_{t-j} - \bar{e}\right)^2 \tag{3.10}$$

where σ_t^2 is the estimate of the variance of the currency for period *t*, $\bar{e}$ is the average (log) exchange rate change over the observations up to time *t*, and λ is the decay factor, which determines how much weight is given to recent versus older observations. We set the decay factor at 0.94, which implies a half-life in the exponential weights of about 14

[22] To simplify notation, we omit a country (or currency) subscript. We remind the reader that these statistics are computed independently for each currency pair against the USD.

days.[23] The forecast of next-period volatility is then the square-root of the estimate of the variance.

We then define high volatility episodes as all periods of time in which the EWMA estimate of volatility is one standard deviation above the historical mean, where both these statistics are also computed as exponentially weighted moving averages. That is,

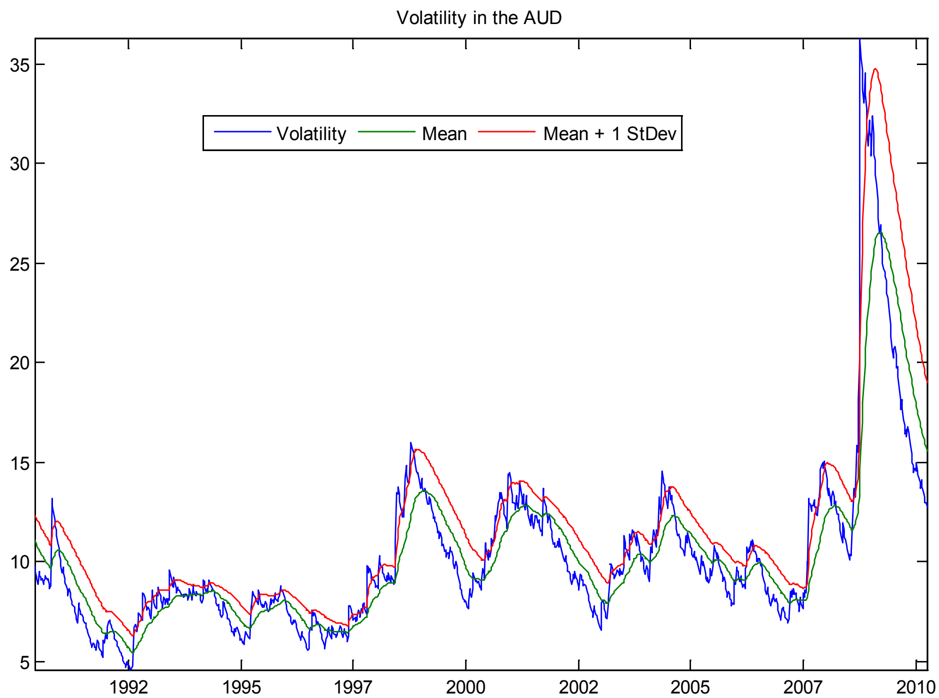
$$\begin{array}{llll} REGIME_t = 1 & if & \sigma_t^2 > \overline{\sigma_t^2} + sd(\sigma_t^2) \\ REGIME_t = 0 & if & otherwise \end{array} \tag{3.11}$$

where $REGIME_t$ is a dummy variable indicating high (*REGIME* = 1) and low (*REGIME* = 0) volatility regimes, and where the mean-volatility, $\overline{\sigma_t^2}$, and the standard deviation of volatility, $sd(\sigma_t^2)$, are also estimated with EWMA models.

We provide an example in Figure 3.2, where we estimate the volatility for the Australian dollar. The blue line is the EWMA estimate of the volatility in the AUD. The green line is the mean volatility plus one standard deviation. Both these statistics, the mean and standard deviation, are also exponentially-weighted moving averages. When volatility exceeds its mean plus one standard deviation (that is, when the blue line is above the red line), we are on a *high volatility* regime.[24]

[23] This is the value recommended by RiskMetrics, a firm specializing in risk management software. Also, in their construction of a volatility measure, Clarida et al (2009) set this value to 0.95.
[24] We use a one standard deviation threshold to ensure that only rare and significant upward jumps in volatility are considered. Otherwise, we would risk identifying to many false signals.

Figure 3.2. An example of EWMA Volatility for the AUD



Notes: Exponentially weighted moving average volatility for the Australian dollar. The decay factor is set to 0.94.The mean volatility and the standard deviation, are also exponentially weighted moving averages.

Trading rule from the EWMA volatility model

Single crosses

For each foreign currency against the USD, the EWMA trading strategy calls for a long position in the high-yielding currency and a short position in the low-yielding currency if the foreign exchange market is in the low volatility regime, as in the standard carry trade. However, when volatility is high, the opposite of the carry trade is done. A long position is taken in the low-yielding currency and a short position is taken in the high-yielding currency. Letting z_t be a binary variable which takes the value +1 for a long position in the foreign currency at time t and -1 for a short position, we have,

$$\begin{aligned}
&if\ REGIME_t = 0, \quad && z_t = +1 \quad && if \quad && f_t - e_t > 0 \\
& && z_t = -1 \quad && if \quad && f_t - e_t \le 0 \\
&if\ REGIME_t = 1, \quad && z_t = +1 \quad && if \quad && f_t - e_t < 0 \\
& && z_t = -1 \quad && if \quad && f_t - e_t \ge 0
\end{aligned} \tag{3.12}$$

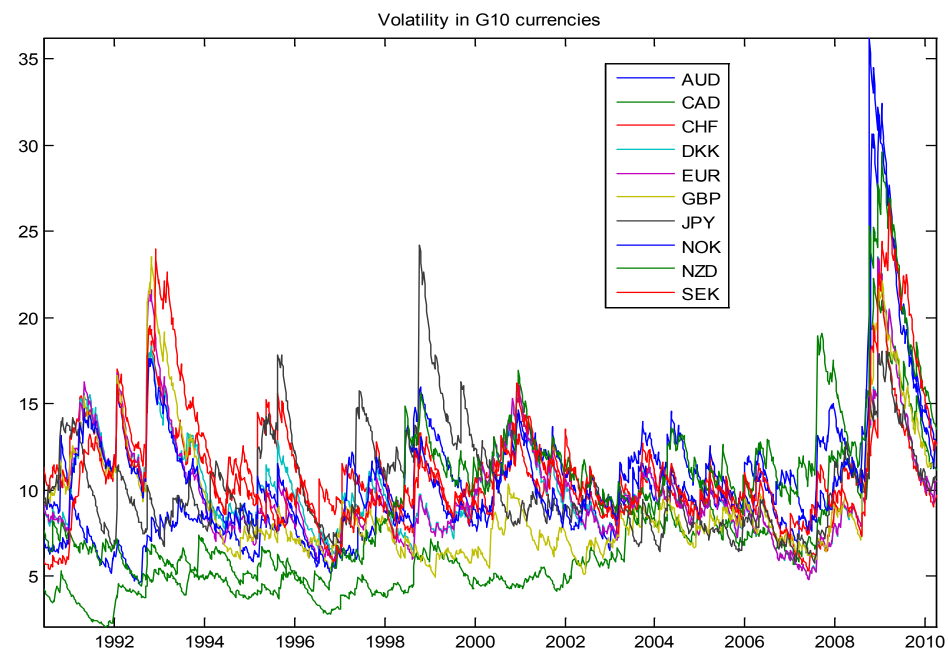
where again we have used covered interest parity to substitute the forward premium for the interest rate differential.

Portfolios 3v3

For portfolios consisting of several currencies, the strategy would call for an equal-weighted long position in the three highest-yielding currencies and an equal-weighted short position in the three lowest-yielding currencies when volatility is low, and the reverse when volatility is high. In order to do that, we first need to construct and overall volatility measure since the EWMA volatility measures computed above are currency-specific.

We proceed to construct an *overall volatility index* in a very straightforward manner. We simply take an equal-weighted average of the volatility indices of the 10 currencies. Although one might think that such an approach would waste a lot of information – by averaging currencies with perhaps different volatility regimes – it turns out that volatilities across currencies are highly correlated. Figure 3.3 plots the EWMA estimates of volatility for all G10 currencies over the last 20 years. Although some differences can be seen, they broadly all move in tandem.[25]

Figure 3.3. Volatility in the G10 currencies



Notes: Exponentially weighted moving average volatility for G10 currencies. The decay factor is set to 0.94.

The trading rule for portfolios 3v3 of currencies then uses the *overall volatility index* in order to determine the volatility regime, and the corresponding strategy. When

[25] We also computed all possible cross-correlations. They were all positive and the mean correlation coefficient was 0.60.

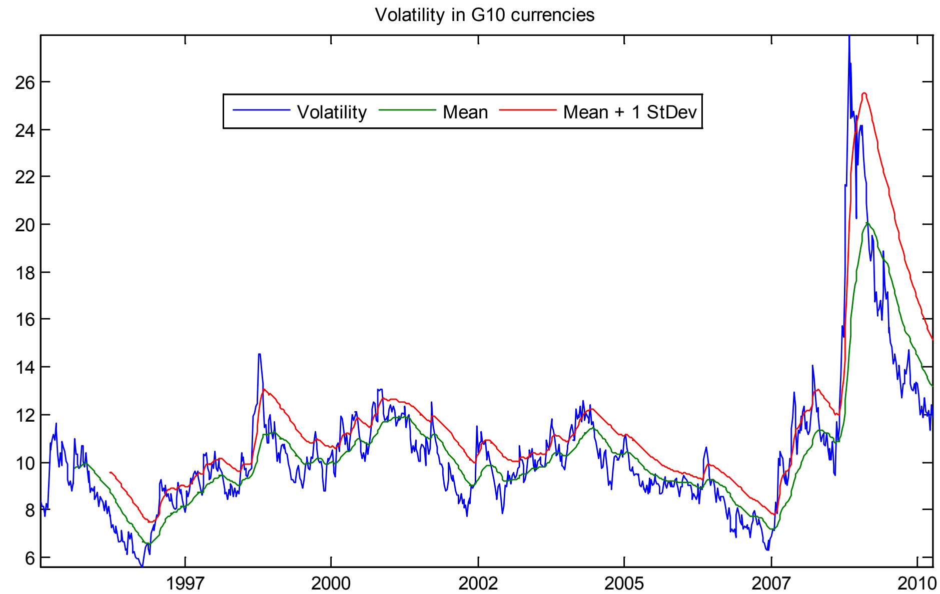
volatility is below the threshold (mean plus one standard deviation), a standard carry trade is followed. When volatility exceeds the threshold, the reverse carry trade is done.

3.3.3. Implied volatility model

The third model we test is based on implied volatility measures from currency options. Since currency options require a volatility estimate as an input, it is possible to back-out the volatility forecast over the lifetime of the option from option prices. One advantage of using option prices is that the implied volatility from option contracts is the market's forecast of the volatility of the underlying asset, the foreign exchange in our case. That is, these are *forward-looking* volatility measures, as opposed to the EWMA model of the previous section, which is based on past foreign exchange returns.

We use *implied volatility* measures from currency options to first identify the volatility regime (high or low) and then to generate trading rules, in the same manner as before. A regime of high volatility is in place when volatility is above its mean plus one standard deviation. In such an environment, a reverse carry trade is followed. When volatility is low, a standard carry trade is followed. Figure 3.4 plots the *overall volatility index* for G10 currencies derived from 1-month FX Options, along with the mean and standard deviation.

Figure 3.4. Implied Volatility in G10 currencies



Notes: Simple average implied volatility for G10 currencies. Mean and average are exponentially weighted with a decay factor of 0.94. When the volatility index (blue line) exceeds by one standard deviation the mean (red line) the forex market is considered to be in a High volatility state.

3.4 Data sample and sources

The data consists of weekly observations for spot exchange rates and 1-week forward rates for the G10 currencies: Australian dollar, Canadian dollar, Swiss franc, Danish krone, Euro, British pound, Japanese yen, Norwegian krone, New Zealand dollar and Swedish krone. The sample runs from May 30 of 1990 to March 31 of 2010, for a total of 1036 observations, and is obtained from *Thomson Reuters* via *Datastream*. As is customary when working with weekly data, we use closing quotes sampled every

Wednesday of every week. The advantage of using daily quotes sampled every Wednesday is that it minimizes irregularities due to holidays, which tend to be concentrated at the beginning or at the end of the week. Implied volatility measures are taken from 1-month FX Options, also from *Datastream*. Due to data availability, the sample for implied volatilities runs from January 11 of 1995 to March 31 of 2010. We use the 1-month US Treasury-bill Total Return Index as a proxy for the risk-free rate. For CAMP regressions, we use the Citigroup World Government Bond Index 7-10yr Total Return Index as our bond-market portfolio, and the MSCI World Total Return Index as our stock-market portfolio.

The Markov-switching model is estimated every week using the previous 5 years of data. Carry trade returns are calculated every week, assuming that covered interest parity holds. That is, the Markov-switching exchange rate change forecast over the next week is added to the forward premium. All returns are net of transaction costs, which we assume to be of 10 basis points per trade, which is on the conservative side.[26]

In what follows, results for two different currency portfolios are reported. The *3v3 Portfolio* is a portfolio that consists of equally-weighted long positions in three currencies financed with equally-weighted short positions in another three currencies. The currencies are selected according to expected returns for each model, as discussed earlier. We also construct and report results for a portfolio of currencies which we name *All G10*.

[26] See for example Dueker and Neely (2007) who also assume identical transaction costs. They argue that these are about twice the size that even a small trader could obtain today.

This portfolio consists of equally-weighted positions in all 10 single crosses against the US dollar.

3.5 Estimation results

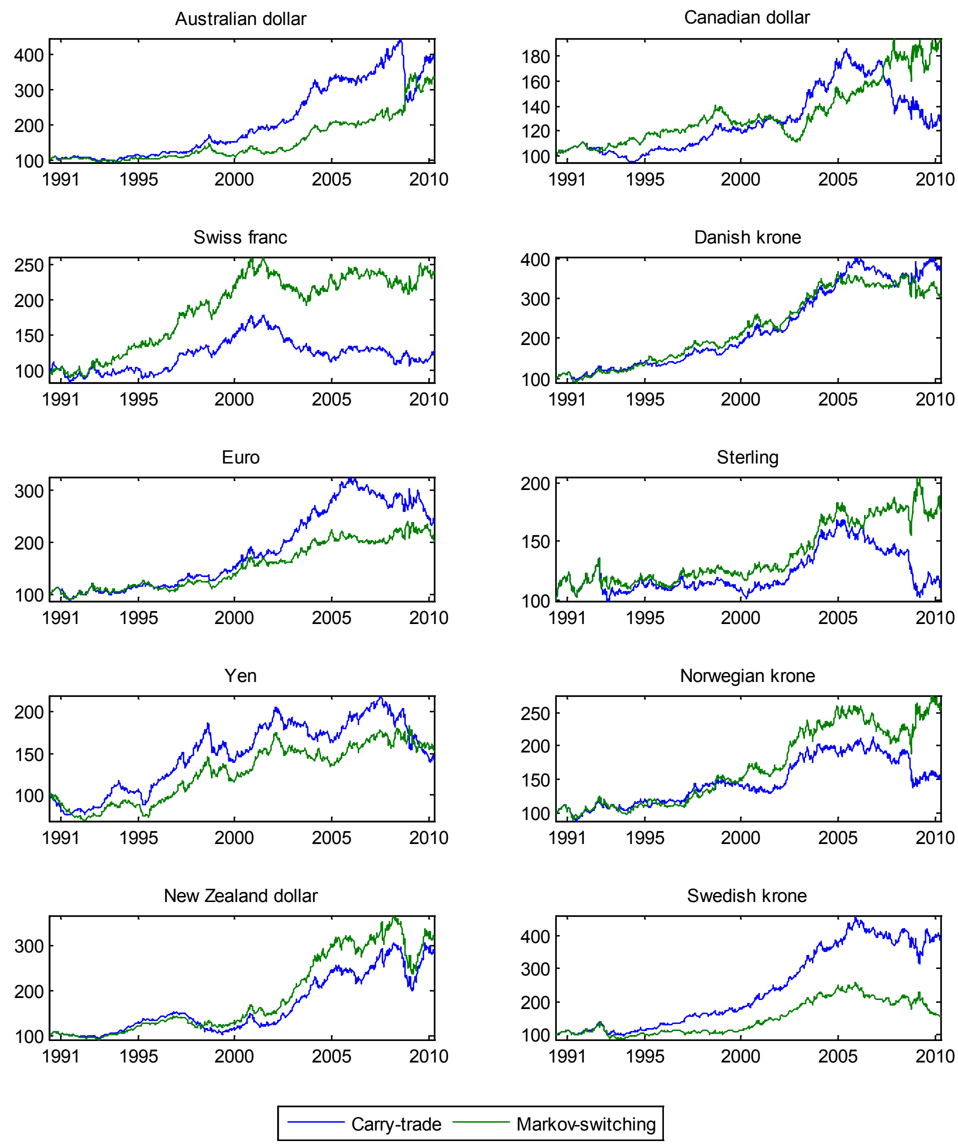
3.5.1. Cumulative returns: 1990-2010

We first study each model by plotting the cumulative returns that a dollar-based investor would have earned by following each strategy over the period May 1990 – March 2010.

Figure 3.5 plots the cumulative returns of following the Markov-switching strategy against the standard carry trade for all G10 single crosses against the USD. By this measure, the Markov model outperforms the carry trade for 6 currencies (CAD, CHF, GBP, JPY, NOK, NZD) and underperforms for the remaining 4 currencies (AUD, DKK, EUR, SEK). Figure 6 plots the cumulative returns of following the EWMA volatility model against the standard carry trade. Following the EWMA volatility model, higher returns would have been obtained over the sample period for 7 currencies (AUD, CAD, CHF, GBP, JPY, NZD, SEK). Lower cumulative returns would have been earned for 2 currencies (DKK, EUR), while virtually identical returns are obtained for the remaining currency (NOK).

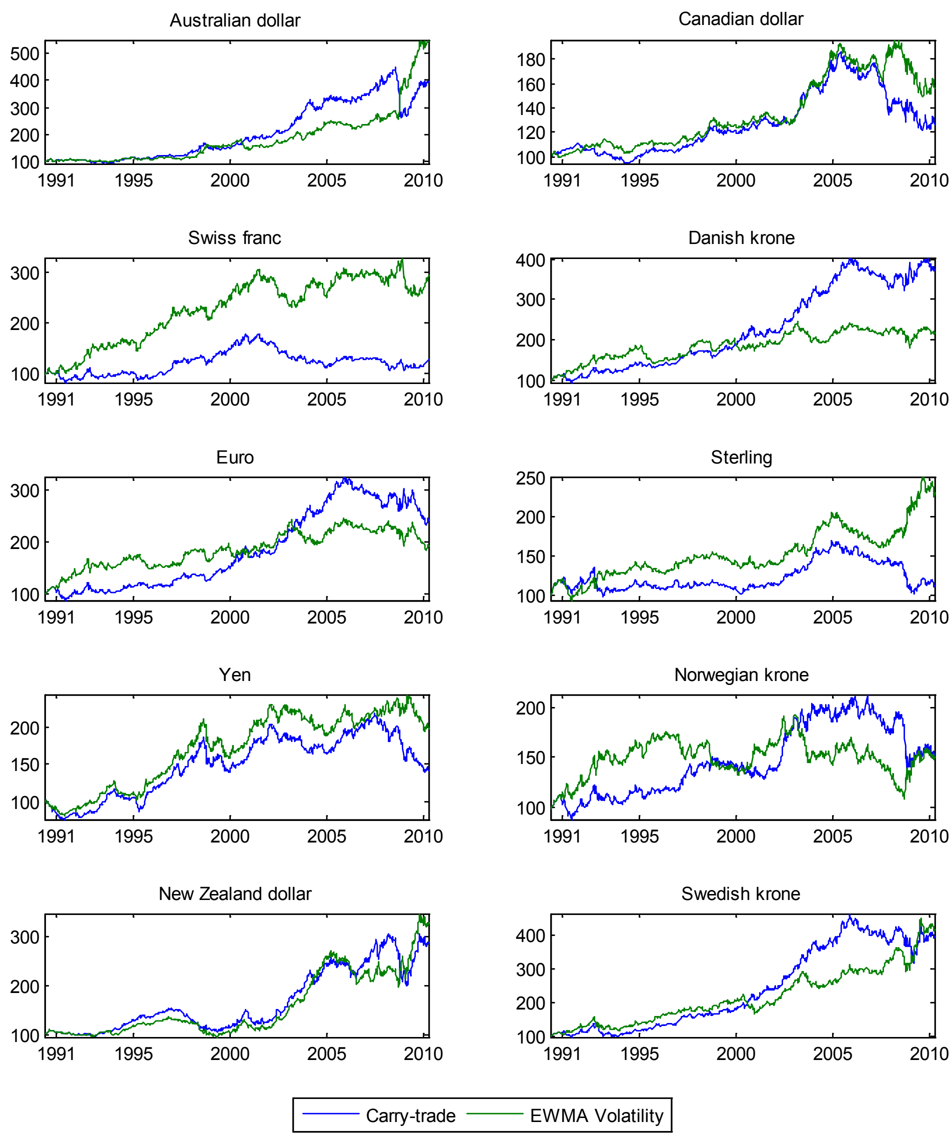
We also look at cumulative returns for portfolios 3v3 of currencies. These portfolios are formed by equal-weighted 3 long positions and 3 short positions. The standard carry trade takes a long position in the 3 highest-yielding currencies and a short position in the 3 lowest-yielding currencies. The Markov-switching model sorts all currencies by expected carry returns (taking into account estimated expected currency changes) and takes a long position in the 3 currencies with highest expected carry returns and a short position in the 3 currencies with lowest expected carry returns, as explained in section 3.3.2. Finally, the EWMA volatility model follows a standard carry trade strategy when volatility is below an estimated threshold and follows a reverse carry trade (long in low-yielding currencies, short in high yielding currencies) when volatility exceeds the estimated threshold, as explained in section 3.3.3.

Figure 3.5. Markov-switching model: Cumulative returns



Notes: Cumulative returns of the carry trade and Markov-switching strategies. The filter size for the Markov-strategy is set to 25bps. Transaction costs per trade are 10bps. The Markov-switching model was estimated recursively by Maximum likelihood using in each case the previous 5 years of data.

Figure 3.6. EWMA Volatility model: Cumulative returns



Notes: Cumulative returns of the carry trade and EWMA volatility strategies. The decay factor for the EWMA model is set to 0.94. Transaction costs per trade are 10bps. The EWMA strategy is based on exiting the carry trade and investing in a contrarian carry trade whenever volatility exceeds its mean plus one standard deviation.

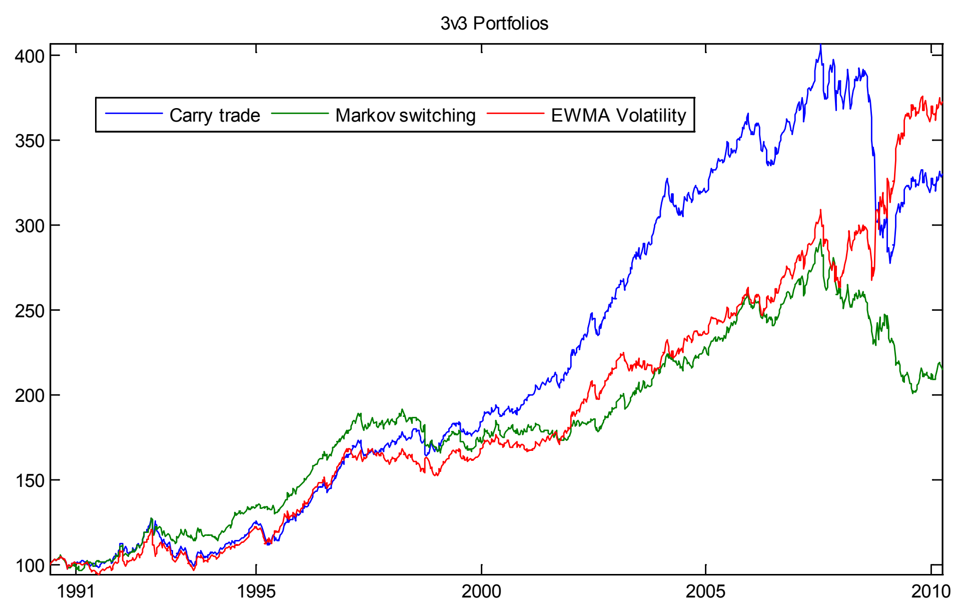
Figure 3.7 plots the cumulative returns for 3v3 portfolios for the three strategies. Over the entire sample period, the EWMA volatility model delivers the highest cumulative returns while the Markov-switching model the lowest. A key aspect that can be appreciated from the plot is how the three strategies perform during the recent global financial crises. This was a period of extreme volatility and high-yielding currencies tend to depreciate in such environment while low-yielding currencies tend to appreciate. This translates into large losses over this period for standard carry trade investors. Indeed, the AUD and NZD, two currencies that where consistently on the long-side of the carry trade, depreciated by 37 and 35 respectively, in the weeks after the Lehman collapse. Losses were also amplified by a 26 percent appreciation of the JPY, the historical funding currency of the carry trade for the last 20 years. On the other hand, a EWMA volatility investor would have earned significant profits over the financial crisis period. It would have suffered some losses at the very beginning of the crisis, as can be observed from Figure 3, but the model would have very quickly given a signal for exiting the carry trade and doing in fact the opposite, buying the JPY and selling short the AUD and the NZD.

There is a negative side to the EWMA volatility model. There can be period of times where *false signals* are given, that is, periods when volatility exceeds by one standard deviation its mean value, but with no major reversals to exchange rate paths. An investor would experience losses by switching from high-yielding currencies to low-yielding currencies, in the hope of a *flight-to-quality* that actually does not happen.

Nevertheless, this seems to be a price worth paying, given the high excess returns that are obtained when major currency reversals do indeed occur.

Finally, we find that the Markov-switching strategy performs poorly. Although it seems to be a somewhat successful strategy for single crosses against the USD (for 6 out of the 10 currencies it delivers superior returns than the standard carry trade) it does a poor job in correctly sorting the currencies for forming portfolios.

Figure 3.7. Currency Portfolios: Cumulative returns



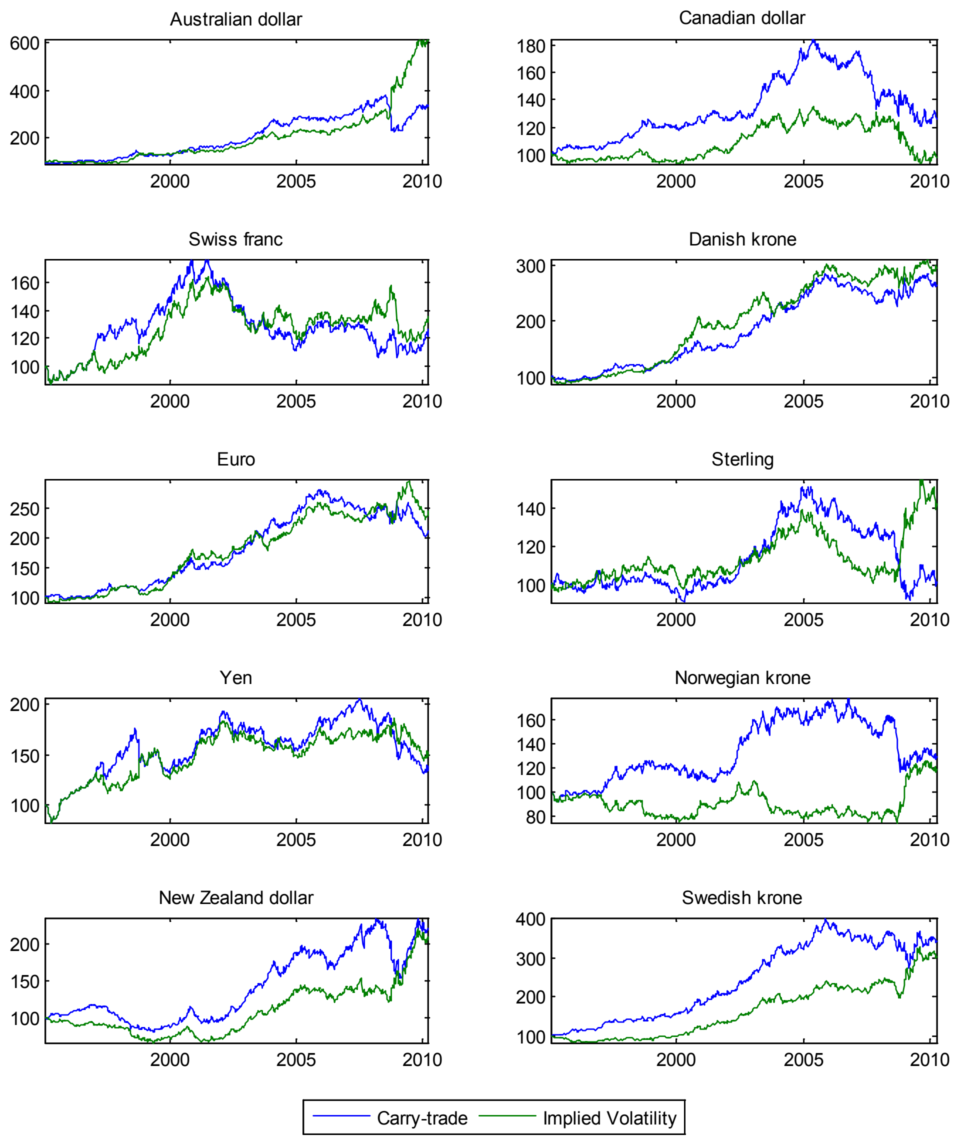
Notes: Cumulative returns for 3v3 portfolios for the three different strategies. The decay factor for the EWMA model is set to 0.94. The filter size for the Markov-strategy is set to 25bps. Transaction costs per trade are 10bps.

3.5.2. Cumulative returns: 1995-2010

As mentioned earlier, we only have data on implied volatility derived from FX options since January 1995 onwards, for a total of 795 observations. We therefore study the cumulative returns of the Implied Volatility model separately. Figure 3.8 plots the cumulative returns for the Implied Volatility-based model for all single crosses against the USD. The model outperforms the standard carry trade strategy in 6 cases (AUD, CHF, DKK, EUR, GBP, JPY) while it underperforms in 4 cases (CAD, NOK, NZD, SEK).

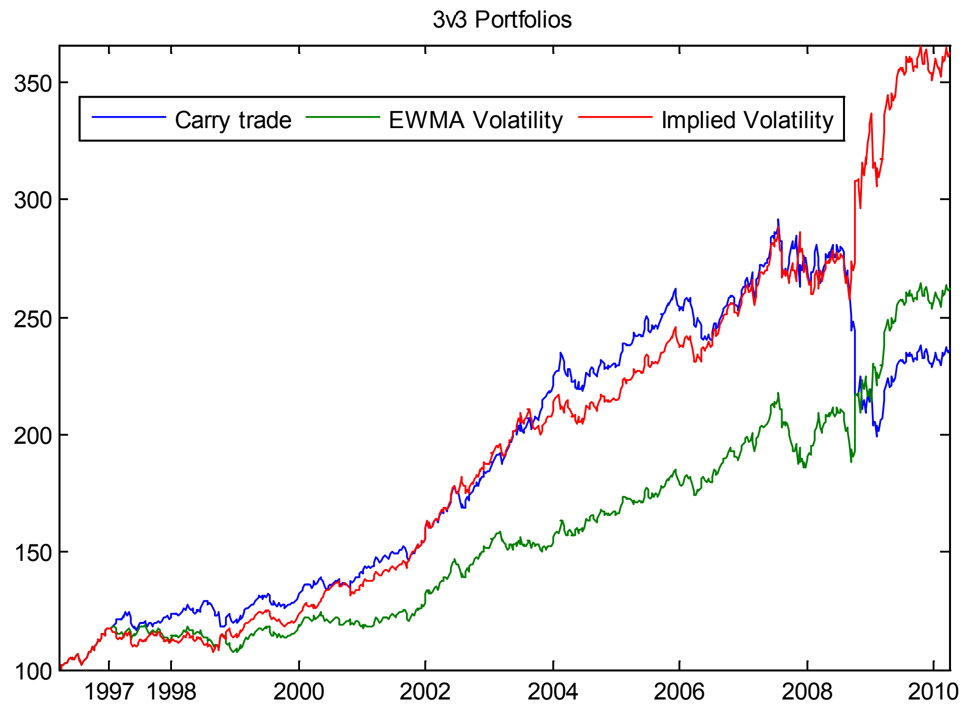
Cumulative returns on a portfolio 3v3 following the Implied Volatility model are shown in Figure 3.9. We can observe that the Implied Volatility model does significantly better than the standard carry trade and the EWMA volatility model for the sub-sample starting in 1995. The success of the Implied Volatility model can be almost fully explained buy its success in avoiding losses during the financial crises period of 2008. In fact, by exiting the carry trade and buying low-yield currencies and shorting high-yield currencies, the strategy is able to deliver superior returns over this period. A crucial aspect that can be appreciated from the plot is that the Implied Volatility model seems to be able to do well in high-volatility times, without sacrificing profits when volatility is low. Cumulative returns were very similar to those from the standard carry trade until the beginning of the financial crisis of 2008, a period characterized by mostly low and stable volatility levels.

Figure 3.8. Implied Volatility model: Cumulative returns



Notes: Cumulative returns of the carry trade and Implied Volatility strategies. The Implied Volatility model is based on 1-month FX Options. Transaction costs per trade are 10bps. The Implied Volatility strategy is based on exiting the carry trade and investing in a contrarian carry trade whenever volatility exceeds its mean plus one standard deviation

Figure 3.9. Currency Portfolios: Cumulative returns



Notes: Cumulative returns of the carry trade, the EWMA and Implied Volatility strategies. The Implied Volatility model is based on 1-month FX Options. Transaction costs per trade are 10bps. The Implied Volatility strategy is based on exiting the carry trade and investing in a contrarian carry trade whenever volatility exceeds its mean plus one standard deviation The first 63 observations are lost on the estimation of the mean and standard deviation.

Table 3.1 reports some summary statistics for FX volatility as estimated by each model. The average annualized volatility is around 10 percent for all currencies (the Canadian dollar being an exception, with lower volatility). Using our specified threshold of one standard deviation above the mean for identifying high-volatility states, each currency spends between 15-20 percent of the time on high-volatility states. This allows us to have an objective criteria that does not identify high-volatility states too often nor too sporadically.

Table 3.1: Summary statistics: FX Volatility

	EWMA volatility model			Implied volatility model		
Currency	*Mean*	*StDev*	*Frequency*	*Mean*	*StDev*	*Frequency*
AUD	10.3	4.7	17.6	11.4	4.5	18.6
CAD	5.8	3.2	19.1	8.0	3.6	16.6
CHF	11.4	2.6	17.0	10.9	2.4	15.6
DKK	10.4	2.7	18.9	10.3	2.8	17.7
EUR	10.2	2.8	18.6	9.9	3.0	16.9
GBP	9.9	3.5	16.0	9.0	3.0	16.9
JPY	10.4	2.8	15.6	11.4	3.5	14.5
NOK	10.3	3.5	18.9	10.8	3.4	17.2
NZD	10.8	5.2	19.1	11.7	4.7	19.1
SEK	10.4	3.7	15.1	10.9	3.5	12.6
G10 index	10.0	3.0	18.1	10.4	3.0	16.4

Note: Summary statistics based on the sub-sample 1995-2010. Mean and StDev are the mean and standard deviation for annualized volatility estimates from each model. Frequency is the frequency the given currency is declared to be in a High-Volatility state. The G10 index refers to the overall index as defined in the text. All statistics are in percentage points.

3.5.3. Sharpe ratios

We provide here some evidence on risk-adjusted returns of the different strategies. Table 3.2 reports the mean annualized return, standard deviation, number of average trades per year, the fraction of weeks that the strategy is long a particular currency and Sharpe ratios for all three strategies over the period 1990-2010. Table 3.3 reports the same statistics for the sample 1995-2010, which includes the Implied Volatility model. We also include, for comparison purposes, statistics for a benchmark bond portfolio and a benchmark stock portfolio. The bond portfolio is the *Citigroup US Government Bond 7-10yr Index* and the stock portfolio is the *Morgan Stanley Capital International World Index*. Sharpe ratios for these two portfolios are calculated with the 1-month US Treasury Bill as the risk-free rate. Sharpe ratios for currency portfolios are calculated as the average return over the standard deviation of returns. No risk-free rate is used for currency portfolios, since these are zero net investments that already account for the opportunity cost by borrowing funds in the currencies being shorted.[27]

Sharpe ratios for the *3v3 Portfolio* are in all cases, and significantly, higher than Sharpe ratios for the bond and stock portfolio. With respect to the stock portfolio, the higher Sharpe ratios of the currency portfolios are the result of significantly lower standard deviations. With respect to the bond portfolio, the higher Sharpe ratios of the currency portfolio are due to higher excess-returns with only slightly higher standard deviations. We also point out that the bond portfolio has a higher Sharpe ratio than the

[27] Sharpe ratios measure the excess returns that an investor earns, per unit of risk. The excess return for a bond or stock portfolio is the return above the risk-free rate. Returns for currency portfolios, are already excess returns, since the opportunity cost is taken into account in the short positions.

stock portfolio. This is just a confirmation of the overall underperformance of equity markets in the last 10-15 years. The superior Sharpe ratios associated to currency investing over bond and stock investing is a well known result that has been reported by, among others, Menkhoff et al (2009), Burnside et al (2006 and 2008), and Hochradl and Wagner (2010). Our contribution here is to show that the results still holds when one includes the recent global financial crisis, a period that was not included in the cited articles.

What about our proposed currency strategies? We can observe from Table 3.2 that the Markov-switching strategy is not particularly successful. It delivers a lower Sharpe ratio than the standard carry trade (0.48 vs. 0.68) although still higher than that of the bond portfolio (0.32) and that of the stock portfolio (0.23). On the other hand, the EWMA Volatility strategy is an improvement over the carry trade, with a Sharpe ratio of 0.75. This is due to a higher excess return with the same volatility.

Table 3.3, which includes the Implied Volatility model, shows our main result, the exceptionally profitability of the Implied Volatility strategy. Its Sharpe ratio (1.08) is higher than that of the EWMA Volatility strategy (0.80), the carry trade (0.72), the bond portfolio (0.24) and the stock portfolio (0.12). Excess returns of this trading strategy are well above of the rest portfolios and its standard deviation is only about 1 percent higher than that of the bond portfolio.

Table 3.2: Return statistics and Sharpe ratios, 1990-2010

	Currency										Portfolio		
	AUD	CAD	CHF	DKK	EUR	GBP	JPY	NOK	NZD	SEK	3v3	Bonds	Stocks
Panel A: Standard carry-trade													
Return	6.87	1.18	1.22	6.63	4.42	0.62	1.75	2.15	5.30	6.86	5.99	6.46	8.00
Volatility	11.34	7.54	11.13	10.50	10.43	9.88	10.72	11.68	11.23	11.78	8.77	7.23	16.60
Trades	1.75	3.36	2.15	1.35	2.15	4.06	2.61	2.15	0.85	1.95	50.94	-	-
% Long	80.69	57.52	22.00	54.24	52.60	82.72	15.15	63.70	87.93	56.66	-	-	-
Sharpe	0.61	0.16	0.11	0.63	0.42	0.06	0.16	0.18	0.47	0.58	0.68	0.32	0.23
Panel B: Markov-switching trading strategy													
Return	6.04	3.30	4.38	5.61	3.54	2.82	2.12	4.77	5.82	2.29	3.84	6.46	8.00
Volatility	11.35	7.54	11.14	10.53	10.45	9.89	10.73	11.68	11.25	11.84	7.93	7.23	16.60
Trades	8.78	6.47	5.47	5.37	5.47	4.16	5.22	6.07	3.56	4.96	131.00	-	-
% Long	69.98	54.34	39.19	53.18	48.45	79.63	27.41	64.28	80.50	55.79	-	-	-
Sharpe	0.53	0.44	0.39	0.53	0.34	0.29	0.20	0.41	0.52	0.19	0.48	0.32	0.23
Panel C: EWMA Volatility trading strategy													
Return	8.49	2.22	5.38	3.87	3.26	4.18	3.45	2.04	5.96	7.16	6.60	6.46	8.00
Volatility	11.33	7.53	11.11	10.54	10.44	9.87	10.71	11.69	11.24	11.79	8.78	7.23	16.60
Trades	5.77	7.47	6.47	5.37	5.87	7.47	5.62	5.57	5.16	5.77	72.77	-	-
% Long	75.48	50.48	31.37	53.86	53.18	73.16	27.12	57.72	76.44	55.88	-	-	-
Sharpe	0.75	0.29	0.48	0.37	0.31	0.42	0.32	0.17	0.53	0.61	0.75	0.32	0.23

Notes: The rows show the annualized return, net of transaction costs, in percentage points, the annualized volatility of returns, the average number of trades per year, the percentage of weeks the trading rule was long in the foreign currency and the Sharpe ratio. The 3v3 Portfolio is a currency portfolio composed of equally-weighted long positions on three currencies financed with equally-weighted short positions on other three currencies, according to the trading strategies as explained in the text. The Bond Portfolio corresponds to the Citigroup US Government Bond 7-10yr index. The Stock Portfolio corresponds to the Morgan Stanley Capital International World index. Sharpe ratios for the Bond Portfolio and Stock Portfolio are calculated using the 1-month US Treasury Bill as the risk-free rate. Sharpe ratios for all currencies and the 3v3 Portfolio are calculated as the ratio of the mean return to volatility, since these are zero net investment strategies.

Table 3.3: Return statistics and Sharpe ratios, 1995-2010

	Currency										Portfolio		
	AUD	CAD	CHF	DKK	EUR	GBP	JPY	NOK	NZD	SEK	3v3	Bonds	Stocks
Panel A: Standard carry-trade													
Return	8.46	1.31	1.97	7.16	5.19	0.28	1.30	1.92	4.94	7.72	6.10	5.60	6.05
Volatility	12.55	8.52	10.42	10.02	10.00	9.09	10.77	11.98	12.79	11.43	8.52	7.47	18.16
Trades	1.45	3.06	1.70	1.15	2.05	3.71	1.40	1.90	0.35	1.95	45.96	-	-
% Long	57.81	35.23	2.31	31.46	29.44	60.13	1.93	40.83	65.15	33.39	-	-	-
Sharpe	0.67	0.15	0.19	0.71	0.52	0.03	0.12	0.16	0.39	0.68	0.72	0.24	0.12
Panel B: EWMA Volatility trading strategy													
Return	11.09	2.40	3.24	2.74	1.59	4.09	2.96	-0.85	6.65	6.72	6.84	5.60	6.05
Volatility	12.51	8.51	10.42	10.07	10.03	9.08	10.77	11.99	12.79	11.45	8.52	7.47	18.16
Trades	4.36	6.17	5.62	4.76	5.57	6.52	3.81	5.01	4.26	5.27	71.81	-	-
% Long	55.30	31.37	14.76	34.36	33.30	53.66	13.70	37.93	55.11	36.87	-	-	-
Sharpe	0.89	0.28	0.31	0.27	0.16	0.45	0.27	-0.07	0.52	0.59	0.80	0.24	0.12
Panel C: Implied Volatility trading strategy													
Return	13.03	0.09	2.50	8.15	6.37	2.36	1.99	1.52	5.85	8.82	9.14	5.60	6.05
Volatility	12.47	8.53	10.42	10.01	9.98	9.08	10.79	11.98	12.81	11.42	8.49	7.47	18.16
Trades	5.01	5.82	6.12	4.81	5.92	6.92	5.72	4.71	4.81	4.81	75.37	-	-
% Long	49.90	29.82	12.93	31.17	30.30	48.55	12.16	34.36	50.86	29.72	-	-	-
Sharpe	1.04	0.01	0.24	0.81	0.64	0.26	0.18	0.13	0.46	0.77	1.08	0.24	0.12

Notes: The rows show the annualized return, net of transaction costs, in percentage points, the annualized volatility of returns, the average number of trades per year, the percentage of weeks the trading rule was long in the foreign currency and the Sharpe ratio. The 3v3 Portfolio is a currency portfolio composed of equally-weighted long positions on three currencies financed with equally-weighted short positions on other three currencies, according to the trading strategies as explained in the text. The Bond Portfolio corresponds to the Citigroup US Government Bond 7-10yr index. The Stock Portfolio corresponds to the Morgan Stanley Capital International World index. Sharpe ratios for the Bond Portfolio and Stock Portfolio are calculated using the 1-month US Treasury Bill as the risk-free rate. Sharpe ratios for all currencies and the 3v3 Portfolio are calculated as the ratio of the mean return to volatility, since these are zero net investment strategies.

3.5.4. CAPM regressions

We investigate in this section if excess returns from currency portfolios are just a compensation for additional risk. A risk premium is a covariance with a stochastic discount factor which, in general, can be specified as the return on a market portfolio. We therefore focus on the risk premium as specified by the standard CAPM, using the bond and stock portfolio described earlier as the market portfolio. Specifically, we run the following regressions,

$$r_{fx} = \alpha + \beta(r_m - r) + \varepsilon \tag{3.13}$$

where r_{fx} is the excess return on the currency portfolio, r_m is the return on the market portfolio and r is the risk-free rate. We run regressions for all individual currencies and for the *3v3 portfolio*, for all different strategies. In one set of regressions, the bond portfolio is used as the market portfolio, whereas in another set of regressions, the stock portfolio is used as the market portfolio.

Results from CAMP regressions are reported in Table 3.4 (for the 1990-2010 sample period) and in Table 3.5 (for the 1995-2010 sample period). If we assume that the average investor is risk-averse, then a negative beta is a desirable property of any portfolio. A negative beta implies that the currency portfolio delivers higher payoffs when the market portfolio is performing poorly (ie. when marginal utility is higher) and vice versa. If we consider the bond portfolio as the market portfolio, we see from Tables 3.4 and 3.5 that in most cases the associated betas are not statistically different from zero. The standard errors of the beta estimates are quite large. When we consider the stock portfolio as the market portfolio, the assumption of the original CAPM model, we see that the standard carry trade strategy (for the *3v3 portfolio)* is positively correlated with the market portfolio, an undesirable property. For the 1990-2010 sample, the beta-estimate is 0.156 with a standard error of 0.015, while for the 1995-2010 sample, the beta-estimate is 0.181 with a standard error of 0.015. On the other hand, the three currency strategies we analyze produce beta-estimates that are not statistically different from zero. The pattern for individual currencies against the US dollar is similar. For most currencies, our proposed strategies reduce the positive correlation of currency returns with stock returns, a desirable property.

Table 3.4: CAPM regressions, 1990-2010

	Currency										Portfolio
	AUD	CAD	CHF	DKK	EUR	GBP	JPY	NOK	NZD	SEK	3v3
Panel A: Standard carry-trade											
$\alpha_{CAPM,Bonds}$	6.769	1.113	1.486	6.200	4.004	0.292	2.128	1.865	5.243	6.586	6.097
SE(α)	2.543	1.691	2.489	2.337	2.321	2.204	2.389	2.613	2.519	2.636	1.965
$\beta_{CAPM,Bonds}$	0.045	0.031	-0.117	0.188	0.180	0.144	-0.165	0.124	0.025	0.117	-0.048
SE(β)	0.048	0.032	0.047	0.044	0.044	0.042	0.045	0.050	0.048	0.050	0.037
R-sq	0.001	0.001	0.006	0.016	0.015	0.011	0.012	0.006	0.000	0.005	0.002
$\alpha_{CAPM,Stocks}$	6.090	1.235	0.915	6.489	4.306	0.606	1.435	1.866	4.634	6.730	5.386
SE(α)	2.426	1.690	2.478	2.351	2.336	2.215	2.383	2.605	2.433	2.639	1.877
$\beta_{CAPM,Stocks}$	0.204	-0.013	0.079	0.037	0.029	0.004	0.081	0.074	0.174	0.032	0.156
SE(β)	0.020	0.014	0.020	0.019	0.019	0.018	0.019	0.021	0.020	0.022	0.015
R-sq	0.089	0.001	0.013	0.004	0.002	0.000	0.016	0.011	0.066	0.002	0.088
Panel B: Markov-switching trading strategy											
$\alpha_{CAPM,Bonds}$	5.816	3.283	4.282	5.518	3.493	2.426	2.101	4.196	5.773	2.195	3.857
SE(α)	2.541	1.691	2.497	2.361	2.344	2.202	2.407	2.590	2.522	2.655	1.778
$\beta_{CAPM,Bonds}$	0.098	0.008	0.041	0.040	0.021	0.171	0.007	0.248	0.021	0.039	-0.005
SE(β)	0.048	0.032	0.048	0.045	0.045	0.042	0.046	0.049	0.048	0.051	0.034
R-sq	0.004	0.000	0.001	0.001	0.000	0.016	0.000	0.024	0.000	0.001	0.000
$\alpha_{CAPM,Stocks}$	6.146	3.553	4.080	5.668	3.668	3.178	1.978	4.979	5.208	2.625	3.763
SE(α)	2.542	1.673	2.480	2.360	2.340	2.191	2.402	2.611	2.450	2.634	1.776
$\beta_{CAPM,Stocks}$	-0.027	-0.065	0.077	-0.015	-0.032	-0.093	0.036	-0.055	0.160	-0.088	0.020
SE(β)	0.021	0.013	0.020	0.019	0.019	0.018	0.020	0.021	0.020	0.022	0.014
R-sq	0.002	0.020	0.013	0.001	0.003	0.025	0.003	0.006	0.056	0.016	0.002
Panel C: EWMA Volatility trading strategy											
$\alpha_{CAPM,Bonds}$	8.592	2.238	5.579	3.807	3.280	3.927	3.555	1.759	5.992	6.923	6.563

SE(α)	2.540	1.690	2.489	2.364	2.342	2.208	2.401	2.614	2.521	2.639	1.969
$\beta_{CAPM,Bonds}$	-0.043	-0.008	-0.085	0.027	-0.007	0.110	-0.047	0.124	-0.150	0.101	0.015
SE(β)	0.048	0.032	0.047	0.045	0.045	0.042	0.046	0.050	0.048	0.050	0.037
R-sq	0.001	0.000	0.003	0.000	0.000	0.007	0.001	0.006	0.000	0.004	0.000
$\alpha_{CAPM,Stocks}$	8.505	2.415	5.298	3.973	3.394	4.330	3.258	2.104	5.946	7.213	6.666
SE(α)	2.540	1.678	2.490	2.361	2.338	2.209	2.395	2.620	2.519	2.642	1.967
$\beta_{CAPM,Stocks}$	-0.003	-0.051	0.022	-0.026	-0.034	-0.039	0.048	-0.015	0.002	-0.015	-0.017
SE(β)	0.021	0.014	0.020	0.019	0.019	0.018	0.020	0.021	0.021	0.022	0.016
R-sq	0.000	0.013	0.001	0.002	0.003	0.004	0.006	0.001	0.000	0.001	0.001

Notes: The rows show the CAPM betas, standard errors and R-squared of CAPM regressions using the Citigroup US Government Bond 7-10yr index (Bonds) and the Morgan Stanley Capital International World index (Stocks) as the market portfolio. Excess returns are calculated using the 1-month US Treasury Bill Total Return Index as the risk-free rate. Currency returns are already excess returns, since they represent zero net investments.

Table 3.5: CAPM regressions, 1995-2010

	Currency										Portfolio
	AUD	CAD	CHF	DKK	EUR	GBP	JPY	NOK	NZD	SEK	3v3
Panel A: Standard carry-trade											
$\alpha_{CAPM,Bonds}$	8.355	1.277	2.536	6.957	4.991	0.154	1.817	1.867	4.913	7.598	6.337
SE(α)	3.344	2.272	2.708	2.662	2.656	2.419	2.816	3.194	3.411	3.045	2.255
$\beta_{CAPM,Bonds}$	0.056	0.018	-0.309	0.113	0.109	0.071	-0.283	0.031	0.013	0.069	-0.133
SE(β)	0.062	0.042	0.050	0.049	0.049	0.045	0.052	0.059	0.063	0.056	0.041
R-sq	0.001	0.000	0.049	0.007	0.007	0.004	0.039	0.000	0.000	0.002	0.014
$\alpha_{CAPM,Stocks}$	7.906	1.347	1.770	7.075	5.123	0.274	1.118	1.753	4.476	7.616	5.683
SE(α)	3.130	2.270	2.742	2.663	2.660	2.422	2.843	3.172	3.264	3.038	2.093
$\beta_{CAPM,Stocks}$	0.243	-0.016	0.089	0.038	0.029	0.004	0.080	0.075	0.203	0.047	0.181
SE(β)	0.023	0.017	0.020	0.020	0.020	0.018	0.021	0.024	0.024	0.023	0.015
R-sq	0.124	0.001	0.024	0.005	0.003	0.000	0.019	0.013	0.084	0.006	0.150
Panel B: EWMA Volatility trading strategy											
$\alpha_{CAPM,Bonds}$	11.177	2.410	3.553	2.373	1.666	3.872	3.153	-1.041	6.723	6.498	6.870
SE(α)	3.335	2.270	2.757	2.684	2.672	2.409	2.865	3.191	3.410	3.043	2.271
$\beta_{CAPM,Bonds}$	-0.047	-0.008	-0.171	0.000	-0.041	0.117	-0.109	0.103	-0.039	0.121	-0.160
SE(β)	0.062	0.042	0.051	0.049	0.049	0.044	0.053	0.059	0.063	0.056	0.042
R-sq	0.001	0.000	0.015	0.000	0.001	0.009	0.006	0.004	0.001	0.006	0.000
$\alpha_{CAPM,Stocks}$	11.085	2.521	3.154	2.781	1.644	4.158	2.832	-0.823	6.648	6.730	6.898

SE(α)	3.335	2.253	2.770	2.681	2.669	2.415	2.860	3.195	3.409	3.051	2.267
$\beta_{CAPM,Stocks}$	0.002	-0.055	0.038	-0.018	-0.023	-0.031	0.054	-0.013	0.001	-0.004	-0.025
SE(β)	0.025	0.017	0.021	0.020	0.020	0.018	0.021	0.024	0.026	0.023	0.017
R-sq	0.000	0.014	0.005	0.001	0.002	0.004	0.008	0.000	0.000	0.000	0.003
Panel C: Implied Volatility trading strategy											
$\alpha_{CAPM,Bonds}$	13.031	0.119	2.817	7.943	6.202	2.187	2.341	1.134	5.796	8.534	9.155
SE(α)	3.326	2.273	2.757	2.659	2.654	2.415	2.851	3.167	3.414	3.028	2.262
$\beta_{CAPM,Bonds}$	-0.001	-0.015	-0.173	0.111	0.089	0.094	-0.195	0.210	0.028	0.158	-0.007
SE(β)	0.061	0.042	0.051	0.049	0.049	0.044	0.053	0.058	0.063	0.056	0.042
R-sq	0.000	0.000	0.016	0.007	0.005	0.006	0.018	0.017	0.000	0.011	0.000
$\alpha_{CAPM,Stocks}$	13.036	0.099	2.474	8.138	6.403	2.417	1.996	1.519	5.758	8.826	9.212
SE(α)	3.325	2.272	2.777	2.667	2.658	2.418	2.876	3.193	3.408	3.043	2.256
$\beta_{CAPM,Stocks}$	-0.003	-0.003	0.011	0.003	-0.016	-0.026	-0.004	-0.001	0.039	-0.001	-0.031
SE(β)	0.025	0.017	0.021	0.020	0.020	0.018	0.021	0.024	0.026	0.023	0.017
R-sq	0.000	0.000	0.000	0.000	0.001	0.003	0.000	0.000	0.003	0.000	0.005

Notes: The rows show the CAPM betas, standard errors and R-squared of CAPM regressions using the Citigroup US Government Bond 7-10yr index (Bonds) and the Morgan Stanley Capital International World index (Stocks) as the market portfolio. Excess returns are calculated using the 1-month US Treasury Bill Total Return Index as the risk-free rate. Currency returns are already excess returns, since they represent zero net investments.

3.6 Conclusions

The main conclusion of this paper is that currency trading strategies that incorporate volatility can be designed to deliver improved risk-adjusted returns relative to the standard carry trade. Using data of G10 currencies for the last two decades, we find that currency portfolios that follow the carry trade when volatility is low, but do the opposite (ie. long positions in low-yielding currencies and short positions in high-yielding currencies) when volatility is high, provide better cumulative and risk-adjusted returns than the benchmark carry trade. Moreover, trading strategies that use a forward-looking measure of volatility, like implied volatility derived from FX options, are superior to strategies that use a backward-looking estimate volatility measure, like the exponentially-weighted moving average model. We also find that a trading strategy based on two-state Markov-switching forecasts is able to beat the standard carry trade but only for a subset of individual currencies against the United States dollar, and it fails to generate higher returns for currency portfolios.

An additional contribution of our work is to show that the superior risk-adjusted returns of currency investing, as measured by the Sharpe ratio, over bond and stock portfolios is robust to the inclusion of the recent global financial crisis. Previous work showed that carry trade returns unwind sharply when volatility increases, and the period surrounding the Lehman collapse was no exception. But Sharpe ratios associated with the carry trade are still significantly higher than those associated with equity markets (which suffered significant losses during the financial crisis) and bond markets (which did not). Two of the three currency trading strategies we investigate actually improve the risk-adjusted returns profile by, on average, successfully exiting the carry trade during high volatility times.

Bibliography

Agénor, P., Montiel, P. (1999). *Development Macroeconomics*, Second Edition, Princeton University Press.

Aguiar, M., Gopinath, G., (2006). "Defaultable debt, interest rates and the current account." *Journal of International Economics* 69: 64-83.

Alesina, A., Wagner, A. (2006). "Choosing (and Reneging on) Exchange Rate Regimes." *Journal of the European Economic Association* 4: 770-799.

Arellano, C., (2008). "Default risk and income fluctuations in emerging economies." *American Economic Review* (forthcoming).

Arellano, M., (1989). "A note on the Anderson-Hsiao estimator for panel data." *Economics Letters* 31: 337-341.

Arellano, M., Bond, S. (1991). "Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations." *Review of Economic Studies* 58: 277-297.

Backus, D., Kehoe, P., (1992). "International evidence on the historical properties of business cycles." *American Economic Review* 82: 864-888.

Backus, D., Kehoe, P., Kydland, F., (1992). "International real business cycles." *Journal of Political Economy* 101: 745-775.

Brunnermeier, M., Nagel, S., Pedersen, L. (2008). "Carry Trades and Currency Crashes," *NBER Macroeconomics Annual, 2008*.

Burnside, A. C., Eichenbaum, M. S., Kleshchelski, I., Rebelo, S. (2008). "The Returns to Currency Speculation," *NBER Working Paper* 12489.

Burnside, A. C., Eichenbaum, M. S., Kleshchelski, I., Rebelo, S. (2008). "Do Peso Problems Explain the Returns to the Carry Trade?" *NBER Working Paper* 14054.

Calvo, G., Leiderman, L., Reinhart, C. (1993). "Capital inflows and real exchange appreciation in Latin America: the role of external factors." *IMF Staff Papers* 40: 108-151.

Calvo, G., Leiderman, L., Reinhart, C. (1996). "Inflows of capital to developing countries in the 1990's." *Journal of Economic Perspectives* 10: 123-139.

Calvo, G., Reinhart, C. (2002). "Fear of Floating." *The Quarterly Journal of Economics* 117: 379-408.

Calvo, G., Végh, C. (1994). "Inflation stabilization and nominal anchors." *Contemporary Economic Policy* 12: 35-45.

Calvo, G., Végh, C. (1999). "Inflation stabilization and BOP crises in developing countries." *NBER Working Paper No. 6925* [Published in Handbook of Macroeconomics, Volume 1C (North-Holland, 1999), edited by J. Taylor and M. Woodford].

Clarida, R., Davis, J., Pedersen, N. (2009). "Currency Carry Trade Regimes: Beyond the Fama Regression," *Journal of International Money and Finance*, 28, 1375-1389.

Clarida, R., Sarno, L., Taylor, M. P., Valente, G. (2003). "The Out-of-Sample Success of Term Structure Models as Exchange Rate Predictors: A Step Beyond," *Journal of International Economics*, 60, 61-83.

Clinton, K. (1988). "Transaction Costs and Covered Interest Arbitrage: Theory and Evidence," *Journal of Political Economy*, 96, 358-370.

Correia, I., Neves, J., Rebelo, S., (1995). "Business cycles in a small open economy." *European Economic Review* 39: 1089-1113.

DeBock, R., (2008). "Imported capital goods and emerging economy business cycles." Working Paper.

De Melo, M., Denizer, C., Gelb, A. (1996). "From plan to market: patterns of transition." *Policy Research Working Paper* 1564, World Bank.

Dueker, M., Neely, C. J. (2007). "Can Markov Switching Models Predict Excess Foreign Exchange Returns?" *Journal of Banking and Finance*, 31, 279-296.

Easterly, W. (1996). "When is stabilization expansionary?" *Economic Policy* 22: 67-107.

Eaton, J., Gersovitz, M., (1981). "Debt with potential repudiation: theoretical and empirical analysis." *Review of Economic Studies* 48: 289-309.

Echenique, F., Forteza, A. (2000). "Are stabilizations programs expansionary?" *Estudios Económicos* v15(1).

Eichengreen, B., Mody, A., (2000). ”What explains changing spreads on emerging-market debt: Fundamentals or market sentiment?” in Sebastian Edwards ed., The Economics of International Capital Flows, Chicago University Press.

Engel, C. (1994). “Testing for the Absence of Expected Real Profits from Forward Market Speculation,” *Journal of International Economics*, 17, 299-308.

Engel, C., Hamilton, J. D. (1990). “Long Swings in the Dollar: Are They in the Data and Do Markets Know It?” *American Economic Review*, 80(4), 689-713.

Fama, E. (1984). “Forward and Spot Exchange Rates,” *Journal of Monetary Economics*, 14, 319-338.

Fernandez-Villaverde, J., Guerron, P., Rubio-Ramirez, J., Uribe, M., (2009). “Risk matters: the real effects of volatility shocks.” Working Paper, April 2009.

Fischer, S. (1988). “Real balances, the exchange rate, and indexation: real variables in disinflation.” *Quarterly Journal of Economics* 53: 27-49.

Friedman, M., (1957). “A theory of the consumption function.” Princeton, NJ. Princeton University Press.

Geenwood, J., (1984). “Non-traded goods, the trade balance, and the balance of payments.” *Canadian Journal of Economics* 17: 806-823.

Greenwood, J., Hercovitz, Z., Huffman, G.W., (1988). “Investment, capacity utilization, and the real business cycle.” *American Economic Review* 78: 402-417.

Hamilton, J.D. (1989). “A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle,” *Econometrica*, 57, 357-384.

Hamilton, J. D. (1990). “Analysis of Time Series Subject to Changes in Regime,” *Journal of Econometrics*, 45, 39-70.

Hansen, L. P., Hodrick, R. J. (1980). ”Forward Exchange Rates as Optimal Predictors of Future Spot Rates: An Econometric Analysis,” *Journal of Political Economy*, 88(5), 829-853.

Hochradl, M., Wagner, C. (2010). “Trading the Forward Bias: Are There Limits to Speculation?” *Journal of International Money and Finance* 29, 423-441.

Holtz-Eakin, D., Newey, W., Rosen, H.S., (1988). "Estimating vector autoregressions with panel data." *Econometrica* 56: 1371-1395.

Kiguel, M., Liviatan, N. (1992). "The business cycle associated with exchange rate based stabilizations." *The World Bank Economic Review* 6:279-305.

Kydland, F., Prescott, E., (1982). "Time to build and aggregate fluctuations." *Econometrica* 50: 1345-1370.

Melvin, M., Taylor, M. Π. (2009). "The Crisis in the Foreign Exchange Market," *Journal of International Money and Finance* 28, 1317-1330.

Mendoza, E., (1991). "Real business cycles in a small open economy." *American Economic Review* 81: 797-818.

Mendoza, E., (1995). "The terms of trade, the real exchange rate, and economic fluctuations." *International Economic Review* 36: 101-137.

Menkhoff, L., Sarno, L., Schmeling, M., Schrimpf, A. (2009). "Carry Trades and Global FX Volatility," *MPRA Working Paper*.

Neumeyer, P., Perri, F., (2005). "Business cycles in emerging economies: the role of interest rates." *Journal of Monetary Economics* 52: 345-380.

Nickell, S., (1981). "Biases in dynamic models with fixed effects." *Econometrica* 49: 1417-1426.

Ostry, J., (1988). "The balance of trade, terms of trade, and real exchange rate: an intertemporal optimizing framework." *IMF Staff Papers* 35: 541-573.

Ostry, J., Reinhart, C., (1992). "Private saving and terms of trade shocks: evidence from developing countries." *Staff Papers*, International Monetary Fund 39: 495-517.

Pazos, F. (1972). *Chronic Inflation in Latin America*. New York: Prager Publishers.

Prasad, E.,Rogoff, K., Wei, S.J., Kose, M.A., (2003). "Effects of financial globalization on developing countries: some empirical evidence." *International Monetary Fund Occasional Paper 220*. International Monetary Fund, Washington.

Raffo, A., (2008). "Net exports, consumption volatility and international business cycles models." *Journal of International Economics* 75: 14-29.

Reinhart, C., Rogoff, K. (2004). "The modern history of exchange rate arrangements: a reinterpretation." *The Quarterly Journal of Economics* 69: 1-48.

Reinhart, C., Végh, C. (1994). "Inflation stabilization in chronic inflation countries: the empirical evidence." Mimeo, IMF.

Rodriguez, C.A. (1982). "The Argentine stabilization plan of December 20th." *World Development* 10: 801-811.

Schmitt-Grohé, S., Uribe, M., (2003). "Closing small open economy models." *Journal of International Economics* 61: 163-185.

Sims, C., (1980). "Macroeconomics and reality." *Econometrica* 48: 1-48.

Taylor, M. (1987). "Covered Interest Parity: A High-Frequency, High-Quality Data Study," *Economica*, 54, 429-438.

Uhlig, H., (1999). "A Toolkit for Analyzing Dynamic Stochastic Models Easily," in Computational Methods for the Study of Dynamic Economies, eds. R. Marimon and A.Scott, Oxford: Oxford University Press.

Uribe, M., Yue, V., (2006). "Country spreads and emerging countries: Who drives whom?" *Journal of International Economics* 69: 6-36.

Végh, C. (1992). "Stopping high inflation: An analytical overview." *IMF Staff Papers* 39: 626-695.

Appendix A

Appendix to Chapter 1

Table A1. Exchange Rate-Based Stabilization Programs in 1960-2005

Date	**Classification**	**Plans**
Argentina 67:03 – 71:03	Peg to US dollar	10%, 20%
Argentina 78:12 – 81:02	Pre-announced crawling peg (The Tablita Plan)	10%, 20%, 40%
Argentina 85:06 – 86:03	Peg to US dollar (The Austral Plan)	10%, 20%, 40%
Argentina 91:04 – 01:12	Currency Board (The Convertibility Plan)	10%, 20%, 40%
Bolivia 57:12 – 71:02	De facto crawling band around US dollar	10%, 20%, 40%
Bolivia 87:01 – 01:12	Crawling band / Crawling peg to US dollar	10%, 20%, 40%
Brazil 68:08 – 75:03	De facto band around US dollar (PPP rule)	10%, 20%
Brazil 86:02 – 86:09	Peg to US dollar (The Cruzado Plan)	10%, 20%, 40%
Brazil 89:01 – 89:04	Peg to US dollar	10%, 20%, 40%
Brazil 94:07 – 99:01	Pre-announced band to US dollar (The Real Plan)	10%, 20%, 40%
Chile 60:01 – 62:01	Peg to US dollar (The Escudo)	10%, 20%
Chile 78:02 – 82:06	Pre-announced crawling peg (The Tablita Plan)	10%, 20%, 40%
Chile 88:01 – 99:09	Pre-announced crawling band (PPP rule)	10%
Ecuador 93:10 – 97:09	De facto crawling band around US dollar	10%, 20%, 40%
Ecuador 00:03 – 01:12	No separate legal tender (US dollar)	10%, 20%
Mexico 77:03 – 81:04	De facto peg to US dollar	10%
Mexico 88:12 – 94:12	Crawling peg / De facto peg / Crawling Band	10%, 20%, 40%
Paraguay 86:05 – 89:02	De facto crawling band around US dollar	10%, 20%
Paraguay 91:02 – 01:12	De facto crawling peg to US dollar (PPP rule)	10%, 20%

Peru 93:11 – 01:12	De facto crawling band around US dollar	10%, 20%, 40%
Uruguay 68:06 – 70:12	Peg to US dollar	10%, 20%, 40%
Uruguay 78:10 – 82:11	Pre-announced crawling peg (The Tablita Plan)	10%, 20%, 40%
Uruguay 90:12 – 91:12	Pre-announced crawling band	10%, 20%, 40%
Uruguay 95:10 – 01:12	De facto crawling band	10%, 20%, 40%
Venezuela 96:07 – 01:12	Pre-announced crawling band to US dollar	10%, 20%, 40%
Costa Rica 83:11 – 01:12	De facto crawling band around US dollar	10%, 20%
Dominican Rep 85:12 – 87:06	De facto crawling band around US dollar	10%, 20%
El Salvador 90:03 – 01:12	Peg to US dollar	10%
Guatemala 91:05 – 01:12	De facto crawling peg to US dollar	10%
Jamaica 79:05 – 90:09	Peg to US dollar / Crawling band to US dollar	10%
Jamaica 93:05 – 01:12	De facto crawling band/peg to US dollar	10%, 20%, 40%
Nicaragua 91:04 – 01:12	Peg to US dollar / Crawling peg to US dollar	10%, 20%, 40%
Suriname 95:12 – 98:01	De facto crawling band around US dollar	10%, 20%, 40%
Israel 85:10 – 01:12	Crawling band around US dollar	10%, 20%, 40%
Iceland 76:02 – 77:04	De facto crawling band around US dollar	10%, 20%, 40%
Iceland 84:06 – 00:10	De facto crawling band around DM	10%, 20%, 40%
Greece 84:09 – 01:12	De facto band/peg to DM	10%
Turkey 98:02 – 01:01	Crawling band around DM/euro	10%, 20%, 40%
Indonesia 69:04 – 72:06	De facto crawling band/peg to US dollar	10%, 20%, 40%
Indonesia 74:07 – 97:07	De facto crawling band/peg to US dollar	10%, 20%
Philippines 85:03 – 97:06	De facto peg/band around US dollar	10%

Note: a 10%, 20% and 40% under the Plans column denotes that the program is identified as an ERBS plan using a cut-off inflation of 10%, 20% and 40%, respectively.

Appendix B

Appendix to Chapter 2

B.1 Data Appendix

National Accounts

For all countries quarterly series for gross domestic product, private consumption, gross fixed capital formation, and net exports of goods and services are obtained from the IMF-IFS statistics. All series are in constant local currency, seasonally adjusted using the Census Bureau's X-11 method, and Hodrick-Prescott filtered.

Terms of Trade

The data for the terms-of-trade are the ratio of export prices (or export unit values) to import prices (or import unit values). Export and import prices at a quarterly frequency are taken from the following sources: INDEC (Argentina), IPEADATA (Brazil), Banco Central de Chile, Banco de la Republica de Colombia, Banco Central de Ecuador, INEGI (Mexico), Banco Central Reserva de Peru, Banco Central de Uruguay, Banco Central de Venezuela, Biro Pusat Statistik (Indonesia), Bank Negara Malaysia, National Statistical Coordination Board (Philippines), Global Insight (Russia), Central Bank of Turkey and the South African Reserve Bank.

Real Effective Exchange Rates

For all countries the quarterly real effective exchange rate is from JPMorgan Trade Weighted Indices. The series are broad indices encompassing major industrialized and emerging market currencies. A country's real effective exchange rate is defined as a geometric weighted average of the ratios of its own domestic price level to its partner's domestic price levels, where all the price levels are restated in a common currency via the relevant nominal exchange rates. The last incarnation of the series derives the weights from the 2000 global pattern of trade in manufactured goods. Formally, the weights are defined as follows:

$$W_{xj} = aW_{xj}^{x} + (1-a)W_{xj}^{m}, \quad with\ a = \frac{X_x}{X_x + M_x} \tag{B.1}$$

$$W_{xj}^{x} = \sum_{i \neq x} \left(\frac{X_{xi}}{X_x} \frac{M_{ij}}{M_i + M_i^d - M_{ij}} \right) \tag{B.2}$$

$$W_{xj}^{m} = \frac{M_{xj}}{M_x} \tag{B.3}$$

where

W_{xj} Trade weight for the importance of country j to country x

W_{xj}^{x} Modified export component of final trade weight

W_{xj}^{m} Import component of final trade weight

X_x Total exports of country x

M_x Total imports of country x

X_{xi} Exports of country x to country i

M_{ij} Imports of country i from country j

M_i^d Manufacturing GDP of country i

Real Interest Rates

For all countries the nominal interest rate in dollars is constructed as the sum of the 3 month US T-Bill rate plus the JPMorgan EMBI+ stripped spread. Real interest rates are obtained by subtracting expected US GDP inflation from the nominal rate. Expected inflation is computed as the average inflation in the previous four quarters. For Chile, Malaysia and Uruguay the EMBI Global stripped spread was used.