Institut für Wirtschaftspolitik an der Universität zu Köln

INSTITUT FÜR WIRTSCHAFTSPOLITIK
AN DER UNIVERSITÄT ZU KÖLN

Real Effective Exchange Rate Uncertainty, Threshold Effects, and Aggregate Investment – Evidence from Latin American Countries

Bianca Clausen

IWP Discussion Paper No. 2008/2

October 2008

Real Effective Exchange Rate Uncertainty, Threshold Effects, and Aggregate Investment – Evidence from Latin American Countries[1]

Abstract

This paper provides new empirical evidence on the relationship between real effective exchange rate uncertainty and aggregate investment in six Latin American economies. Its main contributions are that it explicitly tests for linear as well as non-linear effects of uncertainty in a time-series model that allows the country-specific interpretation. A (G)ARCH-based uncertainty measure is constructed for each country which is then included in a GMM time-series model that accounts for the endogeneity of the variables. When accounting for threshold effects, this paper finds that high levels of real effective exchange rate uncertainty affect aggregate investment negatively in all countries in the sample.

JEL classification: F21; F31

Keywords: exchange rate uncertainty; GARCH; investment; threshold effects; GMM

Bianca Clausen

University of Cologne, Department of Economics

Chair of Prof. Dr. Juergen B. Donges (emiritiert)

D-50931 Köln

Corresponding Address:

8816 Hawkins Lane

Chevy Chase, MD 20815

USA

bclausen@uni-koeln.de

[1] I am indebted to Jens R. Clausen, Juergen B. Donges, Magda Kandil, and Dmitriy Kovtun and thank them for their support and for many fruitful discussions and valuable comments. This paper has also benefited from suggestions from seminar participants at the University of Cologne for which I am very grateful.

I. Introduction

Developing and emerging market economies experience a degree of real exchange rate uncertainty far larger than that in industrial countries.[1] Accordingly, the issue of uncertainty has received increased attention in the recent debate regarding the benefits of different exchange rate regimes and their implied exchange rate volatility for the development of emerging economies. As a result, the consequences of exchange rate uncertainty on performance in areas like growth, trade, and investment have attracted considerable attention in the recently published empirical literature. In the case of uncertainty's impact on investment, this has been enforced by the theoretical literature's progress in identifying various channels through which investment is affected by exchange rate uncertainty. However, the theoretical literature fails to give a clear answer about the sign of the investment-uncertainty relationship as some of the effects identified in the models operate in opposing directions.

Most models are developed under the assumption of risk-neutral investors. The classical strand of literature was pioneered by Hartman (1972) and Abel (1983) who show that under perfect competition, constant returns to scale, and symmetric adjustment costs, the relationship between prices and the expected profitability of capital is convex. Therefore Jensen's inequality implies that a rise in (price) uncertainty raises the expected profitability of capital, increases the desired capital stock and thus stimulates investment. However, the assumption of symmetric adjustment costs is challenged by other theoretical contributions. Most notably, Dixit and Pyndick (1994) argue that in reality downward adjustment is costlier than upward adjustment, leading to asymmetric adjustment costs. In their argumentation, the asymmetry results from the irreversibility of most fixed investment projects. They make two additional assumptions: uncertainty about future benefits and costs of the investment and the presence of timing flexibility in the conduct of the project. They argue that this possibility to postpone the investment is a valuable asset that has to be incorporated in the decision making process. The value of this option arises from the fact that a delay of the project may give a more accurate view of market conditions that may influence the decision to invest. The net present value of the project must therefore exceed zero by the value of the option in order to be profitable. The authors conclude that utilizing the option to delay the project due to increased uncertainty will ultimately result in a fall in investment.

This lack of unambiguous results in the theoretical literature has given rise to empirical studies that focus on the impact of exchange rate uncertainty on investment.[2] Most authors find a negative effect of uncertainty on investment. More specifically, Darby et al. (1999) estimate the relationship between uncertainty and investment for several industrial countries in a dynamic error correction model and find a negative sign in every case. Serven (2003) uses a large cross-country data set of developing countries in a GMM model with a GARCH-based uncertainty measure and concludes that the investment-uncertainty link is strongly negative. He also finds evidence for threshold effects and a dependence on the level of trade openness and the development of financial markets. Atella et al. (2003) use a panel of Italian firms also in a dynamic error correction model and conclude that exchange rate volatility reduces investment, with a decreasing sensitivity the greater the firm's market power. Byrne and Davis (2003) focus on the distinction between the effects of transitory versus permanent exchange rate volatility derived from a GARCH model. For their sample of EU countries, they conclude that especially the transitory component of exchange rate uncertainty adversely affects investment. Pradhan et al. (2004) estimate the relationship between real exchange rate volatility and private investment for several south-east Asian countries with a GARCH-based uncertainty measure. Their results vary in both sign and significance for the four countries under consideration.

This paper re-examines the relationship between real effective exchange rate uncertainty and aggregate investment empirically for six Latin American economies, which are Brazil, Chile, Colombia, Ecuador, Mexico, and Peru. Despite Latin America's extensive experience with different exchange rate regimes and uncertainty, remarkably little attention has been paid to the region in the empirical literature on the subject. Our approach differs from other studies in that, in contrast to the prevailing cross-country studies, we use six time series data sets that allow for the country-specific interpretation of the results and facilitate taking account of key features of the specific economies that may increase or mitigate the effects. Moreover, we pay particular attention to the estimation of the uncertainty series by using (G)ARCH models to separate variability from uncertainty. Also, this paper not only estimates linear effects of uncertainty but also provides evidence on the presence of threshold effects in the uncertainty-investment relationship.

Finally, we use aggregate investment as defined by gross fixed capital formation as the investment variable as domestic as well as foreign direct investment decisions are inherently affected by developments of the real exchange rate. While a large body of literature already exists on the effects of uncertainty on foreign investment, the impact on domestic investment has been less thoroughly researched.[3] However, domestic investment decisions, especially in the tradables sector of the economy, are equally affected by exchange rate changes as they aggravate the planning process and directly affect revenues by impacting production costs and by changing the domestic currency price of goods sold abroad. Also, our wide definition of investment includes private as well as public investment in the economy, the latter of which is of significant importance in the economies that are represented in our sample.[4]

The remainder of this paper is organized as follows: Section II develops the measure for real exchange rate uncertainty that will later be used in the econometric model and tests the estimated uncertainty measure for economic soundness in the respective countries. Section III describes the econometric methodology used to estimate the uncertainty-investment model and section IV presents the empirical results. Section V re-estimates the model with adjusted uncertainty measures representing phases of high and low uncertainty and tests for the presence of threshold effects. Section VI concludes.

II. Estimation of a Real Effective Exchange Rate Uncertainty Measure

In many existing studies, exchange rate uncertainty is proxied by sample variability. However, variability does not equal uncertainty as it contains predictable and seasonal events that do not induce uncertainty in the investor's decision making process. To measure actual uncertainty, we use ARCH and GARCH models in the construction of the uncertainty series in this study. These models center on prediction errors and are suited to deal with clustering and the resulting heteroskedasticity of financial time series. We estimate either an ARCH or GARCH model in a simple equation, which can have a different specification for each country.[5] The conditional variance from the (G)ARCH procedure will then be used as the measure for real effective exchange rate uncertainty. More specifically we estimate one of the following equations for each country:

ARCH(p): $\sigma_t^2 = \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + ... + \alpha_p\varepsilon_{t-p}^2$

GARCH(p,p): $\sigma_t^2 = \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + ... + \alpha_p\varepsilon_{t-p}^2 + \beta_1\sigma_{t-1}^2 + ... + \beta_p\sigma_{t-p}^2$

with $\alpha_0 > 0, \alpha_1 \geq 0, \beta_1 \geq 0.$ We estimate the uncertainty equation using the log of monthly real effective exchange rate data for the period 1980:1 to 2005:6.[6] The data has been obtained from the IMF *Global Data Source* database. As using non-stationary data in the estimation can lead to spurious regression results, we use the Augmented Dickey Fuller Test and the Phillips Perron Test to test for stationarity of the real effective exchange rate series (see table 2). The null hypothesis of a unit root cannot be rejected for any of the six series. To correct for non-stationarity, the log of the series is differenced. In order to test for the appropriateness of fitting (G)ARCH models to the series, we test for autocorrelation in the residuals and find no evidence of serial correlation. However, the *squared* residuals exhibit serial correlation, which suggests the presence ARCH errors. To test for these a Lagrange multiplier test is conducted. It provides significant results, confirming the presence of ARCH effects. As such, it is appropriate to fit (G)ARCH models to the series.[7] Table 1 summarizes the (G)ARCH models that were fitted to the log of the differenced real effective exchange rate series.[8]

Table 1: ARCH and GARCH Model Summary

	Brazil	Chile	Colombia	Ecuador	Mexico	Peru
α_0	0.001*	0.001*	0.001*	0.001*	0.001*	0.025*
	(8.77)	(8.61)	(9.46)	(2.66)	(7.78)	(10.91)
α_p	0.625*	0.229***	0.544*	0.683*	0.909*	0.564**
	(4.57)	(1.83)	(4.82)	(4.25)	(5.32)	(2.34)
β	---	---	---	0.535*	0.119**	---
				(8.59)	(2.15)	

t-statistics in parenthesis
*,**,*** denotes statistical significance on the 1%, 5%, and 10% level, respectively.

The conditional variance of each of the (G)ARCH models will serve as the uncertainty measure in the model for the respective country. Figure A.1 in the appendix shows these six (G)ARCH-based conditional variance series. It can be seen in the graphed real effective exchange rate uncertainty series, that phases of volatility clustering are present. A quick reality check reveals that the uncertainty measures appear to accurately reflect the actual political and economic situation in the respective countries: Brazil's currency crises in the early and late 1990s are depicted in the graph as well as the increased uncertainty during a renewed phase of currency weakness in 2002 that resulted from concerns about government solvency. Colombia's crisis in the late 1990s and the Mexican peso crises in the early 1980s and mid-1990s are clearly reflected. Also, the Peruvian debt crisis in the mid-1980s and the increase in uncertainty before the introduction of dollarization in Ecuador in the year 2000 are identifiable.

III. Model Specification

We use an empirical model relating the log of the gross fixed capital formation to GDP ratio to a set of conventional investment determinants that include the log of the real effective exchange rate uncertainty measure introduced above.[9] We work with quarterly data that is sourced from the IMF *International Financial Statistics* database.[10] The model to be estimated is as follows:

$$I_t = f(c_t, uncert_t, gcons_t, pcred_t, oil, realin_t, inv_{t-1}) + u_t .$$

I_t is the log of gross fixed capital formation to GDP, $uncert_t$ is the exchange rate uncertainty measure, and u_t is a random disturbance term. Among the conventional investment determinants, we include the log of government consumption to GDP $(gcons_t)$ to measure crowding out and the real interest rate $(realin_t)$ as an approximation of the cost of capital. As the true cost of funds in emerging markets sometimes is not adequately reflected in the real interest rate, we add a measure of the overall tightness of credit markets, namely the log of private credit relative to nominal GDP $(pcred_t)$.[11] We also include the log of the price of oil (oil_t) as the industry is of such importance for the (investment) performance of most of the economies in the region. In addition, we add a constant (c_t) and a lagged investment term (inv_{t-1}).

Estimation of the model using OLS would be inconsistent because simultaneity is likely to be a problem as some or all of the coefficients may be jointly determined with investment. Therefore, we choose a General Method of Moments (GMM) approach that corrects for endogeneity of the coefficients and for the correlation between the lagged difference of the dependent variable and the error term. In the construction of the instruments set, we follow Arellano and Bond (1991). Their *difference GMM estimator* assumes that second or higher-order lags of these variables are uncorrelated with the error term but are correlated to the endogenous explanatory variable in question. However, the (lagged) (G)ARCH-based measure for exchange rate uncertainty used in the model cannot be used as an instrument as its construction employs future as well as past information and hence its lagged values may be correlated with the time-varying disturbance and thus not be endogenous. Therefore, we follow Serven (2003) and construct a naïve measure of real-exchange rate uncertainty for each of the six countries by computing the three-year variance of the forecast errors from an AR(1) real exchange rate equation estimated recursively using only current and lagged real-exchange-rate data. We use this backward-looking uncertainty measure to instrument the (G)ARCH-based real-exchange-rate uncertainty indicator.

All variables that enter the model are tested for stationarity using the Augmented-Dickey-Fuller and the Phillips-Perron tests in order to avoid spurious regression results. Test results are reported in table 2. Variables for which the null hypothesis of a unit root cannot be rejected enter the regression in a log differenced form.

Table 2: Unit Root Test Results

ADF and PP: ($H_0 : X_t \sim I(1)$, $H_a : X_t \sim I(0)$)

		(inv)	*(uncert)*	*(gcon)*	*(realin)*	*(pcred)*	*(oil)*
Brazil	ADF	-5.68*	-9.58*	-7.64*	-3.40**	-2.07	-0.91
	PP	-5.82	-9.55*	-7.64*	-3.39**	-1.96	-1.43
Chile	ADF	-2.43	-8.20*	-5.26*	-4.02*	-1.16	-0.91
	PP	-2.52	-8.23*	-5.28*	-3.86*	-0.95	-1.43
Colombia	ADF	-1.11	-6.53*	-1.93	-0.70	-0.65	-0.91
	PP	-1.17	-6.52*	-1.87	-0.89	-0.50	-1.43
Ecuador	ADF	-1.70	-4.49*	-1.64	-1.71	-1.85	-0.91
	PP	-2.11	-4.84*	-1.74	-1.35	-2.14	-1.43
Mexico	ADF	-2.12	-7.65*	-11.16*	-2.38	-1.30	-0.91
	PP	-2.19	-7.79*	-11.18*	-2.02	-1.57	-1.43
Peru	ADF	-3.53*	-35.38*	-3.84*	-4.97*	-0.76	-0.91
	PP	-3.41**	-32.31*	-3.78	-4.98*	-0.81	-1.43

Investment, Government Consumption and Private Credit denote their respective ratios to GDP.
ADF and PP are abbreviations for Augmented Dickey Fuller Test and Phillips Perron Test, respectively.
Variables carrying an * are stationary.

Source: Author's calculations.

IV. Empirical Results

The model for each country has been estimated using quarterly data. Due to data limitations, the sample periods differ among countries. Dummies have been used when significant to account for phases of excess volatility.[12] The central question of this study is how real effective exchange rate uncertainty influences gross fixed capital formation. Therefore, special attention will be given to the *exchange rate uncertainty* coefficient. A *positive* sign of the coefficient would indicate that an increase in exchange rate uncertainty raises investment. A *negative* sign would point to a decrease in investment when exchange rate uncertainty increases.

The *government consumption* coefficient is expected to exhibit a negative coefficient if increased government spending crowds out investment whereas a positive sign of this coefficient would lead to the conclusion that increased consumption of the public sector serves as a stimulus for investment in the economy. *Oil* prices do not per se affect investment one way or another. It may depend on whether the country in question is a net oil importer or exporter and on how important investment in the oil sector is for the economy as a whole. The *real interest rate* as a proxy for the cost of capital is expected to carry a negative coefficient as higher interest rates tend to discourage investment. However, as the interest rate channel does not always work efficiently in the light of interest rate controls and non-price rationing mechanisms in developing country financial markets, observed interest rates may be uninformative as to the true marginal cost of funds. For this reason the liquidity parameter *private credit* has been included in the regression. The larger availability of private credit should have a positive influence on investment. Estimation results for all countries are reported in table 3. Considering that all variables entered the regression in first differenced form, the empirical results suggest a good statistical fit of each model to the data, as indicated by the adjusted R^2. Also, almost all coefficients are highly statistically significant, most at the one percent level. More specifically, we obtain the following results:

The government consumption coefficients point to a crowding out effect in Brazil and Mexico, which carry negative signs, albeit in the latter case the coefficient is not statistically significant. Especially Brazil has been known for excessive government expenditure that pushed up interest rates and crowded out private lending. All other countries actually show a positive influence of government consumption on investment. This could be due to the high level of government involvement in the respective economies for example through the state-owned copper company in Chile and state petroleum companies in Colombia and Ecuador.

Oil prices are positively related to investment in Brazil, Chile, Colombia, and Mexico. A positive sign would be expected for countries that are net oil exporters and whose revenues are thus increased by a rise in oil prices. Of the countries with a positive coefficient, this is indeed the case for all with the exception of Chile, which only has tiny oil reserves. However, Chile is the world's largest copper producer and as copper and oil prices have displayed a correlation of 0.97 over the last 20 years, the positive oil price coefficient in the regression can be understood as being a proxy for the price of copper.

The coefficient of the real interest rates does not carry a uniform sign across countries and is often very small and sometimes not statistically significant. As we had assumed, the real interest rate does not seem to be a good indicator for the true marginal cost of capital. As the effects of the banking crisis in the countries have not fully subsided yet, the efficient intermediary role between savers and borrowers often is not fulfilled and high base interest rates and wide spreads between deposits and loans hinder efficient capital allocation. To account for this, we include the liquidity parameter private credit in the regression. As expected, it carries a positive sign for most countries.

Table 3: Real Effective Exchange Rate Uncertainty and Aggregate Investment: GMM Estimates

	Constant (c)	REER Uncertainty (vol)	Gov Cons (gcons)	Private Credit (pcredit)	Oil Price (oil)	Real Interest Rate (realin)	Investment{1} (inv{1})	Dummy(1)	Dummy(2)	DW	R^2
Brazil	-1.189* (-3.48)	-0.042** (-2.21)	-0.213** (-2.42)	0.400* (5.91)	0.625** (1.97)	0.000 (0.88)	0.662* (8.92)	---	---	1.823	0.329
Chile	1.760* (4.41)	0.133** (2.12)	0.410* (3.94)	0.302 (0.87)	0.232* (3.29)	0.007* (4.86)	0.460* (4.00)	---	---	1.879	0.229
Colombia	-0.243* (-2.84)	-0.036* (-3.28)	-2.657* (-4.64)	0.634* (2.94)	-0.199* (-4.48)	-0.003 (1.13)	-0.163** (-2.05)	0.279* (5.59)	-0.152** (2.21)	2.101	0.261
Ecuador	-0.109** (-2.12)	-0.016** (-1.96)	0.547* (3.24)	-0.185** (-2.20)	-0.229* (-4.11)	0.003* (6.00)	0.161** (2.22)	0.132* (5.75)	---	1.973	0.146
Mexico	0.321*** (1.83)	0.044** (2.34)	-0.003 (-0.008)	0.364** (2.81)	0.051** (2.16)	-0.002*** (-1.65)	-0.375* (-2.99)	-0.285* (-4.14)	---	2.170	0.221
Peru	0.323** (1.98)	-0.041* (-2.85)	0.200* (3.20)	0.273** (2.05)	-0.154** (-2.34)	0.002* (3.42)	-0.363* (-6.26)	0.469* (5.30)	---	1.916	0.256

Regression coefficient with autocorrelation consistent t-statistic (in parenthesis); Durbin Watson Statistic and equation R^2 in final two colums.
*,**,*** denotes statistical significance on the 1%, 5%, and 10% level, respectively.
Sample sizes are as follows: Brazil 1991:1-2004:4, Chile 1990:1-2004:4, Colombia 1994:1-2003:1, Ecuador 1991:1-2003:1, Mexico 1987:1-2004:4, Peru 1986:1-2004:4.

Source: Author's calculations.

The effect of an increase in real effective exchange rate uncertainty on aggregate investment differs across the six countries but is statistically significant for all of them at the five percent level. For four countries, the coefficient is negative, indicating a detrimental effect of increased uncertainty on investment. This is the case for Brazil, Colombia, Ecuador, and Peru. In the remaining two countries, namely Chile and Mexico, a rise in exchange rate uncertainty seems to actually stimulate investment. The coefficient carries a positive and statistically significant sign in these countries. While the positive sign may appear puzzling at first, it is worth noticing, however, that Chile and Mexico are also the most developed and politically and economically stable economies. Also, they are among the countries in the sample that exhibit the lowest overall level of real effective exchange rate uncertainty. This suggests the existence of threshold effects and may be an indication that the nature of the effect of exchange rate uncertainty on investment depends on the *level* of uncertainty. Therefore, we will go on to investigate whether there is evidence that the sign of the relationship differs depending on the level of uncertainty.

V. Empirical Evidence for Threshold Effects

The theoretical literature on the investment-uncertainty relationship finds that the effects of uncertainty on investment may in fact be non-linear and hence depend on the level of uncertainty. One such model can be found in Sakar (2000).[13] Sakar shows that the (linear) negative uncertainty-investment relationship that is the result of the real options approach is not always correct and that an increase in uncertainty my actually increase the probability of investing and thereby have a positive effect on investment. He proves the existence of a threshold effect in the sense that investment reacts different to low and high levels of uncertainty. In particular, he shows that while the probability of investing is initially an *increasing* function of uncertainty, it becomes a *decreasing* function of uncertainty once it has reached a certain threshold. Therefore, with low levels of uncertainty, an increase in uncertainty increases investment and thereby has a positive effect on the expected rate of investment. Once the uncertainty threshold is reached, the relationship turns negative. The relationship can therefore be described by an inverted U-shaped curve.

Table 4: Real Effective Exchange Rate Uncertainty, Threshold Effects, and Aggregate Investment: GMM Estimates

	Constant *(c)*	Gov Cons *(gcons)*	Private Credit *(pcredit)*	Oil Price *(oil)*	Real Interest Rate *(realin)*	Investment{1} *(inv{1})*	*(lowvol)*	*(highvol)*	DW	R^2
Chile	0.805*	0.429*	0.393***	0.127*	0.007*	0.453*	---	-0.009		
	(5.28)	(5.91)	(1.84)	(2.83)	(5.94)	(6.13)		(-2.55)	1.979	0.279
	0.860*	0.424*	0.405***	0.130*	0.007*	0.454*	0.009**	---		
	(6.18)	(5.74)	(1.87)	(2.93)	(5.92)	(6.14)	(2.56)		1.981	0.280
Mexico	-0.132***	-0.054***	0.284*	0.051*	-0.003*	-0.043	---	-0.007**		
	(-1.87)	(-1.67)	(3.77)	(3.06)	(-5.21)	(-0.79)		(-2.19)	2.281	0.458
	-0.092	-0.055***	0.290*	0.051*	-0.003*	-0.032	0.006**	---		
	(-1.12)	(-1.66)	(3.75)	(3.23)	(-4.61)	(-0.50)	(2.37)		2.260	0.510

Regression coefficient with autocorrelation consistent t-statistic (in parenthesis); Durbin Watson Statistic and equation R^2 in final two colums.
*,**,*** denotes statistical significance on the 1%, 5%, and 10% level, respectively.

Source: Author's calculations.

The theoretical findings of threshold effects will be re-examined in the empirical model by distinguishing between the impact of high and low levels of uncertainty. For each country two new volatility variables will be constructed with the use of dummy variables. One variable *(lowvol)* contains the periods in which volatility is smaller than the sample mean and the other *(highvol)* contains periods with above sample-mean volatility. Two regressions are estimated for each Chile and Mexico and either the low or the high volatility measure enters the regression.

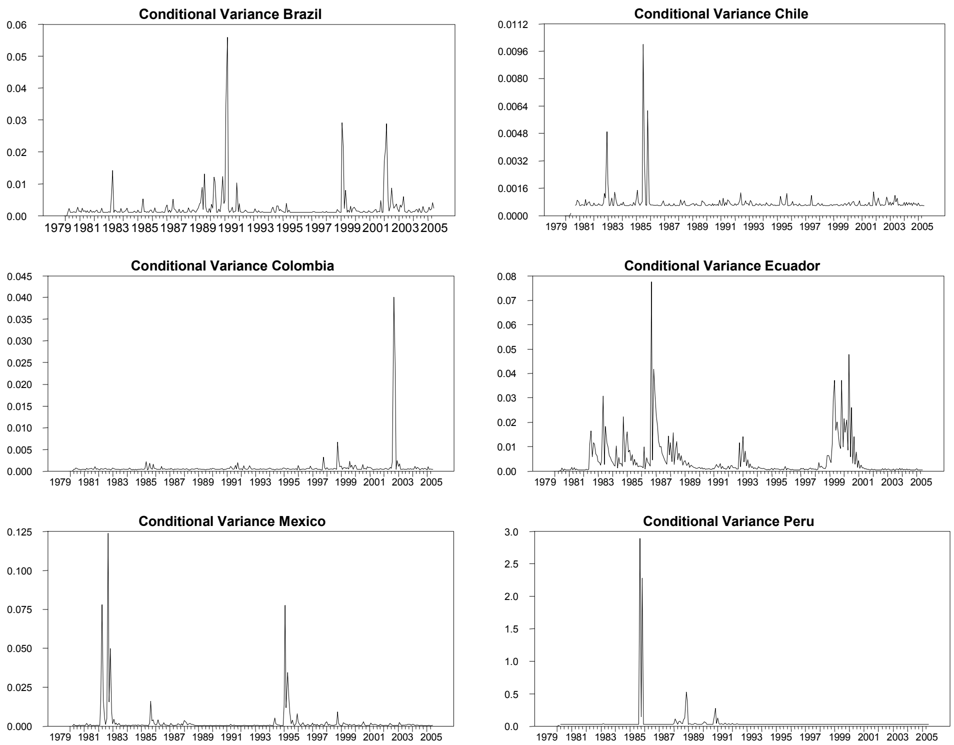
The theoretical findings of a non-linear relationship between investment and uncertainty can be empirically confirmed for both countries as can be seen in table 4 above. In both Chile and Mexico, the *(lowvol)* coefficient is positive while the *(highvol)* coefficient is negative. Both are statistically significant. We can therefore conclude for these countries that investment reacts positively to an increase in uncertainty from a low level whereas a negative investment-uncertainty relationship exists for high levels of uncertainty. All other coefficients seem to be very stable compared to the previously estimated general model. They exhibit the same signs and are even roughly of the same size compared to the estimation results of the linear model.

VI. Conclusion

This paper provides empirical evidence on the sign of the relationship between real effective exchange rate uncertainty and aggregate investment. To capture real effective exchange rate uncertainty, an indicator is constructed using (G)ARCH models for six Latin American countries. The uncertainty indicator then enters the regression alongside other standard investment determinant and the model is estimated using an instrumental variable (GMM) procedure. The major finding is that an increase in real exchange rate uncertainty acts as an impediment to aggregate investment. We find a significantly negative effect of high levels of uncertainty on investment for all countries after accounting for threshold effects.

Appendix

Graph A.1: (G)ARCH-based Uncertainty Measure



References

Abel, Andrew B. (1983): „Optimal Investment Under Uncertainty“, *American Economic Review*, 73, March, 228-233.

Arellano, Manuel and Stephen Bond (1991): Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations, *Review of Economic Studies*, 58, 277-297.

Atella, Vincenzo, Gianfranco Enrico Atzeni and Pier Luigi Belvisi (2003): “Investment and Exchange Rate Uncertainty”, *Journal of Policy Modeling*, 25, 811-824.

Blonigen, Bruce A. (2005): A Review of the Empirical Literature on FDI Determinants, *NBER Working Paper*, No. 11299.

Bollerslev, Tim (1986): ”Generalized Autoregressive Conditional Heteroskedasticity”, *Journal of Econometrics*, 31, 307-327.

Byrne, Joseph P. and E. Philip Davis (2003): “Panel Estimation of the Impact of Exchange Rate Uncertainty on Investment in the Major Industrial Countries”, *NIESR Discussion Paper*, No. 208, National Institute of Economic and Social Research.

Calderón, César and Luis Sérven (2004): The Effects of Infrastructure Development on Growth and Income Distribution, *Central Bank of Chile Working Paper*, No. 270, Central Bank of Chile.

Darby, Julia, Andrew Hughes Hallet, Jonathan Ireland and Laura Piscitella (1999): “The Impact of Exchange Rate Uncertainty on the Level of Investment”, *The Economic Journal*, 109, Conference Paper, C55-C67.

Dixit, Avinash K. and Robert S. Pindyck (1994): “*Investment under Uncertainty*”, Princeton, NJ: Princeton University Press.

Engle, Robert F. (1982): “Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of UK Inflation”, *Econometrica*, 50, 987-1008.

Hartman, Richard (1972): “The Effects of Price and Cost Uncertainty on Investment”, *Journal of Economic Theory*, 5, 258-266.

IMF (2002): *“World Economic Outlook – Trade and Finance”*, International Monetary Fund, Washington DC, September.

Lensink, Robert (2002): “Is the Uncertainty-Investment Link Non-linear? Empirical Evidence for Developed Economies”, *Weltwirtschaftliches Archiv*, 138, 131-147.

McClain, Katherine T., H. Brett Humphreys and Atahualpa Boscan (1996): “Measuring Risk in the Mining Sector with ARCH Models with Important Observation on Sample Size”, *Journal of Empirical Finance*, 3, 369-391.

McDonald, Robert and Daniel Siegel (1986): “The Value of Waiting to Invest”, *Quarterly Journal of Economics*, 101, 707-727.

McKenzie, Michael D. (1998): “The Impact of Exchange Rate Volatility on Australian Trade Flows”, *Journal of International Financial Markets, Institutions and Money*, 8, 21-38.

Pradhan, Gyan, Zeljan Schuster and Kamal P. Upadhyaya (2004): „Exchange Rate Uncertainty and the Level of Investment in Selected South-East Asian countries”, *Applied Economics*, 36, 2161-2165.

Ramirez, Miguel D. and Nader Nazmi (2003): Public Investment and Economic Growth in Latin America: An Empirical Test, *Review of Development Economics*, Vol. 7, 115-126.

Sakar, Sudipto (2000): “On the Investment-Uncertainty Relationship in a Real Options Model”, *Journal of Economic Dynamics and Control*, 24, 219-225.

Servén, Luis (1998): “Macroeconomic Uncertainty and Private Investment in Developing Countries, An Empirical Investigation”, *World Bank Policy Research Paper*, No. 2035.

Servén, Luis (2003): “Real-Exchange-Rate Uncertainty and Private Investment in LCDs”, *The Review of Economics and Statistics*, February, 85, 212-218.

Footnotes

[1] See IMF (2002) for a comparison of exchange rate volatility in emerging and developed economies.

[2] See Lensink (2001) for a comprehensive overview.

[3] See Blonigen (2005) for a thorough review of the empirical literature on the exchange rate uncertainty – FDI relationship.

[4] An increase in public investment in infrastructure, health care, and education has been found to increase economic growth in several emerging economies. See for example Ramirez and Nazmi (2003), who find a significantly positive growth effect of both private and public investment for nine Latin American economies. Calderón and Serven (2004) provide further empirical evidence on the matter for Latin American countries.

[5] ARCH and GARCH models were pioneered by the works of Engle (1982) and Bollerslev (1986), respectively.

[6] The choice of either an ARCH or GARCH model depends on the fit for each country. Hereafter, we will shorten the reference to both models as (G)ARCH.

[7] To reliably estimate an ARCH model, it is necessary that (i) the model converges and (ii) the alpha coefficient is greater than zero but less than unity and is statistically significant (McKenzie 1998). Also, McClain et al. (1996) note that 300 observations are necessary for estimating a reliable ARCH model. That threshold value is reached in this study, as each of the ARCH models is based on 307 observations.

[8] The beta coefficient is only present in those countries for which a GARCH instead of an ARCH model was the best model. The respective models for the six countries are: Brazil: ARCH 1, Chile: ARCH ||4||, Colombia: ARCH1, Ecuador: GARCH 1,1, Mexico: GARCH 1,1, Peru: ARCH ||2||.

[9]The (G)ARCH-based real effective exchange rate uncertainty measure has been converted from a monthly to a quarterly frequency to fit the model.

[10]The sample period varies among countries due to data availability. See table 2 for information on the sample period for each country.

[11] This follows a suggestion made by Serven (1998).

[12] For Colombia, two dummy variables have been used for 1996:4 and 1999:3. Ecuador's regression includes a dummy for the transition time to dollarization from 1999:3 to 2000:3 and Mexico's model includes one to account for the Peso crisis in 1995:1 and 1995:2. Finally, for Peru a dummy for 1988:4 has been included.

[13] See Lensink (2002) for an empirical analysis on the subject.