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EXCHANGE RATE VOLATILITY AND RISK-PREMIUM

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Resumen

Este trabajo evalúa empíricamente la importancia del régimen cambiario y de la volatilidad del tipo de cambio sobre el diferencial de tasas de interés, con especial referencia a Chile. Se estima el premio por riego para 16 países con diferentes grados de flexibilidad cambiaria, para luego investigar si el premio por riesgo depende de la volatilidad y/o del esquema cambiario. Se considera un modelo CAPM aumentado por impuestos asumiendo que el riesgo diversificable es transado y se encuentra que existe una relación sistemática, aunque de baja magnitud, entre la volatilidad de tipo de cambio y el premio por riesgo. En el caso de Chile no se encuentra ninguna relación significativa entre volatilidad del tipo de cambio y el premio por riesgo estimado con el modelo CAPM. Sin embargo, si se considera el efecto total de la volatilidad sobre el premio por riesgo en Chile a través de un modelo ARCH-M, se encuentra un importante efecto de la volatilidad sobre el premio por riesgo. El análisis de corte transversal entre países usando este último tipo de modelo no reporta relación alguna entre grado de flexibilidad cambiaria y premio por riesgo.

Abstract

This paper empirically evaluates the importance of exchange rate regimes and exchange rate volatility on interest rate differentials, with special reference to Chile. We estimate risk-premia for 16 country experiences with different exchange rate regimes and then investigate whether these premia vary with volatility and the regime flexibility. When we assume that any diversifiable risk is actually traded and estimate a CAPM model augmented by taxes, we find a systematic but small relation between exchange rate volatility and risk-premium. In the case of Chile we do not find any significant impact of changes in exchange rate volatility on CAPM-estimated risk-premium. However, when we consider the overall effect of volatility on risk-premium and estimate an ARCH-M model we find a large effect of volatility on risk-premium in this country. In this set-up, when we analyze the cross-country experience, we do not find any relation between regime flexibility and risk-premium.

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1 Introduction

It is often argued that more flexible exchange rate regimes are able to sustain a more depreciated real exchange rate (RER), improving competitiveness. More flexibility, the argument goes, would allow for a higher exchange rate variability, which, in turn, would generate a larger risk-premium if investors are risk-averse. This larger risk-premium would induce smaller capital inflows and allow for tighter domestic monetary policy without exchange rate variations. In other words, there could be a trade-off between exchange rate level and volatility.[1]

Partly, the basis for this argument lies on the massive international evidence showing that the bilateral nominal exchange (and the RER) is more volatile in flexible exchange regimes than in rigid regimes. However, it is possible that volatility in exchange rates does not translate into return volatility if domestic interest rate movements undo exchange rate movements. In this case, capital movements, as well as RERs, may not be affected by exchange rate volatility, for total volatility remains unchanged. Furthermore, even if interest rates do not undo exchange rate volatility, it may happen that return volatility does not actually affect expected returns. For instance, if investors have a very low degree of risk aversion, or if domestic risk is completely diversifiable in the international market, a higher volatility may not imply a positive risk-premium. Moreover, if domestic returns are negatively correlated with the world portfolio, it is even possible to have risk discounts when volatility is higher. Because diversification is costly, however, it could be optimal not to diversify or trade all diversifiable risk. In that case, volatility may generate a positive risk-premium regardless of its covariance with other asset returns.

The objective of this paper is to empirically analyze the importance of exchange rate flexibility and exchange rate volatility in determining exchange rate risk-premium. The focus is emerging markets and small industrialized economies, with special reference to the case of Chile. We present four different exercises along these lines, trying to quantify the economic importance of risk-premium and the effect of volatility. Thus, the paper indirectly evaluates whether exchange rate regimes and exchange

[1] Goldfajn and Valdés (1999) provide indirect evidence that regime flexibility is able to sustain a higher RER. In a large panel of countries they find that countries with fixed exchange rates are more likely to suffer an overvaluation.

rate volatility are important determinants of capital inflows, the degree of monetary policy autonomy, and the level of RERs.

First, we analyze whether returns are more volatile in flexible exchange rate regimes *vis-à-vis* rigid ones using data of 16 country experiences. Second, using a CAPM model augmented with taxes (such as capital controls) and 3-month deposit excess return data with monthly frequency, we estimate risk-premia (or expected excess return) for the country experiences in our panel. Then we check whether there is a systematic relation between these premia and regime flexibility. Of course, being a CAPM model, this exercise implicitly assumes that any diversifiable risk is effectively diversified (traded). Third, using weekly data of excess returns in Chile we evaluate whether there is a relation between the CAPM-estimated risk-premium and the volatility of the exchange rate. Lastly, using weekly exchange rate data, we analyze whether there is a relation between overall exchange rate volatility and a proxy of risk-premium estimating ARCH-M models. In this case any volatility is considered risky, independently of whether it is diversifiable.

The results of the first exercise show that there is a significant positive correlation between dollar-yields volatility and exchange rate flexibility. Indeed, both the returns on local currency holdings and 3-month deposits are more volatile in more flexible regimes. Therefore, when exchange rates are more volatile interest rates do not undo this volatility.

In the second exercise, when considering only non-diversifiable risk, we find a systematic relation between exchange rate regime volatility and risk-premium. For some countries we find statistically significant (and economically relevant, though small) risk-premia due to covariance between domestic dollar returns and world portfolio returns. We also find that the size of the premium increases with exchange rate volatility, although we do not find clear evidence showing a correlation between regime flexibility and risk-premium (reflecting imperfections in our flexibility measure). An increase in the standard deviation of exchange rate log changes equals to 1% generates a premium of 1 basis point, which is largely irrelevant from an economic perspective.

In the third exercise, focusing on Chile, we find no significant evidence for a relation between CAPM-estimated risk-premium and different proxies for exchange rate volatility. In this case, although we do find a positive and statistically significant risk-premium, we find extremely weak evidence that this premium changes with volatility (measured as standard deviations of daily and weekly observations as well as distance to the limits of the exchange rate band). This finding is consistent with the view that risk-premium in Chile is very small when considering only non-diversifiable risk.

Finally, the results of the ARCH-M model estimation do not show any systematic relation between volatility and risk-premium across countries. In fact, in several experiences this relation is not significantly different from zero, although they have very different exchange rate volatilities. Interestingly, we find that in this exercise the Chilean case presents a significant positive and highly relevant effect of volatility on the premium. On average, the conditional exchange rate volatility in Chile explains an annual premium equivalent to 5%. According to this result, a 20% increase in the conditional exchange rate volatility (equivalent to an increase of 1.1% in the annual conditional standard deviation of log changes in the exchange rate) would create an annual interest rate differential of 1%. This compares with the effect of other policy measures such as the Unremunerated Reserve Requirement, which according to some estimations would have an effect of 1.25% on interest differentials.[2]

The large body of literature that studies the behavior of excess returns in the foreign exchange market is related to this paper, although it focuses on a slightly different subject.[3] It tries to explain why there are large and highly volatile excess returns by considering a time-varying risk-premium. These papers are only partially successful because changes in exchange rate variance are not volatile enough to match excess return volatility (or else, the implied risk aversion is too high). Our objective is rather different because we study whether volatility is important in determining risk-premium and focus on small industrialized countries and emerging markets. Closer to our objective is the paper by Sanhueza (1996) who focuses on the Chilean case. He studies whether the exchange rate band width affects the exchange rate volatility and whether this band width is related to the risk-premium. He provides strong evidence showing that volatility increases with the band width (using an ARCH model to estimate conditional volatility). However, he shows mixed evidence regarding the

[2]See Herrera and Valdés (1997).
[3]See Lewis (1995) for a survey.

relation between risk-premium and band width.[4] He does not directly test whether an increase in volatility generates a higher risk-premium.

The paper is organized as follows. Section 2 presents evidence about the relation between exchange rate regime and volatility of domestic dollar returns. Section 3 presents estimations of a CAPM model and evaluates whether there is a systematic relation between risk-premia and regime flexibility. Section 4 presents CAPM estimates for the case of Chile with weekly data and evaluates whether the risk-premium changes with exchange rate variability. Section 5 presents ARCH-M estimates analyzing the relation between volatility and exchange rate risk-premium.

2 Exchange Rate Regimes and Return Volatility

The first issue we analyze is whether 3-month domestic deposit returns measured in dollars are more volatile under flexible exchange rate regimes. There is strong evidence showing that exchange rate volatility increases with the degree of flexibility of exchange rate regimes. For example, Mussa (1986) analyzes the cases of floating regimes in Canada during the 50s and of Ireland's switching from a British Pound peg to a Deutsch Mark peg, showing that there is considerably more nominal exchange rate volatility during floating times.[5]

This higher volatility, however, may not translate into deposit return volatility if interest rates and exchange rates move in opposite directions (in terms of returns). In fact, it could happen that interest rate movements completely undo changes in exchange rate, keeping return volatility unchanged. For example, the simplest uncovered interest parity condition assumes that returns are always equal to the international interest rate. Put it differently, even if exchange rates are fixed —therefore showing zero volatility— it could exist high return volatility if interest rates adjust continuously in order to keep the peg. If this were the case, the choice of exchange rate regime (and exchange rate volatility) could be irrelevant in determining the risk-premium.

Table 1 summarizes evidence of 16 country experiences during the 90s grouped in

[4] He calculates average risk-premium for three different band widths, finding that the premium did not increase when the band increased from 5% to 10%.

[5] Frankel and Rose (1995) present a survey of related studies. It should be noted, however, that there is no defined pattern between exchange rate regimes and short run *multilateral* RERs variability in countries with moderate inflation levels (Kent and Nadja, 1997).

three different exchange rate regime groups: floating, flexible systems and fixed and rigid regimes. The first group includes free floating regimes, the second one includes wide crawling and fixed bands, and the third one includes pegs and narrow crawling and fixed bands. The exchange rate regime is assigned according to IFS information. The results show that exchange rate volatility (measured as the standard deviation of log changes in exchange rates) is generally higher in more flexible regimes. The highest volatilities occur in free floating arrangements.

The 3-month deposit excess returns (over the risk-free rate) show a similar pattern, although this time there is a less clear cut between floating and flexible regimes. Excess return volatility is usually higher than exchange rate volatility in fixed and rigid regimes. This reflects the fact that interest rates have to move to defend the peg. However, these interest rate movements do not undo the volatility of exchange rates. Thus, the initial hypothesis that flexibility in exchange rates generates more volatile asset returns is verified in the data. Figure 1 presents a scattered diagram showing exchange rate volatility and 3-month deposit excess return volatility, showing a correlation closed to 1 between the two statistics. This is consistent with the findings reported in other papers where exchange rate volatility appears unmatched by volatility of other macro variables (in particular, interest rates) across different exchange rate regimes (Frankel and Rose, 1995). It is also interesting to notice that mean returns appear to be higher in less flexible regimes. Rather than reflecting risk-discounts, these mean returns seem to be correlated to the country stage of development (sovereign risk?). Lastly, notice that generally both exchange rate and domestic deposit return volatilities are smaller than stock market index volatilities (in this case, the Standard & Poor's 500 and the Morgan Stanley World Index). The same does not happen with average excess returns.

3 Diversifiable Risk and CAPM

While last section's analysis shows that flexible exchange rate regimes produce more volatile returns, there is the question of whether this volatility actually translates into a risk-premium. This section analyzes this issue estimating CAPM models for the countries in our panel using monthly excess return data. The model implicitly

Table 1. **3-Month Deposit Returns and Exchange Rate Regimes**

	Sample	Excess Return		Std. Dev.
		Std. Dev.	Mean	ΔExch. Rate
Free Floating Regimes				
Australia	90.01–96.06	13.66	2.94	13.96
Canada	90.01–97.09	7.98	-0.12	7.76
Mexico II	95.01–97.08	30.08	6.06	24.84
New Zealand	90.01–97.09	11.91	4.14	12.04
South Africa	90.01–97.08	17.72	-0.33	16.32
Sweden	93.01–97.09	29.72	-0.92	26.39
Flexible Regimes				
Chile	90.01–97.07	11.59	8.23	13.06
Colombia	90.01–97.08	17.16	7.27	16.43
Israel	90.01–97.07	14.94	-0.99	13.46
Korea	90.01–97.04	7.66	4.10	6.75
Malaysia	90.01–97.04	9.88	2.17	9.65
Mexico I	90.01-94.09	12.04	5.90	9.69
Fixed and Rigid Regimes				
Argentina	91.05–97.07	4.92	6.51	0.82
Brazil	95.01–97.09	8.85	14.31	5.43
Indonesia	90.01–97.03	3.64	6.93	2.10
Thailand	90.01–97.02	3.77	4.97	3.86
Stock Portfolios (in dollars)				
SP500	90.01–97.12	20.52	8.53	–
MSWI	90.01–97.12	21.03	2.49	–

Returns measured in an annual basis as excess over the risk free rate.

3-month deposit operations when available. Otherwise, 30-day deposits.

SP500: Standard & Poors' 500. MSWI: Morgan Stanley World Index.

Data source: IFS and Bloomberg.

assumes that any diversifiable risk is actually diversified away and allows us to calculate the risk-premium that a country would have under this assumption. In this model, what matters for determining the size of the risk-premium is the correlation between the asset return and the return of the market (aggregate) portfolio, and not return volatilities *per se*. Therefore, in the limit, the variability of returns may turn to be irrelevant if the correlation between these returns and the market return is zero. Moreover, if the correlation is negative there can exist a risk-discount.

Because of the existence of different taxes and other distortions, such as capital controls, we estimate a more general version of CAPM. This version considers the existence of entry fees (payments that are independent from return realizations) and is derived in a static general equilibrium set-up in appendix 1. Having estimated a CAPM risk-premium for each country, this section also evaluates whether there is a systematic relation between exchange rate flexibility and the risk-premium.

Specifically, we estimate the following equation for each country:

$$\tilde{z}_{b,t} = \beta_b \tilde{z}_{m,t} + \tau + \varepsilon_t, \tag{1}$$

where $\tilde{z}_{x,t}$ is the excess return of asset x, b denotes the domestic country, m denotes the market (world) portfolio and ε_t is an error that is orthogonal to expected returns. We use monthly excess return data for 3-month deposits. Because of the overlapping structure of these returns in monthly frequency observations we consider an MA(3) error structure in the estimation.[6] When appropriate, and after checking a standard LM test for autocorrelation in residuals, we also incorporate an AR(1) term in the error structure. Additionally, we include an intercept (τ) to capture the effect of taxes and other distortions. We approximate the world portfolio by the Morgan Stanley World Index (MSWI) and the risk-free interest rate by the yield of 90-day US Treasury notes.

Table 2 presents the results of the tax-augmented CAPM estimation of our panel, while figure 2 presents a scattered diagram showing exchange rate volatility (from table 1) and CAPM-estimated risk-premium. Some conclusions that emerge are: (i) 7

[6]Indeed, if originally the data is generated at a monthly frequency, one has $\tilde{z}_{b,t} = \beta_b \tilde{z}_{m,t} + \tau + \varepsilon_t$. 3-month deposit returns, in turn, are described by $\tilde{z}_{b,t,3} = \beta_b \tilde{z}_{m,t,3} + 3\tau + \varepsilon_t + \varepsilon_{t-1} + \varepsilon_{t-2}$, where $\tilde{z}_{i,t,3}$ is the excess return in these deposits. Because we observe monthly interest rate averages, we include an extra MA term.

out of the 16 country experiences show a statistically significant exchange rate premium or discount; (ii) Apparently, there is no systematic relation between exchange rate regime flexibility and non-diversifiable return risk-premium. There are both positive and negative premia in the floating regime category, and while the average premium is marginally smaller in rigid regimes, the difference of average premium across regimes is negligible (10 basis points). Figure 2, however, shows that there is a systematic relation between exchange rate volatility and CAPM-estimated risk-premium. The t-test shows that the slope coefficient is significantly different from zero. Eventually, these findings reflect the lack of an appropriate measure of exchange rate regime flexibility in our panel (other than volatility); (iii) Economically, the premium size is important in 5 or 6 cases. It should be noted, however, that they are smaller than expected because the average excess return of our proxy for the world portfolio (MSWI) is only 2.49% in our sample (considerably smaller than the, say, 6% excess return of the Dow Jones in the last 50 years); (iv) The correlation between exchange rate volatility and risk-premium is largely irrelevant from an economic perspective. A 1% increase in the standard deviation of log changes of the exchange rate would generate a premium of 1 basis point; (v) The Mexican case is interesting because is the only country experiencing a regime switching in our sample (from flexible in Mexico I to floating in Mexico II). After the switching, Mexico shows an important increase in the point estimate of the risk-premium (almost 60 basis points), although it is not statistically significant; and (vi) In the cases of Canada and New Zealand there is a negative covariance between domestic returns and the world portfolio return, implying the existence of a risk-*discount*.

Finally, it is worth mentioning that countries showing a negative covariance with the world portfolio ($\beta < 0$) may have a positive average excess return (e.g., New Zealand in table 1). In a world without taxes this would mean that these countries absolutely dominate the world portfolio, which is a contradiction in an equilibrium model. However, in light of the tax augmented CAMP, this is perfectly valid because we measure gross returns (before taxes and capital controls).

Table 2. Exchange Rate risk-premium and Exchange Regimes

	Sample	$\hat{\beta}_b$	Standard Error	Risk Premium
Free Floating Regimes				
Australia	90.01–96.06	0.11	0.05	0.28
Canada	90.01–97.09	–0.08	0.04	–0.20
Mexico II	95.01–97.08	0.28	0.28	0.69
New Zealand	90.01–97.09	–0.09	0.06	–0.22
South Africa	90.01–97.08	0.14	0.05	0.34
Sweden	93.01–97.09	0.03	0.08	0.07
Group Average				0.16
Flexible Regimes				
Chile	90.01–97.07	0.00	0.05	0.01
Colombia	90.01–97.08	0.15	0.06	0.36
Mexico I	90.01–94.09	0.05	0.05	0.12
Israel	90.01–97.07	0.04	0.05	0.10
Korea	90.01–97.04	0.12	0.03	0.31
Malaysia	90.01–97.04	0.07	0.03	0.18
Group Average				0.18
Fixed and Rigid Regimes				
Argentina	91.05–97.07	0.01	0.01	0.02
Brazil	95.01–97.09	0.04	0.05	0.09
Indonesia	90.01–97.03	0.00	0.01	0.00
Thailand	90.01–97.02	0.08	0.01	0.19
Group Average				0.08

CAPM estimates with intercept (not reported) and ARMA process in residuals to obtain white noise.

risk-premium calculated as $\beta E[\tilde{r}_m - r_f]$ using sample averages.

4 Volatility and CAPM Risk-Premium in Chile

The fact that the CAPM-estimated exchange rate premium shows a systematic but economically irrelevant relation with exchange rate volatility does not necessarily mean that there is an important relation between volatility and risk-premium. One reason is that in a CAPM model one could have time-varying parameters, changing according to volatility, but close to zero on average. Another reason is that one could have imperfect diversification, with a risk-premium determined by overall volatility. This section investigates the extent of the first problem in the case of Chile, while next section estimates the effect of overall volatility on risk-premium in our country panel.

In order to evaluate whether volatility affects the CAPM-estimated risk-premium we try to explain weekly excess return data with the excess return of the world portfolio, allowing for different risk-effects (different *betas*) depending upon past volatility of the exchange rate. The exercise maintains the assumption that any diversifiable risk is actually diversified away.

We consider three alternative investment projects: (i) holding the domestic currency during 1 week; (ii) a 1-month deposit (in pesos); and (iii) a 3-month deposit (in UF). We continue using the 90-day Treasury Note rate as the proxy for the risk-free rate and the MSWI as the world portfolio. As for volatility, we consider three different indicators, defining a dummy variable equal to 1 in times of low volatility. The indicators are: (i) the standard deviation of log changes in the exchange rate during the last 4 weeks; (ii) the standard deviation of log changes in the exchange rate during the last 5 trading days; and (iii) the relative distance of the market exchange rate to the floor of the floating band.[7] In this last indicator we measure the exchange rate distance relative to the width of the band and it can be associated to volatility insofar the band is credible and there are no intra-marginal interventions (see Sanhueza, 1996). Measuring this distance as an absolute number does not make any difference for the final results. Notice that with this criterion we are testing together the hypotheses that volatility decreases near the exchange rate bands and that changes in volatility affect the CAPM-estimated risk-premium. We consider that a

[7]During the sample period Chile had an exchange rate floating band with width that changed from ±5.0% to ±10.0% and then to ±12.5%).

week is a low volatility one (i.e., dummy equal 1) when the indicator of volatility is higher that the sample median of that indicator.

We estimate the following equation for each type of investment:

$$\tilde{z}_{b,t} = \beta_b \tilde{z}_{m,t} + \text{Dummy} \times \beta_b' \tilde{z}_{m,t} + \tau + \varepsilon_t, \tag{2}$$

where Dummy represents a variable that takes the value 1 in low volatility weeks. As long as β_b' is negative, there will be evidence that volatility affects the CAPM risk-premium.

Table 3 presents the results of the estimation of this equation and the implied CAPM risk-premium in periods of high and low volatility, measured as an annual (percentage) premium. In each estimation we consider the appropriate ARMA structure in the residuals to obtain white noise innovations. The results show positive, statistically significant, but very small non-diversifiable risk effects. These results are consistent with those reported in section 2. They also show marginal and almost always insignificant variations of the risk-premium in periods of low volatility. In fact, there is only one significant effect —the case of holding currency for 1 week combined with the second dummy— but the implied change in the estimated risk-premium is largely irrelevant from an economic perspective.

5 GARCH-M Model

This section presents the results of our fourth exercise. We seek to evaluate whether an increase in exchange rate volatility (of any kind) produces a larger risk-premium. In part, we evaluate what happens when we relax the CAPM assumption that any diversifiable risk is traded. The Autoregressive Conditional Heteroscedasticity in Mean model (ARCH-M) is specially well suited for this purpose because it allows us to directly estimate the risk-premium as a function of volatility. For this to be possible, however, the data has to display GARCH (Generalized ARCH) effects or volatility clustering. That is, the variance of the exchange rate —or more generally, the variance of the excess return— has to be time-varying. If there is evidence of this effect, we estimate the premium using the exchange rate conditional standard deviation as an explanatory variable.

Table 3. Exchange Rate Volatility and CAPM risk-premium in Chile

	$\hat{\beta}_b$	Dummy $\times\hat{\beta}'_b$	High Volatility Premium	Low Volatility Premium
Dummy 1: Exchange Rate Volatility < Median (1)				
1-week currency	0.082	–0.004	0.11	0.11
	(0.034)	(0.045)		
1-month deposit	0.075	–0.001	0.08	0.08
	(0.026)	(0.018)		
3-month deposit	0.068	–0.021	0.12	0.08
	(0.026)	(0.027)		
Dummy 2: Exchange Rate Volatility < Median (2)				
1-week currency	0.113	–0.073	0.16	0.06
	(0.029)	(0.045)		
1-month deposit	0.067	0.010	0.08	0.09
	(0.023)	(0.013)		
3-month deposit	0.063	-0.020	0.11	0.08
	(0.025)	(0.018)		
Dummy 3: Exchange Rate − Weighted Floor < Median (3)				
1-week currency	0.080	–0.001	0.11	0.11
	(0.035)	(0.046)		
1-month deposit	0.070	0.007	0.08	0.09
	(0.023)	(0.011)		
3-month deposit	0.062	-0.014	0.11	0.09
	(0.024)	(0.016)		

CAPM estimates with intercept (not reported). Standard error in parenthesis.
ARMA(0,3) process in residuals for 1-week domestic currency investment and
ARMA (1,4) process in residuals for 1-month and 3-month deposit.
(1) Coefficient of variation calculated with data from last 4 weeks.
(2) Coefficient of variation calculated with data from last 5 days.
(3) Relative distance to the floor of the band weighted by band width.
Premium calculated as $\beta E[\tilde{r}_m - r_f]$, using the sample average.

The ARCH-M model has been widely used to study the relation between risk and return in finance.[8] As for the exchange rate premium, initial attempts using large-industrialized-country data with monthly frequency showed poor results. They reflected both the problem of (not) knowing who is to be compensated for the risk —the currency of the investor's consumption bundle— implying time-varying parameters with no a priori sign, and the fact that monthly exchange data usually show insignificant ARCH effects. Later attempts, however, have shown more promising results. To overcome the problems of the initial attempts we use weekly-frequency data (and focus on LDCs and small developed countries).

In our exercise we consider the uncovered interest parity condition augmented by a risk-premium ρ that depends on the (conditional) standard deviation of log changes in exchange rates as of time t:

$$i_t = i_t^* + \hat{e}_t^e + \rho(\sigma^2_{\hat{e}_t}), \tag{3}$$

where $\hat{e}_t^e$ is the expected (log) devaluation rate. Because we do not observe $i_t - i_t^*$ with the required frequency to generate long enough series of risk-premium, we approximate the latter by $-\hat{e}_t$.[9] Linearizing $\rho(.)$ as $\rho(\sigma^2_{\hat{e}_t}) = \alpha_0 + \alpha_1 \sigma^2_{\hat{e}_t}$, one has that the risk-premium proxy evolves according to:

$$-\hat{e}_t = \alpha_0 + \alpha_1 \sigma^2_{\hat{e}_t} + \eta_t, \tag{4}$$

where η_t is a disturbance that includes both an expectational error and the error arising from our proxy for the risk-premium (and, probably, errors arising from our linearization that we assume are negligible). That is, $\eta_t = \hat{e}_t^e - \hat{e}_t - (i_t - i_t^*)$. Rational expectations ensure that $\hat{e}_t - \hat{e}_t^e$ is orthogonal to $\sigma_{\hat{e}_t}$. Considering that these are variables that are known as of time t and that while the level of the exchange rate clearly depends on interest rate levels, its conditional variance does not need to, we assume that the same happens with $i_t - i_t^*$. In order to evaluate whether volatility generates a risk-premium we test if $\alpha_1 > 0$.

[8] See Bollerslev, Chou and Kroner (1992) for a survey.

[9] In this model it is not possible to use the overlapping return structure that we used in the other sections because this would generate a spurious correlation between volatility and risk-premium. Large exchange rate movements will produce both a large and trivial volatility effect and a change in premium in the same observation.

More specifically, we assume that the exchange rate can be written as the following ARMA process augmented by a volatility term:

$$-\hat{e}_t = \phi(L)\hat{e}_t + \theta(L)\varepsilon_t + \alpha_1\sigma^2_{\varepsilon_t}, \tag{5}$$

where $\phi(L)$ and $\theta(L)$ denote polynomials in the lag operator L and in which the variance of the innovation ε_t evolves according to:

$$\sigma^2_{\varepsilon_t} = \omega + \beta(L)\varepsilon^2_t + \gamma(L)\sigma^2_{\varepsilon_t}. \tag{6}$$

where $\beta(L)$ and $\gamma(L)$ denote polynomials in the lag operator L.

In what follows we present estimation results of this model for the countries in our sample that have daily data in Bloomberg and display exchange rate volatility. This implies that we lose Argentina and Malaysia from the panel. The estimation proceeds in three steps. First, we estimate an ARMA model as in equation (5) without the volatility term. The order of the polynomials follows from the standard Box-Jenkins technique. Second, we test whether there are GARCH effects in the residuals with an LM test (considering up to 6 lags). This amounts to test whether there is correlation among the squared residuals from the ARMA model. If there is evidence of volatility clustering we decide the order of the GARCH model by analyzing the autocorrelation functions of the squared residuals. Finally, given the specification for the ARMA and GARCH terms we estimate the system of equations (5) and (6) using maximum likelihood.

Table 4 presents the results of the order of the ARMA model for each country, the LM test for the presence of ARCH(1) against ARCH(0) effects and the GARCH specification we estimate. The sample for each country corresponds to the longest weekly data available since 1990. For Brazil we use the post-stabilization period and for East-Asian countries we exclude the 1997 crisis period. The results show that in the cases of Australia, Indonesia, Mexico, and New Zealand there is no evidence of volatility clustering. These four cases do not provide evidence about the effect of volatility on risk-premium in either way. In all other cases we find evidence of GARCH effects. As mentioned before, we choose the specification of the GARCH equation based on the correlation functions of the squared residuals.

Table 5 presents the results of the estimation of the complete ARCH-M model for the cases in which there is evidence of volatility clustering. The results show very

Table 4. ARMA and GARCH-M Specifications

	ARMA	LM-test	GARCH
Australia	0,0	0.00	—
Brazil	3,3	11.35	1,0
Canada	0,0	3.76	2,0
Chile	0,3	21.81	1,0
Colombia	2,1	2.93	1,0
Indonesia	0,0	0.05	—
Israel	0,0	8.86	1,0
Korea	0,0	15.11	1,0
Mexico	2,2	0.31	—
New Zealand	0,0	2.21	—
South Africa	2,0	4.45	1,0
Sweden	3,0	3.27	1,1
Thailand	0,0	20.59	1,0

The LM test distributes as $\chi^2(1)$.

95% critical value for the LM-test = 3.84.

heterogeneous effects of volatility (measured as standard deviation) on risk-premia. Only the case of Chile shows a strong and significant positive effect. In South Africa, on the contrary, there is a strong and significant negative effect (a discount). In all other cases the estimated ARCH-M effect is not significantly different from zero. This happens even though the parameters of the GARCH processes are usually numerically important and tightly estimated.

In order to evaluate the economic importance of the estimated parameters, table 5 also presents the effect of the mean conditional standard deviation (MCSD) on the premium. The numbers are measured as annual interest rate equivalents and show that the effect is very important in the case of Chile and South Africa, with a point estimate close to 5%. Obviously, given these results, in this exercise we do not find any systematic relation between exchange rate regime flexibility and the size of the risk-premium, nor in the effect of volatility on the risk-premium across regimes.

Table 5. GARCH-M Estimates

	ARCH-M ($\hat{\alpha}_1$)	ARCH(1)	ARCH(2)	GARCH(1)	$\hat{\alpha}_1 \times$MCSD
Brazil	0.130	0.259	–	0.674	0.43
94.08–98.02	(0.117)	(0.075)		(0.069)	
Canada	–0.090	0.036	0.090	–	-0.41
90.01–98.02	(0.645)	(0.048)	(0.045)		
Chile	0.862	0.169	–	–	4.59
90.01–98.02	(0.479)	(0.068)			
Colombia	–0.322	0.122	–	–	-1.69
92.09–98.02	(0.641)	(0.088)			
Israel	–0.215	0.091	–	–	-1.16
91.11–98.02	(0.754)	(0.054)			
Korea	0.187	0.352	–	–	0.62
90.01–97.10	(0.278)	(0.060)			
South Africa	0.761	0.279	–	–	4.78
90.01–98.02	(0.334)	(0.063)			
Sweden	–0.055	0.061	–	0.899	-0.54
92.12–98.02	(0.410)	(0.037)		(0.055)	
Thailand	0.309	0.197	–	–	0.60
90.01–97.05	(0.484)	(0.072)			

Standard errors in parenthesis.

Estimation sample below each country.

$\hat{\alpha}_1 \times$MCSD refers to the annual equivalent of the premium generated by the mean conditional standard deviation.

6 Concluding Remarks

This paper has shown evidence of the relation between exchange rate regime flexibility and exchange rate risk-premium in emerging markets and small industrialized economies. While there is evidence that flexibility translates into a more volatile exchange rate and more volatile domestic asset returns (measured in dollars), we do not find an economically relevant relation between flexibility and risk-premium. We find these results both in a CAPM model, in which it is assumed that any diversifiable risk is effectively diversified, and in an ARCH-M model, in which we study the effect of overall exchange rate volatility on the risk-premium. In the first case we find a statistically significant relation between volatility and risk-premium. These results do not preclude the possibility that exchange rate flexibility and volatility are important in particular cases.

When considering only non-diversifiable risk in Chile we do not find any economically relevant evidence linking exchange rate volatility and risk-premium. In part, this happens because in Chile almost all risk seems to be diversifiable in the international market. This does not mean, however, that diversification actually happens. Quite on the contrary, when we estimate an ARCH-M model we find a strong, positive and statistically significant effect of exchange rate volatility on risk-premium. Average conditional volatility could explain a premium of 5% per year in Chile.

The overall results show that exchange rate flexibility does not need to translate into a higher (and relevant) risk-premium. However, in the particular case of Chile, there is evidence showing that exchange rate volatility matters in determining this premium. Thus, policies that increase this volatility would allow for higher (and economically relevant) interest rate differentials. This is the case of widening the exchange rate band —floating, in the limit— if it actually increases volatility, and lifting some exchange rate controls.[10] Any policy recommendation, nevertheless, has to consider that volatility may also have real costs for private agents, especially if hedging instruments are not readily available.

Finally, one caveat in interpreting our results is that they focus on short-term

[10] Interestingly enough, Soto (1997) estimates that exchange rate volatility in Chile decreased by 20% thanks to the Unremunerated Reserve Requirement. In terms of risk-premium, our estimates predict that this drop in volatility decreases the risk-premium in approximately 1 percentage point.

investment projects and periods of "relative normality" in international capital markets. Potentially, results could be very different if one considers turbulent periods, such as a world large recession, and/or long-term investment projects. However, when considering large swings in returns and longer investment maturities, exchange rate regimes are likely to be less relevant. In fact, the finding of higher exchange rate volatility in flexible regimes is a result for high and medium frequencies.

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Appendix 1. CAPM with Taxes

The Capital Asset Pricing Model establishes a precise relation between the expected excess-return of an asset in period t and the expected excess-return of the aggregate portfolio. This relation is given by the covariance between both returns and can be written as (e.g., Huang and Litzenberger, 1988):

$$E[\tilde{z}_{i,t}] = \beta_i E[\tilde{z}_{m,t}], \tag{7}$$

where $E[.]$ denotes expectation, $\tilde{z}_{i,t}$ is the excess-return of asset i over the risk-free rate ($\tilde{z}_{i,t} \equiv \tilde{r}_{i,t} - r_f$), m denotes market portfolio, and $\beta_i = cov(\tilde{r}_{i,t}, \tilde{r}_{m,t})/var(\tilde{r}_{m,t})$.

This traditional version of CAPM predicts that the expected excess-return is completely explained by the relative covariance between the asset and market return. When analyzing international capital movements, it is usually assumed that the market portfolio is the world portfolio. However, in actual economies there are imperfections such as taxes and other transaction costs that can break this relation.[11] In this appendix we derive a static general-equilibrium CAPM version that incorporates fixed taxes for some assets. These taxes resemble the effect of some forms of capital controls such as reserve requirements. This type of control is now in place in Chile and Colombia.[12]

Time is discrete and there are 2 periods, 0 and 1. Assume that there are two risky assets, a and b, (for example, the rest of the world and Chile) with one share each outstanding. There is also a risk-free asset (with gross return r_f) in zero net supply. Each risky asset gives to investors a total value of $\tilde{v}_i$ in period 1, $i = a, b$. These values have a normal distribution with mean vector and variance-covariance matrix given by:

$$\begin{pmatrix} \tilde{v}_a \\ \tilde{v}_b \end{pmatrix} \sim \mathcal{N}\left\{ \begin{pmatrix} \bar{v}_a \\ \bar{v}_b \end{pmatrix}, \begin{bmatrix} \sigma_a^2 & \sigma_{ab} \\ \sigma_{ab} & \sigma_b^2 \end{bmatrix} \right\}.$$

Assume further that there is a continuum of investors with mass 1 who consume in period 1 only, have initial wealth equal to w_0 and have preferences with constant absolute risk aversion (CARA). Their utility function is given by $U = -E[\exp\{-A\tilde{w}\}]$,

[11] In fact, a usual test to verify CAPM is to estimate equation (7) with an intercept and check whether it is zero. See Campbell et al. (1997).

[12] See Budnevich and Le Fort (1997) for a description.

where $\tilde{w}$ is period 1 wealth and A is the absolute risk aversion coefficient. Lastly, suppose that investors who decide to invest \$1 in asset b have to pay τ in period 0, independently of final returns.

Each agent chooses a portfolio with x_a shares of asset a and x_b shares of asset b maximizing expected utility. Denoting P_a and P_b the prices of assets a and b, respectively, agents solve the following problem:

$$\begin{aligned}\max_{\{x_a,x_b\}} \quad & -E\left[-\exp\{Aw_0(1+r_f)+Ax_a(\tilde{v}_a-(1+r_f)P_a)+\right.\\ & \left.Ax_b(\tilde{v}_b-(1+r_f)P_b(1+\tau))\}\right],\end{aligned} \tag{8}$$

which is equivalent to

$$\begin{aligned}\max_{\{x_a,x_b\}} \quad & x_a\{\bar{v}_a-(1+r_f)P_a\}+x_b\{\bar{v}_b-(1+r_f)P_b(1+\tau)\}-\\ & \tfrac{A}{2}\left\{x_a^2\sigma_a^2+x_b^2\sigma_b^2+2x_ax_b\sigma_{ab}\right\}.\end{aligned} \tag{9}$$

First order conditions (FOC) of this problem are given by:

$$\bar{v}_a-(1+r_f)P_a = A(x_a\sigma_a^2+x_b\sigma_{ab}), \tag{10}$$

and

$$\bar{v}_b-(1+r_f)P_b(1+\tau) = A(x_b\sigma_b^2+x_a\sigma_{ab}). \tag{11}$$

From these FOC one can calculate the optimal x_a and x_b as functions of prices and parameters. Aggregating demands and comparing them to the available supply of each asset (one share of each), on can solve for the price vector of this economy:

$$P_a = \frac{\bar{v}_a-A(\sigma_a^2+\sigma_{ab})}{1+r_f}, \tag{12}$$

and

$$P_b = \frac{\bar{v}_b-A(\sigma_b^2+\sigma_{ab})}{(1+r_f)(1+\tau)}. \tag{13}$$

By definition of net return, $\tilde{r}_i = \tilde{v}_i/P_i - 1$. Thus, in the particular case of asset b, one has

$$E[\tilde{r}_b] = \frac{\bar{v}_b-P_b}{P_b} = r_f - \frac{A(\sigma_b^2+\sigma_{ab})}{P_b} + \tau. \tag{14}$$

The market portfolio, in turn, includes both assets a and b and has expected return given by:

$$E[\tilde{r}_m] = r_f + \frac{A(\sigma_a^2 + \sigma_b^2 + 2\sigma_{ab})}{P_a + P_b} + \frac{\tau P_b}{P_a + P_b}. \tag{15}$$

Insofar asset a has a considerably larger value than asset b (for example, the case of the world portfolio *vis-à-vis* a small developing country), the last component of this equation converges to zero.

Lastly, one has

$$\beta_b = \frac{cov(\tilde{r}_b, \tilde{r}_m)}{var(\tilde{r}_m)} = \frac{(P_a + P_b)(\sigma_b^2 + \sigma_{ab})}{P_b(\sigma_a^2 + \sigma_b^2 + 2\sigma_{ab})}, \tag{16}$$

which, using equation (15), can be replaced in equation (14). Assuming that $P_b/P_a \to 0$ from above, this implies that the expected excess return in asset b is given by:

$$E[\tilde{z}_b] = \beta_b E[\tilde{z}_m] + \tau. \tag{17}$$

This is a relation similar to standard CAPM, but augmented by a constant. Assuming rational expectations, this equation can be written as:

$$\tilde{z}_{b,t} = \beta_b \tilde{z}_{m,t} + \tau + \varepsilon_t, \tag{18}$$

where ε_t is an error that is orthogonal to expected returns. This equation is the base for the estimation of risk-premia in the main text when we assume that all diversifiable risk is effectively diversified.

Appendix 2. Data Description

Countries

- *Interest Rate*: 3 month deposit rate. Source: IFS (IMF).
- *Exchange Rate*: End of month exchange rate. Source: IFS (IMF). End of week exchange rate. Source: Bloomberg.
- *Risk-Free Interest Rate*: 3 month US Tresury Bill. Source: Bloomberg.
- *Market Return*: 3 Monthly variation of the Morgan Stanley World Index. Source: Bloomberg.

Chile

- *Interest Rate*: 3-month deposit real rate. Monthly average and weekly closings. Source: Central Bank of Chile
- *Exchange Rate*: market exchange rate. Monthly average and weekly closings. Source: Central Bank of Chile
- *Future Discount*: UF/dollar 3-month futures. Monthly average and weekly closings. Source: Central Bank of Chile

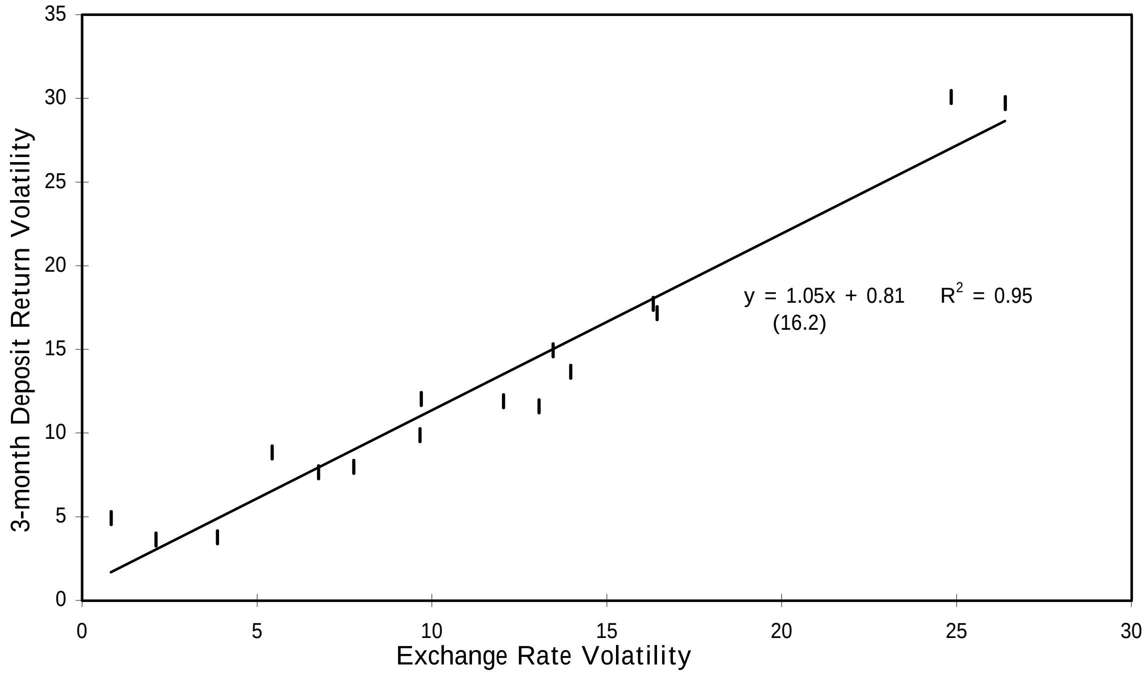

Figure 1. 3-month Excess Return Volatility and Exchange Rate Volatility

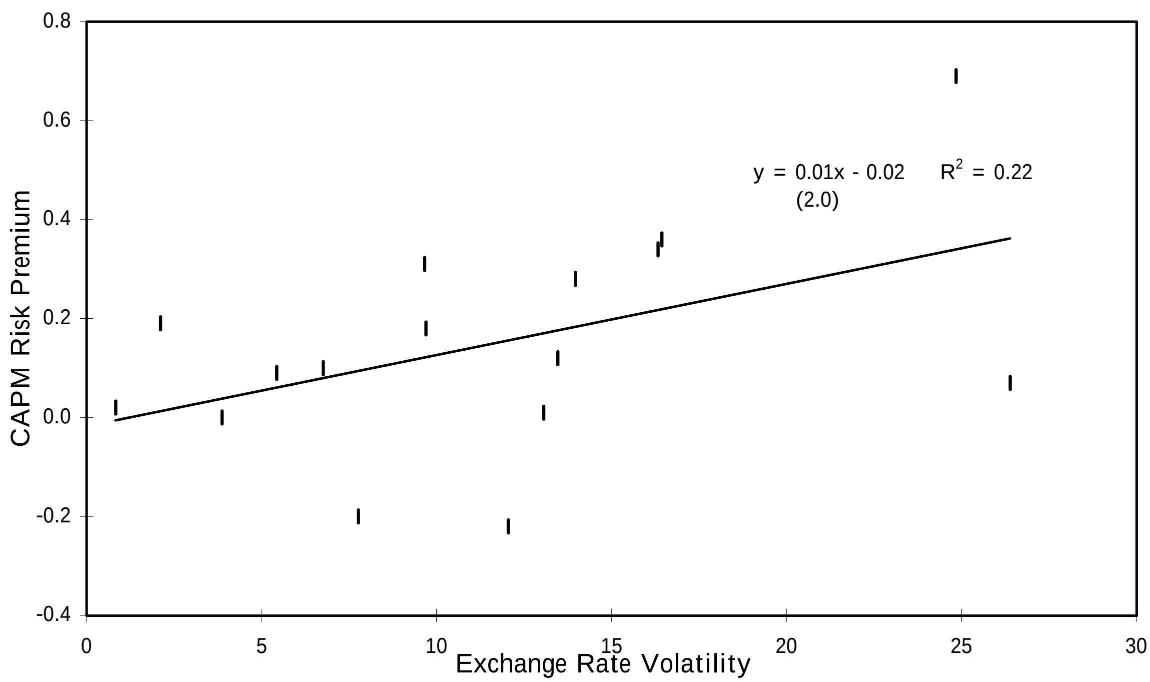

Figure 2. CAPM Risk Premium and Exchange Rate Volatility

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