Affine Term Structure Models for the Foreign Exchange Risk Premium in Armenian Deposit Market[1]

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Abstract

This paper studies foreign exchange risk premium using the uncovered interest rate parity framework in a single country context. The analysis is performed using weekly data on foreign and domestic currency deposits in Armenian banking system. The paper provides the results of the simple tests of uncovered interest parity condition, which indicate that contrary to established view dominating in empirical literature there is a positive correspondence between exchange rate depreciation and interest rate differentials in Armenian deposit market. Furthermore, the paper presents and discusses a systematic positive risk premium required by the economic agents for foreign exchange transactions, which increases over the investment horizon. The two currency affine term structure framework is applied to identify the factors driving the systematic exchange rate risk premium in Armenia. At the end, possible directions for further research are outlined.

1 Introduction

Currency risks constitute one of the most important sources of uncertainty in transition countries, most of which are small open economies very vulnerable to exchange rate fluctuations. Surprisingly, transition economies are missing established derivatives markets (including the foreign exchange derivatives market), which would enable economic agents to hedge risks related to the exchange rate volatility. On the one hand, the absence of derivatives market prevents the economic agents to share the exchange rate risks (with well known welfare implications) using standard methods employed in more developed economies. On the other hand, lack of derivatives prices significantly complicates the analysis of exchange rate risks in transition countries.

A straightforward question which emerges from the discussion above is what is the mechanism of exchange rate risk sharing in transition economies? In other words, how the agents hedge against the exchange rate risks in the absence of foreign exchange derivatives markets?

The empirical evidence coming from most of the transition countries suggests that they are heavily dollarized. Apart from its over functions, dollarization, in fact, serves as a main tool for hedging against exchange rate risks transition economies. In the presence of dollarization a significant portion of agents' financial wealth is allocated in terms of foreign currency denominated financial assets, which results in quite an active market of foreign exchange denominated financial instruments. This observation leaded us to the conclusion that relative prices (interest rates) of domestic and foreign currency denominated financial instruments in the local financial markets must contain important information on how the economic agents in transition economies price exchange rate risks.

This paper studies the driving forces of the foreign exchange risks in transition economies using Armenia as a case study. There are several reasons making this analysis attractive from both theoretical and practical points of view. First, Armenia is one of the fewest transition countries which have never operated under fixed exchange rate regime after gaining the independence (see figure 1), which implies that exchange rate risks were always present in Armenia. Next, Armenia has one of the most liberalized capital accounts among transition economies (ranked 42^{nd} in the Index of Economic Freedom, 2005 issue[1]) and there were no ceilings and other administrative restrictions imposed on deposit rates, which could introduce noisy pattern in the behavior of interest rates series. In addition, the available information on Armenian interest rates (see the discussion below) allows to overcome the problem of imperfect substitutability and to control for the country-specific risks in modeling the foreign exchange risk premium.

Furthermore, despite of the recent advancements in real and financial sectors of the economy and developed legislative background, there is no established market for the foreign exchange derivatives in Armenia. Apart from forward contracts occasionally traded by single banks for unreasonably high costs, there are no forward deals taking place elsewhere (including Armenian stock exchange). This observations goes along with high and persistent level of dollarization in Armenia, which results in quite active market of foreign currency denominated financial instruments (the share of foreign currency denominated deposits is about 70% of total deposits in the banking system).

Finally, the high frequency data on foreign and domestic currency denominated deposits

[1] More detailed information is available at: http://www.heritage.org/research/features/index/

available for Armenia provides a unique opportunity to compare yields on financial instruments which are similar in all relevant characteristics except the currency of denomination. This is one of the most important preconditions in modeling the currency risks often neglected in related literature. To our best knowledge, this is a first attempt to address the issue of exchange rate risks using the *local* financial markets data on financial instruments denominated in two different currencies.

The rest of the paper is organized as follows. The second section provides a review relevant studies and summarizes the main approaches for modeling exchange rate risks employed in the literature. The third section contains a detailed analysis of exchange rate risk premium using data from the Armenian deposit market. The last section summarizes the results of the study.

2 Literature Review

2.1 "Forward premium" puzzle

Economists have long been concerned with the issue of modeling foreign exchange risks. This issue is closely related to a fundamental relationship of uncovered interest parity (UIP) condition. The UIP is a fundamental building block of most theoretical models in international economics literature, which states that when domestic interest rate is higher than the foreign interest rate the domestic currency is expected to depreciate by an amount approximately equal to the interest rate differential. Intuitively, the UIP predicts that the expected foreign exchange gain from holding one currency rather than another - the expected exchange rate change - must be offset by the opportunity cost of holding funds in this currency rather than another - the interest rate differential (Sarno and Taylor, 2002). This condition can be expressed as:

$$s^e_{t+k} - s_t = i_t - i^*_t \qquad (1)$$

where s_t denotes the logarithm[2] of the spot exchange rate at time t, i_t and i^*_t are the nominal interest rates available on similar domestic and foreign assets respectively (with k periods to maturity), superscript e denotes the market expectation based on information at time t. An analog of the UIP often discussed in the literature is the covered interest parity condition (CIP), in which forward exchange rate appears in equation (1) instead of the exchange rate expectations.

In practice, the validity of interest parity conditions has been tested by using the following two approaches. The first approach relies on computing the actual deviations from the interest parity to see if they differ significantly from zero. Among those who employed this approach, Frenkel and Levich (1975) use three-month treasury bills for the UK and the USA to compute whether the covered differential: $CD_t = (i - i^*)_t - f_t$ is equal to zero or not. They report that many observations give non-zero value for CD_t. They explain the difference by the transaction costs facing an investor who engages in a covered position. Frenkel and Levich construct a neutral

[2]The relationship is normally expressed in logarithms in order to circumvent the so-called "Siegel Paradox" (Siegel, 1972) that, because of a mathematical relationship known as Jensen's inequality, one can't simultaneously have an unbiased expectation of, say, the pound-dollar exchange rate (pounds per dollar) and of the dollar-pound exchange rate (dollars per pound), because $1/E[S] \neq E[1/S]$. This problem does not arise if agents are assumed to form expectations of the logarithm of exchange rates, since $E[-s] = -E[s]$.

band (in average ±0.147 percent for the 3 currencies considered) to account for the possibility of transaction costs and report that over 80% of deviations from the CIP lie within the band.

A second method for testing the validity of UIP has been the use of regression analysis. The following regression equation has been used as a workhorse for testing the UIP:

$$s_{t+k} - s_t = \alpha + \beta(i - i^*)_t + u_t \tag{2}$$

If UIP holds, equation (2) should result in estimates of α and β differing insignificantly from zero and unity respectively. In practice, the focus of researchers has mostly been on estimates of the slope parameter β. Using a variety of currencies and time periods, a large number of researches have implemented (2) and obtained results unfavorable to the efficient market hypothesis under risk neutrality. Froot and Thaler (1990) report that the average value of coefficient β over 75 published estimates is -0.88. Only few of the obtained estimates are greater than 0 and neither of the estimates is greater than 1. This result seems particularly robust given the variety of estimation techniques used by the researchers and the mix of overlapping and non-overlapping data sets. This fact has been labeled "forward premium" puzzle, which suggests that the forward premium mispredicts the direction of the subsequent change in the spot rate[3].

A large amount of research effort has been expended in trying to rationalize "forward premium" puzzle[4]. The first and by far the most popular explanation is to argue that *investors are risk averse*. If foreign exchange market participants are risk averse, the uncovered interest parity condition (1) maybe distorted by a risk premium, because agents demand a higher rate of return than the interest differential in return for the risk of holding foreign currency. If risk premium is time varying and correlated with interest differential, equation (2) would result in biased estimates of β. An alternative explanation of the failure of the simple efficient market hypothesis is *rejection of rational expectations hypothesis*. Examples are: the "peso problem"[5] (Rogoff, 1979), the rational bubble phenomenon (Flood and Garber, 1980) and learning about regime shifts or inefficient information processing (Lewis, 1995). Still other explanation of bias was developed by McCallum (1994) and is related to *monetary policy conduct*. McCallum claims that the UIP is implied from the general equilibrium models independently of the manner in which the monetary policy is conducted. However, the outcomes of statistical tests are dependent on the monetary policy behavior, since monetary policy may influence the time series property of nominal interest rate differential. For example, in case exchange rate depreciates, monetary policy could be tightened (raise in domestic interest rate) as a response, which introduces negative correlation between (i_t-i_t^*) and the error term.

Initially, the UIP concept was challenged by the empirical literature, but recently Baillie and Bollerslev (2000) showed that failure to find evidence for the presence of the interest rate parity condition can be due to wrong statistical modeling. More advanced econometric methodologies display evidence in favor of the interest rate parity: based on the cross-equation restrictions on

[3]Negativity of the estimated slope coefficient implies that the more the foreign currency is at premium in the forward market; the less the home currency is predicted to depreciate over k periods to maturity.

[4]A detailed survey of literature can be found in Taylor (1995) and Lewis (1995).

[5]The "peso problem" refers to the situation where agents attach a small probability to a large change in the economic fundamentals, which does not occur in sample. This will tend to produce a skew in the distribution of forecast errors even if agents' expectations are rational and thus may generate small-sample bias in the UIP regressions (Sarno and Taylor, 2002).

a Markov switching process, Kirikos (2002) finds that the parity relationship cannot be rejected for three European currencies vis-à-vis the US dollar.

Empirical evidence, albeit scant, supports the UIP among the European transition countries. Golinelli and Rovelli (2005) adopted the UIP hypothesis for estimating exchange rates in order to account for the process of disinflation in the Czech Republic, Hungary and Poland. They show that the current exchange rate depends on the current interest rate differential and on the expected future exchange rate, augmented by a risk premium. Further empirical support is given by Orlowski (2004) who proposes a model linking exchange rate volatility to differentials over the euro zone in both inflation (target variable) and interest rate (instrument variable). In a VAR framework he shows that an increase in domestic interest rates relative to German rates contributes to currency appreciation with a one-month, and repeatedly, a three month-lag in the Czech Republic and a two-month lag in Hungary, while the results for Poland are inconclusive. Thus, changes in the value of the Polish currency relative to the euro show a considerably weaker response to interest rate differentials than the relative changes in the currencies of the two remaining countries (Czech Republic and Hungary).

During the last decade, some authors revisited this issue using the data from emerging market economies. The paper by Bansal and Dahlquist (2000) analyzes data from 16 developed and 12 developing economies and introduces completely new evidence on the relationship between expected currency depreciation and interest rate differential. Contrary to the established view dominated in the literature, Bansal and Dahlquist (2000) found that the theoretical prediction of positive relationship between future exchange rate changes and current interest rate differentials works better in emerging market economies. Using pooled time series and cross-section data, Bansal and Dahlquist (2000) document that there is a close relation between country specific variables (namely, per capita GNP, inflation rate and its variability, country ratings) and "forward premium" puzzle.

To interpret this new evidence, the authors refer to general equilibrium models, which attempt at explaining "forward premium" puzzle as an outcome of the time varying risk premia. In particular, the authors claim that the cross-sectional evidence is consistent with the intuition contained in the models, which incorporate non-Fisherian effects (Lucas, 1990). A distinguishing feature of this type of models is that with a rise in inflation uncertainty the model behaves almost like standard Fisherian models (see Fuerst, 1992). However, if expected inflation is low, non-Fisherian fundamentals have stronger impact. The authors argue that in emerging economies agents typically have larger inflation expectations; hence the Fisherian relation between expected depreciation and interest rate differential (i.e. absence of the "forward premium" puzzle) seems to find more support in these economies. On the other hand, for low inflation economies non-Fisherian effects dominate, which can potentially lead to the "forward premium" puzzle.

The authors' claim that the theoretical predictions on no-arbitrage relationship in financial markets work better for the emerging countries with less developed financial infrastructure seem to be counterintuitive. In addition, Bansal and Dahlquist do not account for such important country specific attributes as the type of exchange rate regime (fixed versus floating) and the level of capital market liberalization. These aspects were found to be influential in explaining the "forward premium" puzzle in other studies.

Flood and Rose (1996) examine impact of the exchange rate regime adopted by the country on the excess exchange returns. Based on empirical analysis of pooled data for 17 developed economies, the authors reconfirm the established view of negative correlation between interest differential and exchange rate depreciation. In order to evaluate the dependence of this evidence on exchange rate regime differences, the authors compare the pooled regression results with the ones obtained from a similar regression run on data of only fixed exchange rate countries. The obtained results suggest that the uncovered interest parity relationship works much better for fixed exchange rate countries. Instead of being negative, the slope coefficient for fixed exchange regime economies is now +0.6, though still significantly below from its hypothesized value of unity.

The paper also analyzes the impact of the "peso problem" on the uncovered interest parity relationship. For this purpose, the authors compare results from regressions run on data on European countries with realignments due to ERM mechanism (those include Belgium, Luxembourg, Denmark, France, Ireland, Italy, the Netherlands, Portugal and Spain) and excluding the realignments. The obtained results indicate that the "peso problem" leads to a bias in the slope coefficient of interest rate differential, amounted to −0.5. Combining the two results, the authors conclude that the "peso problem" is lacking in explaining the overall departure from uncovered interest parity relationship. The reason is that, first of all, the bias created by "peso problem" is not sufficiently high, and second, the "peso problem" by definition should affect only countries with fixed exchange rate regimes, while the departure from the uncovered interest parity condition comes from the information on countries with floating exchange regime.

The potential drawback of this analysis is that it is difficult to draw a borderline between countries based on the type of exchange rate regime, because a number of countries (UK, Spain and Portugal are an examples) changed their exchange rate regimes and policies throughout the analyzed period. Another problem is that there are different types of fixed exchange rate regimes and some of them are quite similar to floating regimes, since they allow for flexibility within quite wide exchange rate bands. This also creates difficulties in evaluating the impact of exchange rate regime flexibility on the parity condition.

In their more recent study, Flood and Rose (2002) revisited the uncovered interest parity relationship by analyzing daily data from 10 developing and 13 developed countries during the various crisis episodes in 1990's. Contrary to Bansal and Dahlquist (2000), the authors document that income differences across countries do not seem to have a significant impact on the uncovered interest parity relationship. The authors fail to find a significant impact of the type of exchange rate regime on the slope coefficient from the regression of exchange rate changes on interest differential yields. Flood and Rose document that the theoretical predictions on uncovered interest parity relationship work better for economies during the crisis period, which constitutes the main message of the paper.

The impact of the capital market liberalization on uncovered interest parity relationship in emerging economies has been studied in Francis, Hasan and Hunter (2002). The study focuses on the time-varying risk premium explanation of deviations from the uncovered interest parity. In the authors' view, the financial markets liberalization package, including elimination of exchange rate controls, stabilization of exchange rates, removal of restrictions on capital flows, removal of interest rate restrictions and inflation stabilization, is expected to change foreign investor's perception of the need for a risk premium and, therefore, affect deviations from the uncovered interest parity condition. Estimation results indicate that the deviations from uncovered interest parity condition are indeed affected by the liberalization of capital markets, but the direction of the impact is regional in nature and varies across countries. More specifically, the authors document that in Latin American countries the capital market liberalization cause an increase in a systematic component of deviations from the uncovered interest parity. On the contrary, Asian countries have experienced decline in excess currency returns following the financial liberalization.

The simplifying assumption that liberalization has taken place at some particular point in time the authors employ in their research, however, does not correspond much to the reality. The financial liberalization procedure historically differs across countries. Usually this procedure includes several stages, so it is hard to come up with single period of time, which could be considered as a borderline between the liberalized and non-liberalized market period.

2.2 Stochastic Discount Factor Models

Most recent studies employ the stochastic discount factor (SDF) and affine term structure models for studying foreign exchange risk premium in international financial markets (see Cuthbertson and Nitzsche, 2005 for a comprehensive review). The first approach is based on multivariate GARCH-in-mean estimation technique, and the second approach makes use of the two-country version of the affine term structure models.

The first approach, which is also known as "observable factors" approach, involves computational difficulties related to estimation of conditional moments. The studies which employed this approach usually imposed ad hoc restrictions on the conditional covariances matrix. For example, one of the most recent studies by Balfoussia and Wickens (2003) uses multivariate GARCH-in-mean model on the US data. The authors pick up changes in consumption and inflation rate as factors explaining the excess return for bonds. In order to avoid computational difficulties, they imposed restrictions on the conditional covariance matrix, assuming that conditional covariance depends only on its own past values and its own past surprises. Overall conclusion of the authors is that the relationship between excess returns and conditional covariances is not statistically well determined to explain the time-varying risk premia in the US.

Another recent study by Smith and Wickens (2002) employs a simpler form of multivariate GARCH-in-mean process with constant correlations to analyze the foreign exchange risk premium using US-UK data. The equations derived from the consumption capital asset pricing model for the excess return on foreign investment are of the form:

$$E_t R_{t+1} + 0.5 V_t(R_{t+1}) = k_{us} cov_t(\Delta c_{t+1}^{US}, R_{t+1}) + cov_t(\Delta p_{t+1}^{US}, R_{t+1}) \quad (3)$$

$$E_t R_{t+1} - 0.5 V_t(R_{t+1}) = -k_{uk} cov_t(\Delta c_{t+1}^{UK}, R_{t+1}) - cov_t(\Delta p_{t+1}^{UK}, R_{t+1}) \quad (4)$$

where $R_{t+1} = (\Delta s_{t+1} + r_t^* - r_t)$ is deviation from the UIP and $V_t(.)$ term stands for Jensen's inequality. These equations imply that the larger the conditional covariance of the depreciation of the currency with the growth of consumption and with inflation, the greater is the risk premium for investors. Adding these two equations, the $V_t(.)$ term disappears and ER_{t+1} depends on the covariance for the both countries' consumption and inflation:

$$E_t R_{t+1} = 0.5[k_{us} cov_t(\Delta c_{t+1}^{US}, R_{t+1}) + cov_t(\Delta p_{t+1}^{US}, R_{t+1}) - k_{uk} cov_t(\Delta c_{t+1}^{UK}, R_{t+1}) - cov_t(\Delta p_{t+1}^{UK}, R_{t+1})] \quad (5)$$

Smith and Wickens applied this equation to the monthly data for 1975-1997 period and got insignificant coefficients for the covariance terms, which stand for coefficients of relative risk aversion. The authors then generalize the model by assuming that stochastic discount factor may be influenced linearly by other important macroeconomic variables, namely, consumption, output and money growth. The expected returns equation now becomes:

$$R_{t+1} = \gamma_1 R_t + \gamma_2 fp_t + \gamma_3 V_t(R_{t+1}) + \phi^{US} Z_{t+1}^{US} + \phi^{UK} Z_{t+1}^{UK} + \varepsilon_{t+1} \quad (6)$$

where R_t and fp_t (forward premium) and $V_t(R_{t+1})$ (variance of R_{t+1}) have been added to create a general model and Z_{t+1}^{US}, Z_{t+1}^{UK} represent the covariance terms for the US and UK variables.

If the stochastic discount factor model holds, then it is expected that $\gamma_i = 0$ for $i = 1, 2, 3$. The authors report that the estimation results predict that additional factors have little support and the "forward premium" puzzle remains.

An alternative method to study time-varying foreign exchange risk premia is based on the affine models of term structure (ATS). The key assumption of these models is that the stochastic discount factor (and therefore also the risk free interest rate) is a linear function of the state variables. The single factor ATS models imply that the shape of the yield curve and the risk premium depend only on the time to maturity and the shape of the yield curve is fixed over time (Vasicek, 1977). The single factor Cox, Ingersoll and Ross (1985) model (CIR) fixes the shape of the yield curve but allows the risk premium to move over time due to changes in the short rate. The greater flexibility in the shape of the yield curve requires multifactor affine models (Cuthbertson and Nitzsche, 2005).

For the foreign exchange risk modeling purposes, the literature usually makes a use of the two-country ATS framework. The idea is that the relationship between the expected exchange rate depreciation and interest rate risks can be characterized by stochastic discount factors for two financial instruments denominated in two different currencies.

To illustrate the two-country ATS approach, let's start from the usual equilibrium asset pricing condition:

$$E_t[M_{t+1}(1 + R_{t+1})] = 1 \tag{7}$$

where M_{t+1} is the domestic currency stochastic discount factor and R_{t+1} is the return on financial instrument. Backus, Foresi and Telmer (2001) show that stochastic discount factor that prices payoffs in foreign currency instruments ($\widetilde{M}_{t+1}$) can be formed by scaling M_{t+1} by the growth in nominal exchange rate $\frac{e_{t+1}}{e_t}$. Hence, the equilibrium asset pricing condition for financial instruments denominated in foreign currency can be expressed as:

$$E_t[\widetilde{M}_{t+1}(1 + \widetilde{R}_{t+1})] = E_t[M_{t+1}\frac{e_{t+1}}{e_t}(1 + \widetilde{R}_{t+1})] = 1 \tag{8}$$

The relationship between different currencies SDFs and exchange rate growth can be stated as:

$$\frac{e_{t+1}}{e_t} = \frac{\widetilde{M}_{t+1}}{M_{t+1}} \tag{9}$$

It is common approach in the two-country ATS economic models to imply particular relation in $\widetilde{M}_{t+1}$ and M_{t+1}, then use relationship (9) to derive restrictions on the expected depreciation and the forward premium. For example, Nielsen and Saá-Requejo (1993) and Backus, Foresi and Telmer (2001) use CIR model to restrict $\widetilde{M}_{t+1}$ and M_{t+1} and derive implications for the forward premium and expected depreciation of exchange rate.

Many celebrated term structure models, such as Vasicek (1977), Cox, Ingersol and Ross (1985)[6], Longstaff and Schwartz (1992), and Duffie and Kan (1996) share the same property: the discount factors M and $\widetilde{M}$ in these models are characterized solely by risks contained in

[6]We will use abbreviation CIR for this study in the rest of the paper.

the domestic interest rates. That is why it is very important to properly model volatility of the interest rates, to derive appropriate conclusions about the behavior of the SDF and the foreign exchange risk premium.

Backus, Foresi and Telmer (2001) use CIR structure to derive restrictions on the foreign exchange risk premium and exchange rate changes. They show that under the assumption of joint log-normal distribution of the variables, the foreign exchange risk premium is the following linear function of the market prices of risk:

$$p_t = \frac{[\widetilde{\lambda}_t^2 - \lambda_t^2]}{2} \tag{10}$$

where $\lambda_t = \frac{c(r_t)}{\sigma(r_t)}$ is the market price of risk in domestic returns, which is denoted as a ratio of conditional returns and conditional volatility; $\widetilde{\lambda}_t = \frac{c(\widetilde{r}_t)}{\sigma(\widetilde{r}_t)}$ is an analogous equation for the market price of risk in foreign returns. Intuitively, the market price of risk determines the slope of the mean standard deviation frontier in domestic and foreign returns.

The last equation implies that the relationship between the interest differential, the expected depreciation rate and the risk premium is:

$$[r_t - \widetilde{r}_t] = d_t + \frac{[\widetilde{\lambda}_t^2 - \lambda_t^2]}{2} \tag{11}$$

Economic intuition behind (10) and (11) is that the expected depreciation and the forward risk premium are determined by interest rate risks across financial instruments denominated in different currencies.

Bansal (1997) imposes some structure on conditional moments of foreign and domestic returns in order to evaluate the explanatory power of the single-factor term structure models in the context of the "forward premium" anomaly. Bansal specifies the following conditional moments:

$$c_t = \mu + \delta r_t \tag{12}$$

$$\sigma_t = \kappa r_t^\gamma \tag{13}$$

where μ, δ, κ and γ are parameters and $\kappa > 0$. The author argues that this specification nests a variety of single-factor models. For instance, the specification $\delta = 0$ and $\gamma = 0$ corresponds to Vasicek's (1977) specification and implies that market risk is constant: $\lambda = \frac{\mu}{\kappa}$. The CIR specification corresponds to $\mu = 0$ and $\gamma = 0.5$, which implies that $\lambda_t = \frac{\delta}{\kappa}\sqrt{r_t}$. In addition, $\gamma = 1$ corresponds to the specification by Brennan and Schwartz (1979), and $\gamma > 1$ is considered in Chan et al. (1992).

Using data on USA, Germany and Japan financial variables, Bansal performs GMM estimations of the two-country ATS model based on the following assumptions: excess returns are conditionally normal, conditional moments can be represented as in (12) and (13) and a single factor is adequate to characterize excess returns and risks. The empirical results suggest that the single-factor parametric term-structure models can not account for the negative slope coefficient in the forward premium equation and the “forward premium” puzzle remains. The author suggests extending the model by developing a framework with quantitative implications that provide a detailed link between the market price of risk and aggregate economic variables.

3 Modeling Foreign Exchange Risk Premium in Armenia

This section studies the foreign exchange risks using the data on deposit rates from Armenian banking system. The analysis is performed using returns from financial instruments similar in all relevant characteristics except the currency of denomination. To our best knowledge, this is the first attempt to use this type of data for foreign exchange risk modeling purposes.

Another reason making Armenia a good case for studying foreign exchange risks is that Armenia has never fixed its currency throughout the period under consideration (1997-2004). This means that the risks associated with uncertainty about the future level of the exchange rate were always present in Armenia (see figure 1). In addition, this observation makes the results of the analysis robust to inconsistencies in the UIP performance resulting from exchange rate regime shifts highlighted in Flood and Rose (1996).

Finally, there were no ceilings and other administrative restrictions imposed on the deposit rates in Armenia, which implies that the returns on the financial assets were determined purely by market forces. To conclude, by the above virtues Armenia serves as an excellent laboratory where naturally occurring events and settings are almost of a quality of a natural experiment.

3.1 Background Analysis

The dataset employed in this study covers whole Armenian banking system for period 1997-2004. It includes weekly interest rates on foreign and domestic currency denominated deposits for 30, 60, 90, 180 and 360 days maturities. Summary statistics of the Armenian deposit interest rates data is provided in the Appendix.

We start the analysis of the exchange rate risks by plotting the interest rate differentials and exchange rate changes for all maturities financial instruments in order to check for the “forward premium” puzzle (see figure 2). As it can be observed from the picture, the slope coefficient is positive, which is in contrast to the anomalous empirical findings widely documented in the literature.

In order to identify the role of the cross-country risks and transaction costs on the UIP relationship we calculate the deviations from the UIP relationship ($d_t = i_t - i_t^* - \Delta s_t$) using local deposit interest rates and conduct t-test to see whether the deviations are significantly different from zero. The results of the test are then contrasted to the deviations obtained using comparable financial instruments in the USA, namely, the secondary market yields on the US deposit certificates. Additionally, the same calculations are performed by using monthly observations for the Armenian and the US T-Bill rates. Table 1 summarizes the results of the performed tests.

The reported results allow us to make several conclusions. First, the UIP works quite well for the local deposit market: the deviations are not significantly different from zero for all maturities' differentials and on average. This observation implies that domestic market financial

Table 1: Deviations from the UIP and mean equality test

	30 days	60 days	90 days	180 days	360 days	Average	TBills rates
USD rates							
Average [$St.Dev.$]	0.011 [0.007]	N/A	0.039* [0.022]	0.084* [0.043]	N/A	0.045* [0.024]	0.263* [0.151]
Prob.	0.1098	N/A	0.0796	0.0513	N/A	0.0676	0.0852
AMD rates							
Average [$St.Dev.$]	0.005 [0.013]	0.007 [0.019]	0.013 [0.023]	0.029 [0.035]	0.046 [0.053]	0.020 [0.021]	N/A
Prob.	0.7228	0.7104	0.5657	0.4034	0.3807	0.3370	N/A
Mean equality test							
$t-stat$	6.489	N/A	13.734	18.648	N/A	14.461	N/A
Prob.	0.0000	N/A	0.0000	0.0000	N/A	0.0000	N/A

Note: * stands for a 10% significance level.

instruments provide more accurate measure of exchange rate risks, which does not contradict to the theoretical predictions.

Next, the cross-order UIP works only for the short-term maturities interest rate differentials (at marginal significance level), while for the long-term maturities and on average the UIP performs poorly. The discrepancy of these results with the ones obtained by using only Armenian data can be interpreted as a consequence of country risk and large transaction costs necessary to make financial operations across countries. These findings are confirmed by the outcome of the mean equality test, which suggests that the null hypothesis of the equality of average deviations from the UIP (negligible transaction costs and country risk factors) is rejected with a very high significance level for all the maturities financial instruments.

Another interesting result emerging from this exercise is that deviations from the UIP are strictly positive on average for all the maturities financial instruments. This suggests that a systematic positive risk premium is required by the agents in order to invest in local currency denominated deposits[7].

To describe the dynamics of the risk premium in greater details, we present its behavior over different years (see Table 2).

The examination of the Table 2 leads to the following conclusions. First, positive deviation from the UIP attributed to risk premium still dominates across the years. Next, the size of the deviation tends to have increasing pattern with maturity of the deposits. This result suggests that as a matter of fact, the amount of risk premium required by agents was larger for longer horizons due to introduction of additional uncertainty. The maturity effect can be more markedly observed in figure 3. As it is clear from the picture, the deviations from UIP are becoming larger for longer maturity interest rates differentials.

[7]This finding is broadly in line with those of Golinelli and Rovelli (2005) for three European emerging market economies (Czech Republic, Hungary and Poland).

Table 2: Deviations from the UIP by years (%)

	30 days	60 days	90 days	180 days	360 days	Average
1998	0.38	-0.06	1.80	4.84	4.05	2.20
1999	0.43	0.82	1.77	2.24	1.14	1.28
2000	-0.08	0.02	0.09	2.00	7.23	1.85
2001	0.50	0.59	1.40	1.56	1.79	1.17
2002	0.07	0.09	0.06	1.19	4.31	1.15
2003	0.46	1.11	1.30	2.13	3.16	1.64
2004	1.30	2.41	2.98	6.62	10.77	4.82
Average	0.44	0.71	1.34	2.94	4.64	

3.2 Affine Term Structure Models

As it has already been mentioned in the previous section, a two currency ATS model provides an intuitive framework for addressing the issue of the foreign exchange risk premium. The single factor ATS models assume that the exchange rate risk premium is determined solely by interest rate risks across the financial instruments denominated in different currencies. This is the reason why volatility of interest rates changes is an important factor characterizing the expected exchange rate depreciation in the ATS models.

Chan et al. (1992) provide a general framework for modeling interest rate processes. The authors describe interest rate volatility using the following general specification for the stochastic behavior of interest rates:

$$dr = (\alpha + \beta r)dt + \sigma r^{\gamma} dZ \tag{14}$$

This specification nests eight well-know interest rates processes, which are extensively discussed in the paper (see Table 3).

Table 3: Nested Interest Rate Processes

Model	α	β	σ^2	γ
Merton		0		0
Vasicek				0
Cox-Ingersoll-Ross, Square Root (CIR-SR)				0.5
Dothan	0	0		1
Geometric Brownian Motion (GBM)	0			1
Brennan-Schwartz (B-S)				1
Cox-Ingersoll-Ross, Variable Return (CIR-VR)	0	0		1.5
Constant Elasticity of Variance (CEV)	0			

The models are ranked according to parameter γ, which controls for the elasticity of interest rate conditional volatility with respect to the changes in the current interest rate. The other two important parameters of the general specification are α are β, which capture for the long run mean and the speed of the mean reversion of the process, respectively. The last parameter σ allows to model the conditional standard deviation[8] of the process.

Table 4: GMM estimation results – test of overidentifying restrictions

Model	AMD30	AMD60	AMD90	AMD180	AMD360	USD30	USD60	USD90	USD180	USD360	TBills
Merton	R	R	R	R	R	R	R	R	R	R	R
Vasicek	R	R	A	A	R	R	R	R	R	R	R
CIR-SR	A	A	A	A	A	A	A	A	A	R	A
Dothan	R	R	A	R	R	R	R	R	R	R	R
GBM	R	R	A	A	R	R	R	R	R	R	R
B-S	R	R	A	A	A	R	R	R	A	A	R
CIR-VR	R	R	R	R	R	R	R	R	R	R	R
CEV	R	R	R	R	R	R	R	R	R	R	A

Note: R indicates that the model specification can be rejected at 10% significance level.
A indicates that the model specification can't be rejected at 10% significance level.

We perform GMM estimations for the eight different specifications of the interest rate processes using Armenian deposit interest rates and TBills rate (see Table 5). The estimations of a continuous time model (14) are performed using the discrete time specification:

Model specification:	$r_{t+1} - r_t = \alpha + \beta r_t + \varepsilon_{t+1}$
Moment conditions:	$E[\varepsilon_{t+1}] = 0,\ E[\varepsilon_{t+1}^2] = \sigma^2 r_t^{2\gamma}$
Instruments:	$[c,\ r_t]$

The outcomes of the GMM estimations suggest that the square root process developed in the Cox, Ingersoll and Ross (1985) paper is the most successful specification for the Armenian interest rates. This specification can not be rejected using the χ^2 test of overidentifying restrictions in most of the cases (with the exception of the USD denominated 360 days deposit rates only).

The results of the GMM estimations for the unrestricted specification (14) and the square root CIR specification (which restricts $\gamma = 0.5$) are summarized in Table 5.

The analysis of the estimation results leads to the following conclusions. First, the square root restriction imposed in the CIR model seems to find support in the unrestricted estimations: the estimated coefficients of γ (which controls for the elasticity of interest rate variability with respect to the interest rate level) are very close to 0.5 in most cases. Second, obtained estimates of parameter β are insignificant for the risk-free interest rate (TBills), while they are significant for all types of deposit rates. This result indicates that the risk-free interest rate series follow a random walk (without drift, since coefficient α is not significant either), while deposit interest rates are mean reverting. Moreover, absolute values of estimated coefficient β suggest that dram deposits have higher speed of mean reversion than dollar deposits for short maturities, and lower speed for longer maturities. Third, in the CIR model, the estimated volatility parameter σ^2 is lower for the risk-free rate, than for the deposit rates. In addition, the volatility parameter is lowest for the 180 days deposits, which have the largest shares in the deposit market (the shares in the total volumes for dram and dollar denominated deposits are 32% and 35% respectively). This finding is not surprising, as it goes in line with the standard prediction from financial markets literature that the yields of the most traded financial instruments have the lowest volatility.

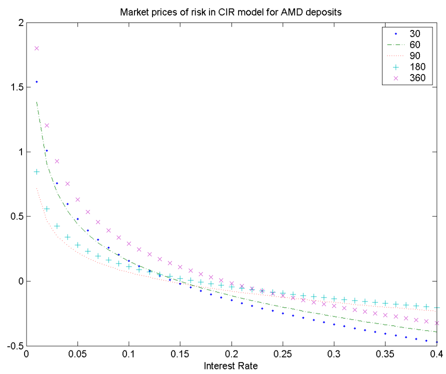
[8]The conditional variance of the interest rate in the general specification is $\sigma^2 r^{2\gamma}$.

Table 5: GMM Estimates of Interest Rates Models

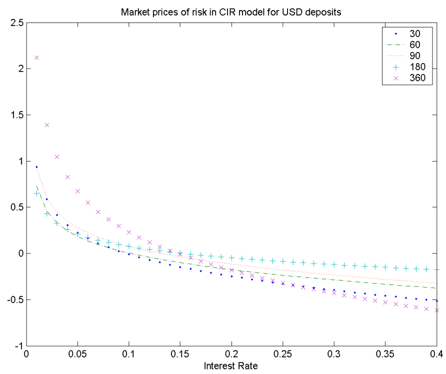
	Unrestricted				CIR SR				χ^2	Volume
	α	β	σ^2	γ	α	β	σ^2	γ	test	shares
TBills	.003	-.016	.003*	.558*	.003	-.014	.003*	.5	.015*	
AMD 30	.018*	-.114*	.006*	.336*	.017*	-.119*	.011*	.5	2.15*	10%
AMD 60	.012*	-.082*	.006	.477*	.012*	-.083*	.007*	.5	0.02*	16%
AMD 90	.007*	-.041*	.001	-.005	.004*	-.031*	.003*	.5	1.67*	12%
AMD 180	.005*	-.027*	.002	.393	.004*	-.027*	.003*	.5	0.16*	32%
AMD 360	.014*	-.077*	.009	.705*	.013*	-.069*	.005*	.5	0.76*	30%
USD 30	.009*	-.085*	.004*	.322*	.009*	-.097*	.008*	.5	3.13*	8%
USD 60	.006*	-.053*	.004*	.390*	.006*	-.056*	.005*	.5	1.58*	20%
USD 90	.006*	-.045*	.004*	.506*	.006*	-.045*	.003*	.5	0.00*	12%
USD 180	.008*	-.057*	.051	1.24*	.004*	-.026*	.003*	.5	3.65*	35%
USD 360	.019*	-.134*	.029*	.871*	.019*	-.131*	.007*	.5	6.28	24%

Note: * stands for a 10% significance level.

Having obtained estimates of conditional mean and conditional volatility of interest rate changes for in the CIR model different maturities financial instruments, in the next step we would like to describe the dynamics of the *market price of risk*. For this reason we apply parameters obtained in the CIR model described in Table 5 to the equation of the market price of risk for deposits in two currencies: $\lambda = \frac{\alpha+\beta r_t}{\sigma r^{0.5}}$. Then we plot the market price of risk with respect to the level of interest rates for different maturities deposits.



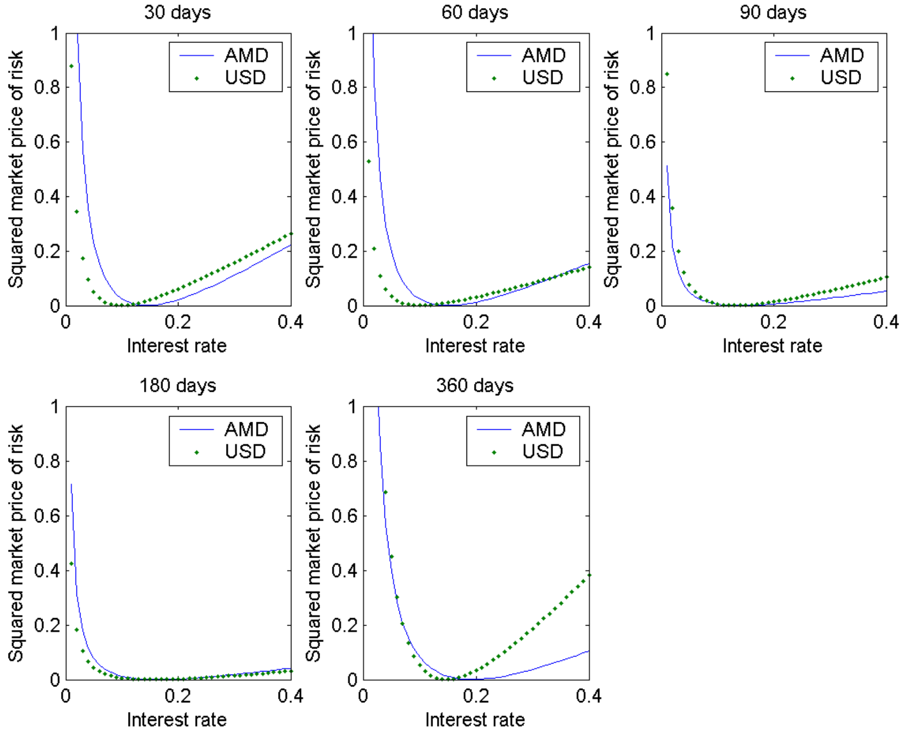
Market price of risk (AMD)



Market price of risk (USD)

The market price of risk is declining function of the interest rate: the larger the level of the interest rate, the lower is the conditional expectation of it's growth in the next period (this results from the mean reversion property of the deposit rates).

As it has already been mentioned before, the squared market price of risk is a key variable which governs the dynamics of the risk premium for the foreign exchange operations in a single factor two currency ATS models. Pictures below show the plot the estimates of squared market prices of risks for domestic and foreign currency denominated deposits (λ^2 and $\widetilde{\lambda}^2$, respectively) as a function of interest rates using parameters from the CIR model.



Squared market price of risks (AMD and USD)

These graphs show that the squared market price of risk has a U-shape behavior for both domestic and foreign currency denominated deposits. The downward sloping part of the squared market price of risk indicates that for low interest rates the interest elasticity of the standard deviation exceeds the interest elasticity of the conditional mean for all maturities deposits. However, for high enough interest rates the relationship reverts and the interest rate elasticity of the conditional mean starts outweighing the interest elasticity of the conditional standard deviation.

The picture also shows that the slope of the squared market price of risk for AMD denominated deposits starts reverting from larger values of interest rates than the USD denominated deposits. This observation implies that starting from a particular level of interest rates the $\widetilde{\lambda}^2$ is going up, while λ^2 is still going down. Equation 11 would predict that this discrepancy between $\widetilde{\lambda}^2$ and λ^2 is a contributing factor to the systematic positive risk premium for the foreign exchange operations. Intuitively, the payoff per unit of risk for a foreign exchange denominated deposit is larger than the payoff per unit of risk for a domestic currency denominated deposit, which leads to a positive exchange rate risk premium. However, one has to be careful in interpreting the the exchange rate risks resulting from different prices of interest rate risks in two different instruments, since the result depends not only on the current level of the interest rate for AMD and USD denominated deposits, but also on their differential.

4 Conclusion

The "forward premium" puzzle - the negative correlation between expected exchange rates and interest rate differentials - has implications which seem anomalous from the perspective of economic models. The empirical evidence coming from developed and emerging market economies does not provide an encompassing answer on possible factors driving this phenomenon. The two main explanations dominated in the studies on developed economies (namely, departures from rational expectations and time varying risk premium) have been supplemented by the evidence coming from emerging market economies. It was found that such country specific factors as the exchange rate regime (fixed versus floating), income level (per capita GDP), macroeconomic stability (inflation) and liberalization of capital accounts play crucial role in the UIP performance.

In contrast to other studies, the available information from Armenian deposit market provides an opportunity to focus on analysis of differences in yields of financial instruments driven *purely* by exchange rate risks considerations. The analysis of data from Armenian deposit market suggests that the country risk and the transaction costs related to cross-border operations play a significant role in departure from the UIP condition. More importantly, a systematic positive excess return is observed in the UIP relationship due to the risk premium demanded by the investors for holding the domestic currency deposits in the presence of a floating exchange rate regime. In addition, the deviations from the UIP relationship display significant maturity effect, which implies that the longer is the investment horizon, the larger risk premium is required by the agents for foreign exchange operations.

The systematic positive risk premium for foreign exchange operations in Armenia is analyzed using the framework provided by the two currency affine term structure models. Single factor two currency affine term structure models assume that the risk premium associated with foreign exchange operations can be explained by the relative size of market prices of risks for financial instruments in two different currencies. The estimations performed for the Armenian deposit market suggest that the risks associated to domestic currency denominated deposits yields are priced relatively higher than the risks associated to the foreign currency denominated deposits yields, which explains a systematic positive risk premium observed over time in Armenia.

To conclude, the main message of this study is that *local* financial markets contain useful information, which might be utilized for modeling the currency risks in transition countries lacking foreign exchange derivatives market. The analysis of information coming from the Armenian deposit market using affine term structure models framework helps in understanding the driving forces of the foreign exchange risk premium in Armenia. In the future the analysis can be extended to the multifactor models, in which the size of the positive excess return depends not only on risks incorporated in the level of the interest rates, but also on other important variables driving foreign exchange risk premium, including monetary policy conduct and external shocks.

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Appendix

Descriptive Statistics

	Mean	Median	Max	Min	St. Dev.
Deposits in Armenian Drams					
30 days	17.8	16.0	49.7	2.3	10.6
60 days	17.7	14.9	44.0	2.3	10.4
90 days	21.1	20.3	51.8	2.6	11.9
180 days	22.5	21.1	47.4	4.2	12.2
360 days	21.9	21.9	48.0	6.3	10.3
Deposits in US Dollars					
30 days	12.8	10.7	35.0	1.1	8.9
60 days	13.5	10.8	39.0	1.0	9.6
90 days	15.8	13.7	43.0	1.4	9.2
180 days	15.6	15.3	45.3	2.1	8.6
360 days	15.6	14.6	45.0	4.4	7.8
US Deposit Certificates					
30 days	3.8	4.9	6.7	1.0	2.0
90 days	3.8	4.9	6.8	1.0	2.1
180 days	4.0	4.9	7.0	0.9	2.1
TBills					
Armenia	33.1	23.5	96.0	5.0	23.7
USA	3.7	4.5	6.2	0.9	1.8

Source: Central Bank of Armenia internal database (Armenian data) and Federal Reserve Bank of St. Louis web site http://research.stlouisfed.org/fred2/ (US data)

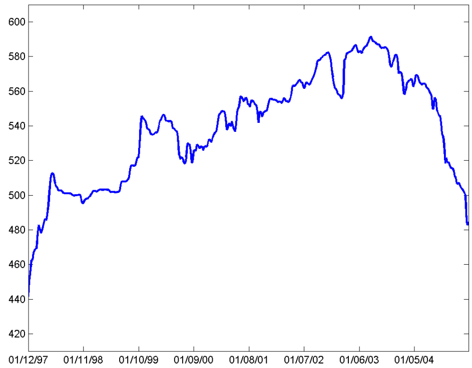

Figure 1: AMD-USD exchange rate (weekly, 1997-2004)

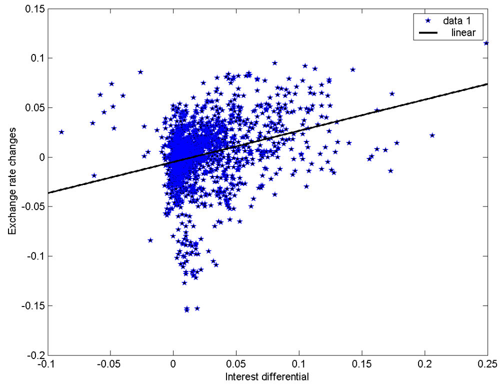

Figure 2: Relationship between interest rate differentials and exchange rate changes

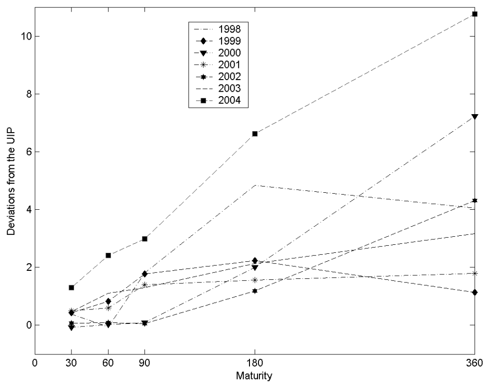

Figure 3: Maturity Effect (Implicit Term Premium)