Discussion Papers In Economics And Business

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Abstract

It has been noted that there is an inconsistency between the Moldovan monetary authorities' declared pursuit of price stability and the de facto exchange rate peg. This paper looks into the exchange rate regime of the Moldovan leu (MDL) aiming to identify the de facto regime, to test whether it differes from the de jure regime stipulated by legislation, whether it can be described by a basket peg (and, if so, to determine the composition of this basket), and whether the regime has been stable over time. The methodology used in our analysis is the celebrated Frankel-Wei regression, to which we apply a Kalman filter algorithm. We show that the MDL generally follows a peg to the US dollar with varying implicit weight and fluctuation bands. Surprisingly, despite the large share of euro-denominated transactions on the Moldovan exchange market, and an even larger share of euro-denominated assets, the euro has never exhibited any statistically signicant weight.

Keywords: Exchange Rate Regime, Moldovan Leu, Frankel-Wei Regression, Kalman Filter, Empirical Fluctuation Process

JEL classification: E42, F31, P33

*The author is grateful to Prof. Shinji Takagi for comments on an earlier draft.

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Introduction

Since the collapse of the USSR in 1991 and replacement of Soviet money with a national currency in 1993, the Moldovan monetary authorities have been in search of an exchange rate regime capable of controlling inflation, maintaining external competitiveness, and at the same time providing sufficient flexibility and adaptability to economic developments in its main trading partners.

The objective of this paper is to identify the *de facto* exchange rate regime for the Moldovan leu. In particular, we test whether it differs from the *de jure* regime stipulated by legislation, whether it can be described by a basket peg (and, if so, to determine the composition of this basket), and whether the regime has been stable over time. The methodology used in our analysis is the celebrated Frankel-Wei regression, to which we apply a Kalman filter algorithm.

The rest of this paper is organized as follows. Section 1 presents an overview of the framework and recent developments in Moldova's foreign exchange and monetary policy. Section 2 reviews the economic literature on exchange rate regime identification. Section 3 describes the data used in the analysis. Section 4 explains the methodologies. Section 5 provides an interpretation of the results obtained. Section 6 provides an assessment of the existing regime against the counterfactuals. Finally, Section 7 summarizes the main findings.

1 Framework of Exchange Rate and Monetary Policy

1.1 Exchange Rate Policy

Although the notion of *official exchange rate* is widely used in Moldova, the exchange rate quoted daily by the National Bank of Moldova (NBM) represents a weighted average of the exchange rates on transactions that took place on the local exchange market during the previous business day as reported by commercial banks. These rates only serve as a reference point for market participants, but provide a set of credible indicators for computations, planning and research (for the exchange rate of the US dollar, see Figure 1).

The NBM has been actively intervening in the exchange market (see, for example, Figure 2) either with the purpose of influencing the exchange rate, or in order to replenish the official reserves, which had declined during the Russian crisis of 1998. The period before the autumn of 2008 was characterized by a rising supply of foreign exchange, coming from exports, foreign investment and remittances by Moldovan citizens working abroad. In order to smooth out excessive fluctuations of the exchange rate, the NBM had intervened in the foreign exchange market, using outright purchases, forward purchases and swaps. The main intervention currency

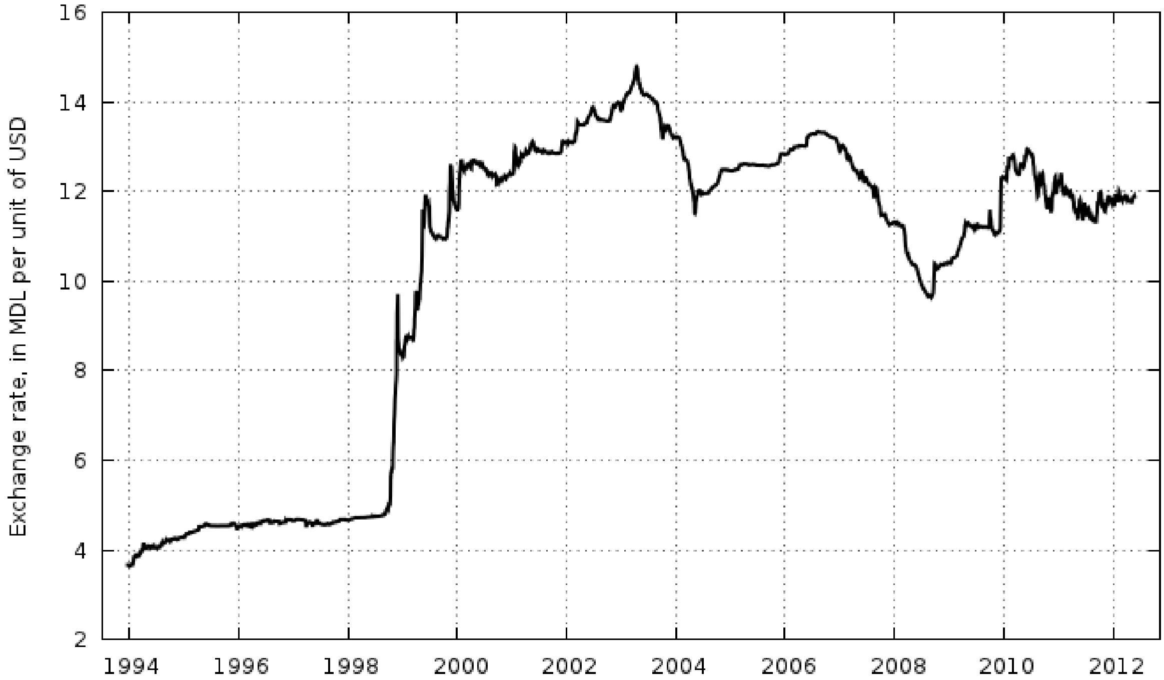

Figure 1: The exchange rate of MDL against the US dollar, daily data, January 1994 – April 2012

had been the United States dollar (USD), while the amount of transactions in other currencies was negligible. Even in 2006, when the Russian Federation suspended imports of wine from Moldova and doubled the price of natural gas delivered to Moldova, the NBM was able to increase the balance of foreign exchange reserves. Until September 2008, the Moldovan leu (MDL) followed an appreciation trend against the US dollar given the large inflow of foreign exchange through remittances, as well as inbound foreign investment, external loans and grants. The trend was reinforced by partial de-dollarization, i.e. conversion of foreign exchange denominated assets, primarily bank deposits, into MDL-denominated assets. Thus, there was an inconsistency between inflation targeting, which was prescribed by legislation, and exchange rate peg, which was the actual policy pursued.[1]

Starting from the fall of 2008, most of these trends reversed themselves: sales of foreign exchange declined (reflecting a decline in remittances), the net inflow of foreign investment turned into a net outflow (reflecting the global crisis), and as a consequence re-dollarization of the economy took place. As the currencies of all neighboring countries depreciated against the US dollar, against which the MDL remained stable through early 2009, the NBM intervened by selling US dollars in an attempt to contain the depreciation pressure. By the end of the

[1]For a discussion of NBM activity in the context of general economic policy, see International Monetary Fund (IMF) (2008), pp. 12–14.

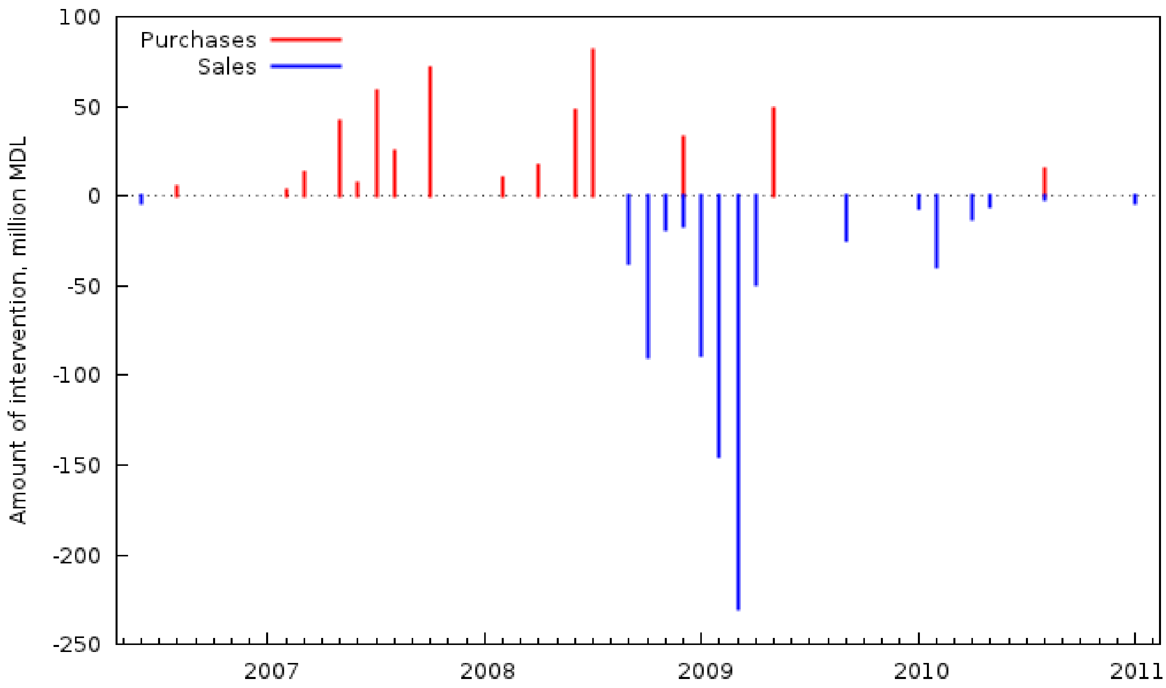

Figure 2: Foreign exchange market interventions, all currencies, monthly data, January 2006 – May 2012

year, however, the NBM had faced the deflationary pressure and reversed the direction of intervention, thus increasing its foreign exchange reserves. In 2010 NBM intervened on both sides of the market in order to smooth out the fluctuations of the exchange rate.

Another notable development over the last decade has been the rising role of the euro in the local foreign exchange market, as well as in the denomination of bank deposits and loans. Between 2001 and 2009 the share of the euro in local exchange market turnover rose from 7.3% to 39.8% while that of the US dollar declined from 86.5% to 57.0%. By the end of 2009 the euro had reached 70.2% of total foreign currency denominated bank deposits. It should be noted that in its Reports on Monetary Policy during 2010 NBM recognized that its foreign exchange interventions were aimed at "smoothing out the excessive fluctuations of the exchange rate of domestic currency vis-à-vis the US dollar," but gave no details as to why the US dollar was selected as the intervention currency.

1.2 Monetary Policy

The origin of national monetary policy dates back to two events: (i) the creation of the National Bank of Moldova, Moldova's central bank, in 1991, and (ii) the introduction of the *leu*, Moldova's national currency, in 1993. The International Monetary Fund (IMF) classifies the Moldovan leu as following a managed float "with no pre-determined path for the exchange rate," with monetary policy targeted at a monetary aggregate. In this section we will look into the accuracy of this assessment.

The ultimate objective of monetary policy is set forth in the Law on the National Bank of Moldova. Before 2006, the law had stipulated that the bank should pursue "the stability of national currency," which implied a dual objective – the internal stability of the currency, usually interpreted as the stability of MDL purchasing power and the rate of inflation, as well as external stability, commonly understood as the stability of the exchange rates of MDL vis-à-vis those of its major trading partners. In June 2006 this prescription was modified, and at present the "fundamental objective of the National Bank is to ensure and maintain price stability." It must be noted, however, that the mechanics of monetary policy (the channels linking the instruments with the objectives) did not change until 2008 when the monetary authorities abandoned monetary aggregates as the intermediate target of monetary policy.

According to Mishkin (2008), inflation targeting is a monetary policy setting that consists of the following five elements:

1 Public announcement of numerical targets for inflation;

2 Institutional commitment to price stability;

3 Strategy relating variables to policy instruments;

4 Transparency concerning the plans, objectives, and decisions; and

5 Accountability for attaining inflation objectives.

In what follows we use these elements to classify Moldova's monetary policy framework.

Public announcement of numerical targets for inflation. For many years the NBM has been routinely announcing, in its annual monetary policy prospects, figures on expected inflation (among other macroeconomic and monetary indicators) for the coming year, based on the government's economic plans, annual budget laws, economic growth strategies and its own forecasts. Also, for many years the monetary authorities have been publishing annual reports on their activity, including a detailed description of factors responsible for the deviation of actual performance (in terms of inflation, monetary aggregates and exchange rates) from what had previously been announced.

Institutional commitment to price stability. Since 2006 the legal mandate of the NBM has included "ensuring and maintaining price stability." NBM's official definition of price stability is essentially Greenspan (1996)'s definition. Quantitatively, price stability is defined in terms of the consumer price index, computed and published by the National Bureau of

Statistics.[2] Thus, a widely known and recognized measure of the price level is used and any conflict of interests (between the institution that collects data and computes the index, and the institution that uses it as its objective) is avoided. In addition, NBM is mandated to pursue other macroeconomic goals – ensuring economic growth and ensuring full employment – to the extent that these secondary goals do not interfere with attaining the primary objective.

Information on the strategy of monetary policy. The body responsible for making and implementing monetary policy decisions in Moldova is the Administrative Council of the NBM. The council performs both the planning of monetary policy (by adopting annual prospects on monetary policy) and ongoing decision-making (such as changing the official interest rates, required reserve ratios and limits on bank credit facilities). The framework of targeting monetary aggregates, which was in place until 2008, had a number of deficiencies:

* The link between changes in monetary aggregates and changes in prices (or, equivalently, changes in aggregates and changes in interest rates) was unstable and unpredictable in the case of Moldova, as frequently pointed out by NBM in its annual reports.

* The instruments employed and the dimensions of monetary policy actions were determined by an intermediary target and not by the final objective.

* Existing instruments, in general, were not able to ensure full control over money supply.

It is for these reasons that the NBM switched, in 2009, to inflation targeting as a framework of monetary policy.

Under the new framework, open-market operations are the main instrument of monetary policy, aimed at keeping the short-term interest rates in the inter-bank market within a narrow corridor of the "base" rate (interest rate on NBM's credit).[3] This, together with changes in the base rate and other instruments, causes changes in interest rates on deposits and loans in the entire banking system. The main problem in this transmission channel, however, is a weak link between the base rate and other interest rates, as well a low responsiveness of real macroeconomic variables to changes in interest rates.

Transparency. Communication with the markets is performed in various forms, including dissemination of electronic publications through the NBM's website, press conferences, and TV interviews by NBM. Regular publications on monetary policy include "Annual Reports," annual "Monetary Policy Prospects," quarterly "Reports on Monetary Policy," quarterly "Reports on Inflation," and press releases. The "Monetary Policy Prospects" had been published every year until 2009, giving an outline of the main macroeconomic indicators and the prospects

[2]For CPI inflation, see Figure 3.

[3]For the NBM's base interest rate, called "short-term repo rate" prior to 2008, see Figure 4.

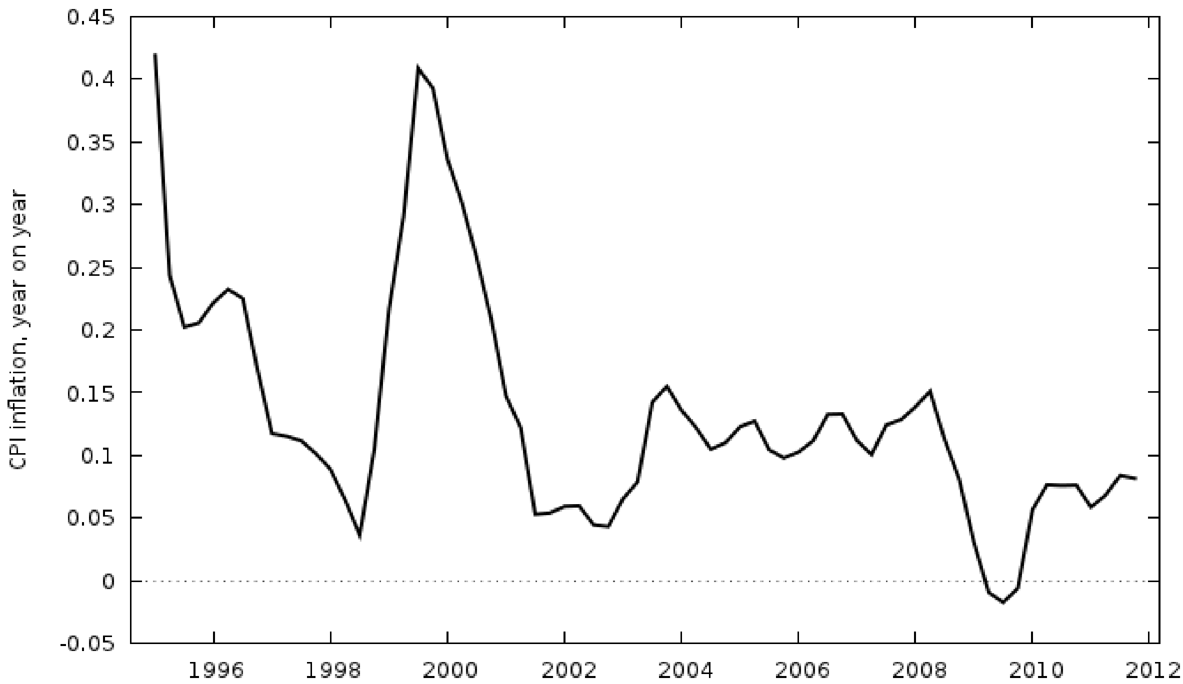

Figure 3: CPI year-on-year inflation (0.1=10%), monthly data, January 1994 – December 2011

thereof, description of monetary policy actions (instruments and objectives), and plans related to bank supervision. It is apparent from these reports that NBM was not focusing on a single indicator (such as inflation), but was instead pursuing a combination of objectives (price stability, stability of monetary aggregates and liquidity of the banking system, exchange rate stability, and the like).

In 2009 these annual prospects were succeeded by a medium-term "Strategy of Monetary Policy for 2010-2012" with a similar content. The first report clearly stated that the central bank had abandoned monetary-aggregate targeting in favor of inflation targeting. During 2010 NBM continued to publish quarterly "Reports on Monetary Policy," but this was followed by "Reports on Inflation" from 2011. In the meantime, press releases remain the most flexible means of public communication, as they contain the periodic decisions taken by the Administrative Council (mostly pertaining to monetary policy instruments). Here, too, there has been an innovation. Recent press releases also provide up-to-date information on monthly changes in CPI and other indicators.

Accountability. There is some ambiguity with respect to the accountability of Moldova's monetary authorities for achieving their objectives. The law states that NBM is "an autonomous legal entity and is accountable to the Parliament." This accountability involves an obligation by NBM officials to "explain in front of the Parliament or its permanent commissions the policy of the bank" (Art. 8) and to "annually provide a report to the Parliament as to (a) evaluation of

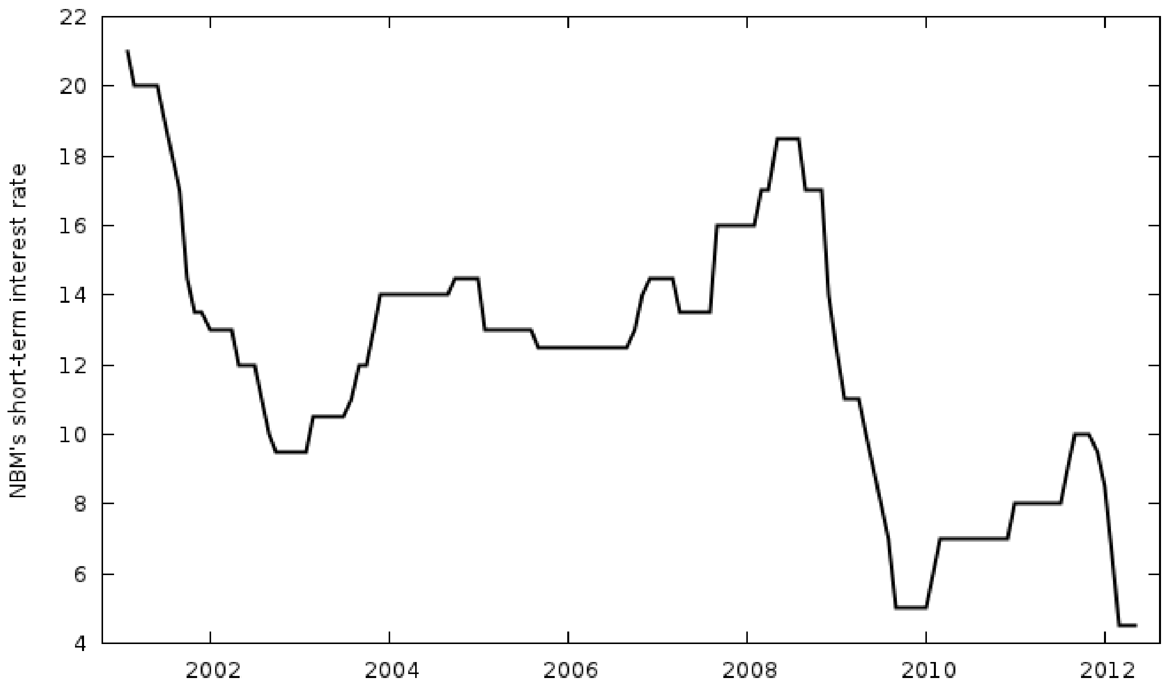

Figure 4: NBM's short-term interest rate, percent per annum, monthly data, January 2001 – May 2012

economic and financial position of the country, description of monetary and foreign exchange ... and its rationale, (b) revision and assessment of monetary and foreign exchange policy from the preceding year"(Art. 69). Thus, the assessment of monetary policy is likely a self-assessment by the NBM. The only sanction that the Governor or a member of the Administrative Council can face is dismissal for an "undue attitude towards the job, which had caused substantial damages to the bank's interests" (Art. 27).

Assessment. On the basis of the considerations noted above, we conclude that there is enough ground to call Moldova's monetary policy framework inflation targeting.

2 A Brief Overview of the Literature

The collapse of the Bretton-Woods system in the early 1970s and the subsequent debate on the merits of floating versus fixed exchange rates led to the emergence of a vast literature on exchange rate regimes. In applying this literature to Moldova we approach the issue of exchange rate regime choice by asking the following three questions:

Regime identification – what has been the de facto, as opposed to de jure, exchange rate regime of a country?

Regime stability – has it changed over time?

Structural breaks – if so, how can we identify the timing of any regime shift?

2.1 Regime identification

Studies that attempt to classify exchange rate regimes fall into two types: (1) those which focus on exchange rate variability; and (2) those which focus on exchange rate co-movements. First, studies that fall into the first group have classified exchange rate regimes by assessing their degree of actual flexibility, thereby offering a *de facto* classification scheme (see, for example, Ghosh, Gulde, and Wolf (2002); Shambaugh (2004); Reinhart and Rogoff (2004); Levy-Yeyati and Sturzenegger (2005)). These and other similar studies often suggest a discrepancy between the "de jure" and "de facto" exchange rate regimes in many countries. As noted by Bénassy-Quéré, Coeure, and Mignon (2006), however, different studies have applied different methodologies, thereby often giving a different de facto assessment of the same de jure regime. This strand of research shares a common limitation, namely, the choice of *numerate* currency (usually, the US dollar), against which variability is measured, is arbitrary.

Second, studies that fall in the second group have focused on finding the co-movement of the currency concerned with other currencies. These works are based on a simple linear regression model popularized by Frankel and Wei (1994) and attempt to estimate the implicit weights of potential anchor currencies (such as the US dollar, the Japanese yen, the euro and other major currencies) in a currency basket framework (for recent contributions, see Bénassy-Quéré, Coeure, and Mignon (2006); and Frankel (2009)). The limitation of this type of studies is that, while inferring the anchor currency or currencies, they fail to measure how the currency concerned moves against the reference value established by the inferred anchor(s). Some recent works employ both metrics of exchange rate regime identification; some even combine the two (for a model incorporating both methodologies, see, for example, Frankel and Wei (2007)).

2.2 Regime stability

Another aspect of the literature relevant to our case concerns whether the exchange rate regime (however defined) is stable over time. Various methodologies have been applied to test the stability of the regime in place, including (1) running a rolling regression, (2) running a regression with separate intervals and (3) using Kalman-type filters to allow for varying coefficients. First, a rolling, or recursive, regression is a procedure of repetitively computing parameter estimates over fixed-length intervals (so-called "rolling window") through the whole sample period. The resulting estimates actually assess not the "true" parameters themselves, but the moving average of these parameters. Among studies of exchange rate regimes employing a rolling regression are McKinnon and Schnabl (2004) for nine Asian currencies, Cavoli and Rajan (2006) for the Indian rupee, and Ogawa and Kudo (2007) for 14 Asian currencies.

Second, regression with separate intervals is used when the sample period is marked by events that are likely to cause a structural shift. Then, the entire period is split into shorter sub-periods and regressions are run separately for each sub-period. Examples of such events include an announcement of devaluation or a financial crisis. Cavoli and Rajan (2005) and Frankel and Xie (2010) have used this type of approach.

Third, another method of testing the stability of an exchange rate regime is based on space-state modeling and Kalman filters (Kalman (1960)). In this method, a certain part of the Frankel-Wei model is allowed to follow a dynamic process, described by the so-called *transition*, or *state*, *equation*. For instance, the exchange rate in question can follow an autoregressive path, thus modelling a crawling peg against a single currency (e.g., Moosa (2008)), or the weights of the anchor currencies can follow an autoregressive path, thus allowing for smooth changes in the basket composition (e.g. Ogawa and Sakane (2006)).

2.3 Structural breaks

A classic test of structural changes is due to Chow (1960). However, the applicability of this test is limited to cases where the timing of a break is either pre-determined or known in advance. Other cases call for different testing techniques. One group of such techniques utilizes F-statistics, developed to test for the existence of one break when its exact location is not known. Another group includes tests based on cumulative sums (*CUSUM*) or moving sums (*MOSUM*) of least-square residuals, especially designed for statistical change detection. An example of procedure for estimating the timing of breaks, based on the sum of squared residuals in the ordinary least squares (OLS) framework, can be found in Bai and Perron (2003).

An entirely different approach to the problem of identifying the timing of structural breaks employs regime switching models, also referred to as *hidden Markov models* (or *chains*). This approach, originally developed by Hamilton (1989) and Engel and Hamilton (1990), and followed in a number of subsequent works, treats the break points (or the duration of each regime) as random variables and not deterministic events. This is why the breaks are estimated in terms of probability of transition from one state (exchange rate regime) to another. A specific feature of this approach is that the number of breaks is also exogenous, given *a priori* and not determined by the model.

All these approaches only look at parameters (such as the weights of currencies in a basket framework), so that only a change in basket composition is considered to be a regime shift. In reality, a change in the fluctuation band should also be considered as a regime shift. For this reason, we follow the approach taken by Zeileis, Shah, and Patnaik (2010b). That is to say, we estimate a regression model that includes variance as a full parameter by the maximum likelihood (*ML*) method.

3 Data Description

The present paper employs daily data (5-day week, Monday to Friday, excluding holidays) on the exchange rate of the Moldovan leu (MDL) vis-à-vis the US dollar (USD), the euro (EUR), the Romanian leu (ROL), the Russian ruble (RUR) and the Ukrainian hrynvia (UAH) (Table 1 summarizes how the exchange rate regimes for these currencies are classified by the International Monetary Fund (IMF) (2010)). The data cover the period from November 31, 2005 to November 30, 2010, and are obtained from the website of the National Bank of Moldova.[4] The bilateral exchange rates between the potential anchor currencies and the numeraire currency are computed as the cross rates of the respective currencies in terms of MDL. The sample period is dictated by data availability.

Table 1: IMF classification of the exchange rate arrangements and monetary policy frameworks for the Moldovan leu's potential anchor currencies, 2010

Currency	Exchange rate arrangement	Monetary policy framework
EUR	independently floating	inflation targeting
ROL	exchange rate within crawling bands	exchange rate anchor
RUR	managed floating with no pre-determined path for the exchange rate	no explicitly stated nominal anchor
UAH	other conventional fixed peg arrangement[i]	against a single currency
USD	independently floating	no explicitly stated nominal anchor

Note: (i) Fixed peg dropped in May 2008

Source: International Monetary Fund, *Annual Report on Exchange Arrangements and Exchange Restrictions*, 2010

[4] http://www.bnm.md

Four numeraires were alternatively used: the Australian dollar (AUD), the Swiss franc (CHF), the Japanese yen (JPY) and the IMF's special drawing right (SDR). The overall characteristics of data series are similar across the three national currencies (for example, in terms of standard deviation, skewness and kurtosis), while with respect to the SDR the data behaved somewhat differently. It is for this reason that only the results based on CHF are reported, though the estimation was performed using all four numeraires. The log returns of all currencies are depicted in Figures 16 through 21 in the appendix. Descriptive statistics for the exchange rate of MDL and the candidate currencies are presented in Table 2.

Table 2: Summary statistics for the bilateral exchange rates of the Moldovan leu and the potential anchor currencies against the Swiss franc, December 1, 2005 – November 30, 2010

Variable	Mean	Median	Minimum	Maximum
dlog(MDL/CHF)	−0.000162525	0.00000	−0.0585855	0.0490655
dlog(USD/CHF)	−0.000205492	0.00000	−0.0577380	0.0495559
dlog(EUR/CHF)	−0.000122528	0.00000	−0.0263092	0.0345140
dlog(RUR/CHF)	−0.000271710	0.00000	−0.0453926	0.0415648
dlog(ROL/CHF)	−0.000248152	0.00000	−0.0547658	0.0347819
dlog(UAH/CHF)	−0.000557000	0.00000	−0.162692	0.201137
Variable	Std. Dev.	C.V.	Skewness	Ex. kurtosis
dlog(MDL/CHF)	0.00741475	45.6222	−0.436013	7.83965
dlog(USD/CHF)	0.00718148	34.9477	−0.182145	8.07215
dlog(EUR/CHF)	0.00410041	33.4651	−0.0394786	8.58042
dlog(RUR/CHF)	0.00628769	23.1412	−0.552588	8.26906
dlog(ROL/CHF)	0.00708952	28.5693	−0.942009	6.94112
dlog(UAH/CHF)	0.0152032	27.2948	−0.609505	55.2554

Note: The sample period covers 1304 observations.

4 The Model

4.1 Regime identification

In order to identify the implicit weights of the potential anchor currencies, a Frankel and Wei (1994) model was applied. It is a linear regression model where the rate of return (log-difference) of a given currency is related to the returns of reference currencies. Recent examples of this approach include Frankel and Wei (2007) and Zeileis, Shah, and Patnaik (2010b).

In particular, we postulate the following equation relating the value of MDL to those of other currencies:

$$y_k(t) = \beta_0 + \sum_{i=1}^{n} \beta_i \cdot x_{i,k}(t) + \varepsilon(t) \tag{1}$$

where y is the log-return of MDL in terms of CHF (or another numeraire currency k), β_0 is the average rate of depreciation, x_i is each of the potential anchor currencies (i.e., USD, EUR, ROL, RUR, and UAH), and $\beta_{i(i>0)}$ are the implied weights of these currencies. If β_0 is significantly different from zero, it can signal a crawling peg. If one of the other β's is not significantly different from unity, it is an indication of a simple peg to that currency. If none of the coefficients are significantly different from zero, the Moldovan leu is a floating currency. All other cases imply a managed float for the Moldovan leu.

The rationale behind the choice of anchor and numeraire currencies. The list of potential currencies for the basket is dictated by their use as an international means of payment (hence the US dollar and the euro), or as legal tender in Moldova's neighbors and main trading partners (hence the Romanian leu, Russian ruble, and Ukrainian hryvna). The numeraire currencies were selected in such a way that they are not correlated with the model variables. The literature suggests that typical choices are *basket* currencies, so-called *remote* currencies (freely floating currencies, to which the model variables are unlikely to be pegged) and real prices. Based on these considerations, we selected one basket currency (SDR) and three remote freely floating currencies (CHF, AUD and JPY). Another option would be to use a real basket, e.g. CPI, but since such data are not available on daily basis, we cannot take advantage of the daily data on exchange rates.

With CHF as numeraire, we use the following specific version of equation (1) for testing purposes:

$$\begin{aligned} d\log\frac{MDL}{CHF} = \beta_0 + \beta_1 \cdot d\log\frac{USD}{CHF} + \beta_2 \cdot d\log\frac{EUR}{CHF} \\ + \beta_3 \cdot d\log\frac{ROL}{CHF} + \beta_4 \cdot d\log\frac{RUR}{CHF} + \beta_5 \cdot d\log\frac{UAH}{CHF} + \varepsilon \end{aligned} \tag{2}$$

for the case of the Swiss franc used as numeraire, where the time index is removed for convenience.

Caution must be exercised when including the Ukrainian currency in equation (2), as Ukraine experienced a discrete change in its exchange rate regime. That is to say, although the currency was pegged at the rate of USD1 = UAH5.05 from April 21, 2005 to May 21, 2008, it subsequently became a floating currency. This means that the two variables – $d\log\frac{USD}{CHF}$ and $d\log\frac{UAH}{CHF}$ – were perfectly collinear in the first sub-period, requiring two separate regressions to be run. Accordingly, the first regression excludes UAH from the model and coveres the first sub-period

(December 1, 2005 to May 21, 2008), while the second regression includes UAH and coveres the second sub-period (May 22, 2008 to November 30, 2010).

4.2 Regime stability

In order to ascertain whether the parameters obtained from the Frankel-Wei model were stable over the entire period, we introduce an additional equation, which allows the weights to vary over time in an autoregressive manner:

$$\beta_{i,t} = \beta_{i,t-1} + \eta_{i,t} \tag{3}$$

where i represents each of the potential anchor currencies. Thus, a state-space model is constructed, with equation (1) being the *signal* and equation (3) being the *state* equation.

In order to extract the dynamics of the implicit currency weights, the state-space model was first estimated by means of minimal (log) likelihood. Once all the system parameters are estimated, the Kalman filter is applied and the "true," but otherwise unobservable, weights are obtained. The Kalman filter is a recursive method of estimating the "true" value of currency weights at date t, given the information (the mean and the covariance, obtained by ML in the previous step) available at date $t-1$. The evolution of the implicit currency weights over time can be seen in Figures 5 through 9.

4.3 Structural breaks

In order to identify any structural breaks, we follow the approach taken by Zeileis, Shah, and Patnaik (2010b). In the first step a regression model that includes variance as a full parameter is estimated by the maximum likelihood (*ML*) method. The estimating functions for parameters are:

$$\psi_\beta(y, x, \beta) = (y - x^T\beta)x \tag{4a}$$

$$\psi^2_\sigma(y, x, \beta, \sigma^2) = (y - x^T\beta)^2 - \sigma^2 \tag{4b}$$

To detect a structural break, the initial exchange rate regime should be estimated. For this purpose, the regression is run on a short sub-period and the parameters (the currency weights and the variance) are estimated.

In the second step, an *empirical fluctuation process* (EFP) is constructed, reflecting the deviations from the estimating functions (set to be zero in ML estimation). The same fluctuation process is extrapolated over the remaining sub-period. A change in any parameter, including the variance, leads to a deviation of the EFP from zero. A statistical test is developed in order to verify whether a change in parameter, and hence a change in regime (structural break), is

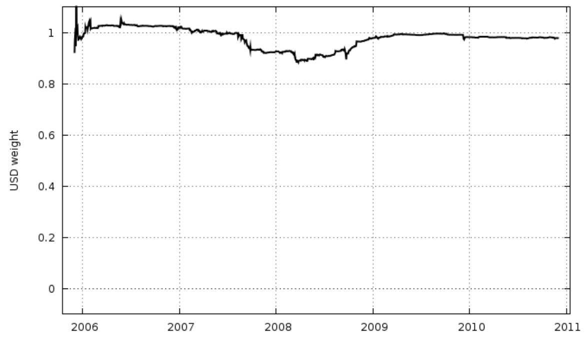

Figure 5: The weight of USD (numeraire: Swiss franc)

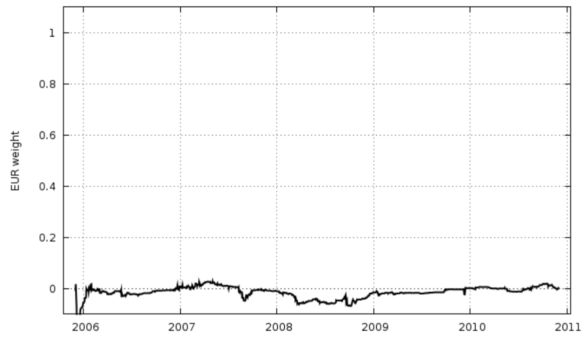

Figure 6: The weight of EUR (numeraire: Swiss franc)

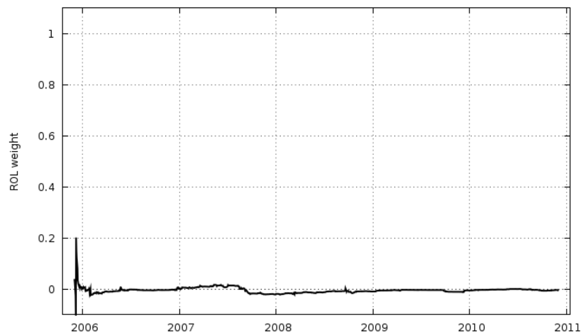

Figure 7: The weight of ROL (numeraire: Swiss franc)

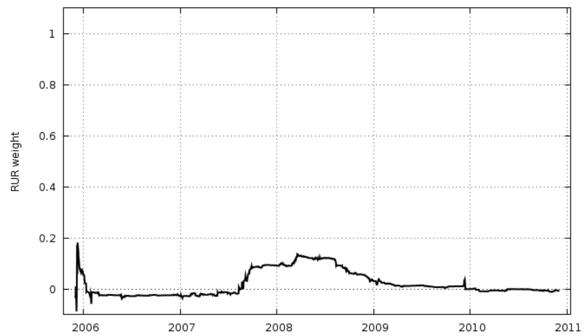

Figure 8: The weight of RUR (numeraire: Swiss franc)

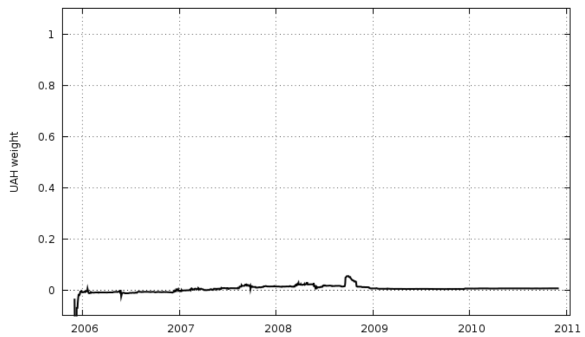

Figure 9: The weight of UAH (numeraire: Swiss franc)

significant. Finally, setting a minimal duration of one regime, it is possible to determine the optimal number of regimes during the sample period and to estimate the probable timings (and confidence intervals) of regime changes. The timings of regime changes are determined based on the Bayesian information criterion.

5 Regression Results

The results of the Frankel-Wei regressions are presented in Tables 3 and 4. In the first sub-period, two potential anchor currencies proved to have weights significantly different from zero: the US dollar with a weight of 0.937 and the Russian ruble with 0.094. This is an indication of exchange rate pegging on the part of the Moldovan leu. However, the weights do not sum up to unity, which means that the peg is not tight, but allows for some margins. The R^2 of 0.957 is another indication of a margin of fluctuation. This result is surprising in so far as the weight of the euro was found statistically not significant, when it was the currency of many of Moldova's major trading partners as well as an important means of international payments for Moldova.

Table 3: OLS estimates of the Frankel-Wei regression, December 1, 2005 through May 21, 2008

Dependent variable: dlog(MDL/CHF)

	coefficient	std. error	t-ratio	p-value	
const	0.000320096	9.18569e–05	3.4847	0.0005	***
dlog(USD/CHF)	0.937470	0.0276439	33.9123	0.0000	***
dlog(EUR/CHF)	-0.0433231	0.0358396	-1.2088	0.2272	
dlog(ROL/CHF)	0.0129818	0.0107667	1.2057	0.2284	
dlog(RUR/CHF)	0.0938480	0.0461921	2.0317	0.0426	**
R^2		0.957304			

Notes: HAC standard errors; UAH is excluded as an independent variable; the Swiss franc is used as numeraire; the subperiod includes 645 observations; *** and ** denote statistical significance at the 99 and 95 percent level, respectively.

In the second sub-period, when the Ukrainian monetary authorities allowed UAH to fluctuate, UAH though included was not significant. Neither was the Russian ruble, while the weight of the US dollar, the only significant currency, rose to 0.982. The overall strength of the model declined, however, with R^2 falling to 0.88.

The application of the Kalman filter has uncovered instability in the implicit weights of the potential anchor currencies. Large fluctuations in the weights of all currencies observed at the beginning of the sample period is probably due to the absence of initial data (with diffuse prior data, the filter "calibration" takes some time), so the results for the first month or two may need to be disregarded.

After the initial period of one or two months, the weight of the US dollar remained close to or above unity until mid-2008, when it fell to the range of 0.9–0.95. By the end of 2009

Table 4: OLS estimates of the Frankel-Wei regression, May 22, 2008 through November 30, 2010

Dependent variable: dlog(MDL/CHF)

	coefficient	std. error	t-ratio	p-value	
const	-0.000245990	0.000219518	-1.121	0.2629	
dlog(USD/CHF)	0.982246	0.0179140	54.83	1.41e–246	***
dlog(EUR/CHF)	-0.00247823	0.0311975	-0.07944	0.9367	
dlog(ROL/CHF)	0.00195484	0.0153824	0.1271	0.8989	
dlog(RUR/CHF)	0.0138570	0.0265583	0.5218	0.6020	
dlog(UAH/CHF)	0.00475704	0.00327540	1.452	0.1469	
R^2		0.880691			

Notes: HAC standard errors; independent variables include all candidate currencies; the Swiss franc is used as numeraire; the subperiod includes 659 observations; *** denotes statistical significance at the 99 percent level.

it had increased again and remained around 0.97 through the end of the sample period. The Russian ruble was a counterpart to this movement: its weight was close to or below zero until mid-2008, when it sharply increased to about 0.1. By the end of 2009 it had gradually declined and then fluctuated around zero through the end of the sample period. The weights of the remaining three currencies gravitated around zero, which is consistent with the results from the Frankel-Wei model. These results seem to hold regardless of which numeraire was used: Figures 37 trough 41 in the appendix show the weights of each anchor currency when different numeraires are used. They all show that the results are quite robust.

The strategy to test for identifying the regime shift was applied as follows. First, to estimate the parameters of the initial exchange rate regime, a period of four months (December 1, 2005 to March 31, 2006) was chosen. The results from this regression are summarized in Table 5. We can see that only the USD coefficient was significantly different from zero (but not significantly different from unity), thus indicating a tight peg to the US dollar during these four months. The R^2 of the regression is 0.997, given the extremely low standard deviation ($\sigma = 0.03$). If we compare this result to the average weights for the entire period and to the results from the Kalman filter, it becomes clear that this four-month period is not typical, that the regime is very likely to change soon, and that multiple breaks will be detected.

Second, an empirical fluctuation process was constructed for this period (see Figure 10). For this, on every observation date the stability of parameter was tested, and test scores obtained. An empirical fluctuation process is the resulting time series, capturing deviations from the null hypothesis of parameter stability. This and all remaining computations were performed in R

Table 5: OLS estimates of currency weights in the initial exchange rate regime, using observations December 1, 2005 – March 31, 2006

coefficient	Estimate	Std. Error	t value	Prob.	
(Intercept)	-0.015501	0.003375	-4.593	1.61e–05	***
USD	1.019833	0.020342	50.135	0.0000	***
EUR	-0.011086	0.028874	-0.384	0.702	
ROL	-0.008864	0.011094	-0.799	0.427	
RUR	-0.011456	0.019986	-0.573	0.568	
UAH	-0.011412	0.012326	-0.926	0.357	
Residual standard error: 0.03029 on 80 degrees of freedom					
Multiple R^2: 0.9969			Adjusted R^2: 0.9967		

Notes: The Swiss franc is used as numeraire; the subperiod includes 87 observations; *** denotes statistical significance at the 99.9 percent level.

language using Fxregime software package.[5]

Third, this process is extended to cover one year (see Figure 11) and critical values (the boundaries) of test scores are calculated. As expected, in less than two months the variance of most parameters increases and approaches the theoretical boundaries (variance of ROL and variance of σ even crossing the upper boundary). This suggests that a transition to a much softer peg is taking place. The number and dates of breakpoints are reported in Table 6. Two structural breaks are detected, and thus three distinct regimes are identified, within a one-year period. The first break is likely to have taken place between the May 8 and May 19, 2006, with May 18 being the most probable date. The second one is dated as June 15, with the 90% confidence interval between June 14 and June 26.

Finally, the segments enclosed between these dates are estimated by ordinary least squares and changes between regimes are clearly visible. During the first regime (Dec 1, 2005 to May 18, 2006) MDL was following a tight peg to the US dollar, the weight of the US dollar being 1.014244 and the R^2 equal to 0.9979. In the second regime (May 19, 2006 to June 15, 2006) the peg was much more relaxed, with the weight of 0.98313 and the R^2 of only 0.9508. The third period (June 16, 2006 to November 30, 2006) is a return to a tight peg, with the weight of the US dollar at 1.0063857, and the R^2 of 0.998.

[5] See software manual in Zeileis, Shah, and Patnaik (2010a)

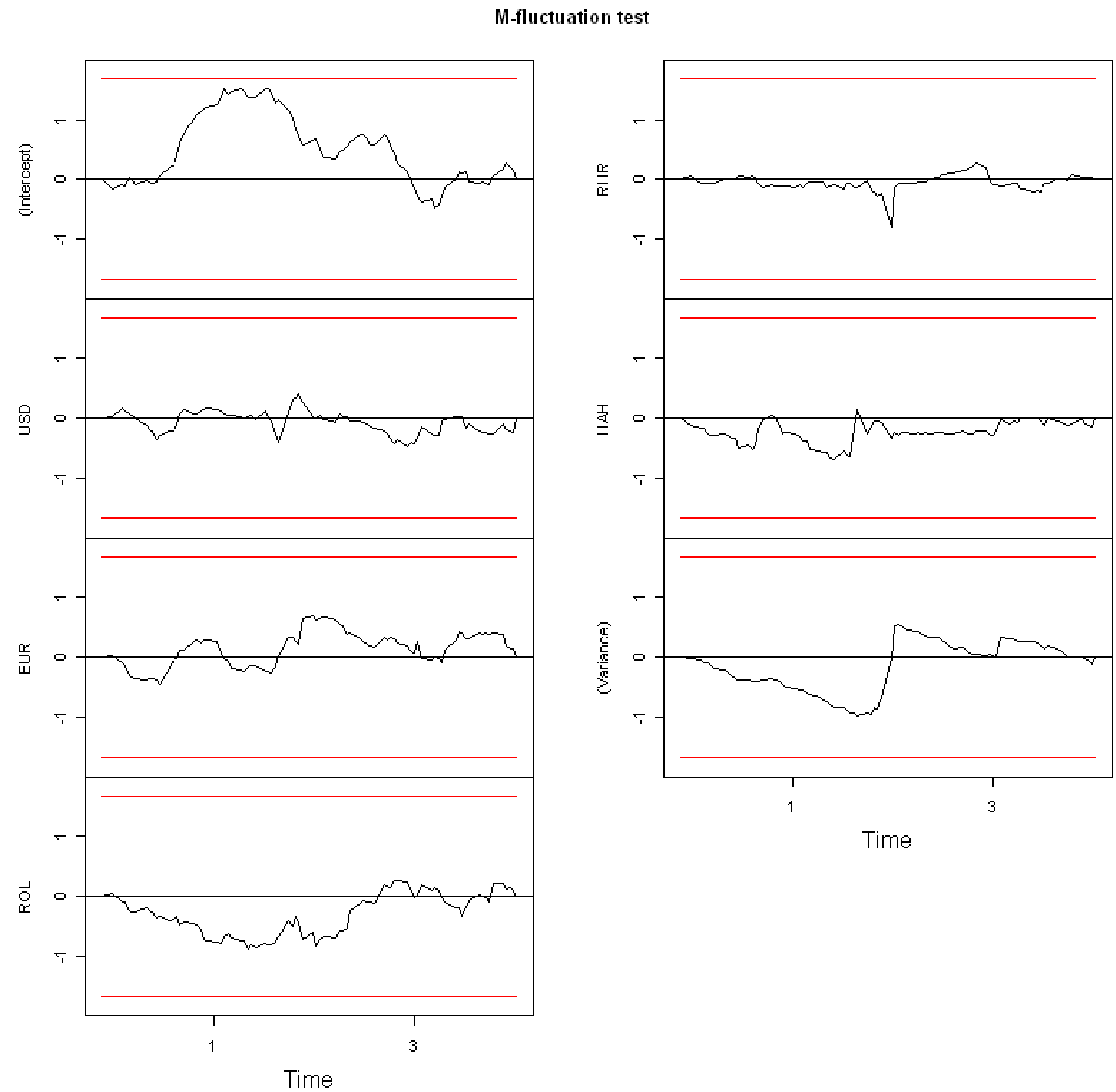

Figure 10: The empirical fluctuation processes for potential basket currencies with their 95% confidence intervals, December 2005 – March 2006

6 Assessment of Moldova's Exchange Rate Regime

In order to assess the economic implications of Moldova's exchange rate policy, we consider its effects upon Moldova's external economic position. The key indicator describing the value of domestic currency (relative to a set of foreign currencies) and the competitive position of a country is the real effective exchange rate. Thus we analyze the evolution of the MDL's real effective exchange rate (REER) over the selected period in order to gain an understanding of how Moldova's exchange rate regime influenced the competitiveness of exports.

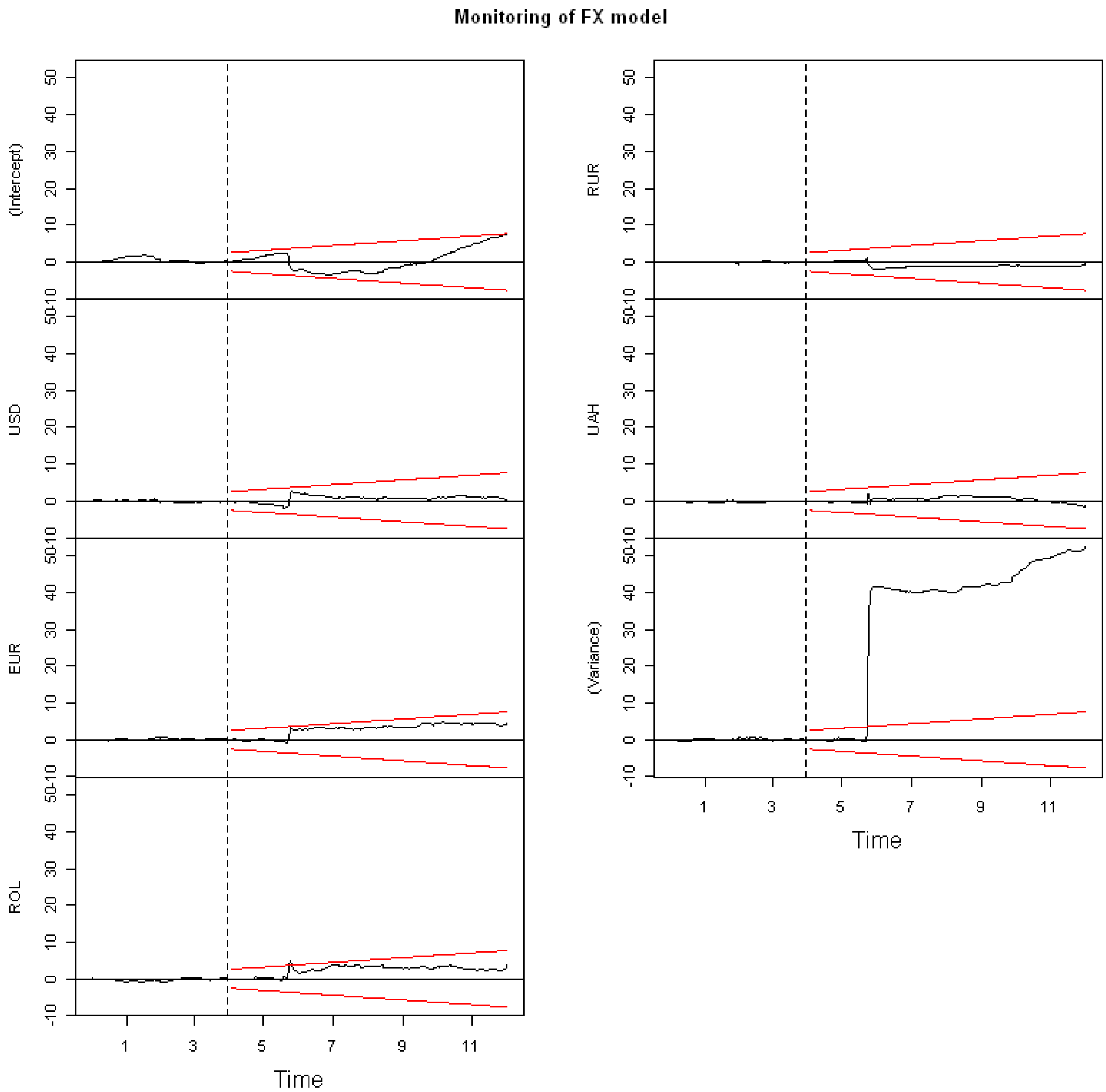

Figure 11: Monitoring the fluctuation processes from the potential basket currencies, April 2006 – November 2006

6.1 Effective exchange rates

According to its Annual Reports, the National Bank of Moldova calculates the nominal and the real effective exchange rates of the MDL, but does not disclose the data series, necessitating that we compute our own measures of nominal and real effective exchange rates (EER). To do so, we used end-of-month bilateral exchange rates of the MDL against the currencies of Moldova's main trading partners (11 countries comprising 10 different currencies) for the period between November 2005 and December 2010. The data were obtained from the NBM

Table 6: Probable dates and confidence intervals of structural breaks between December 1, 2005 and November 30, 2006

Breakpoints at observation number:			
	5%	breakpoints	95%
1	112	120	121
2	139	140	147
Breakpoints at observation date:			
	5%	breakpoints	95%
1	2006-05-08	2006-05-18	2006-05-19
2	2006-06-14	2006-06-15	2006-06-26

and central banks of the respective countries. For the real effective exchange rate, we used monthly consumer price indexes for Moldova and the same 11 countries, covering the same period, which we obtained from the countries' statistical bodies.

Table 7: The weights of foreign currencies in MDL's effective exchange rate

Country	Currency code	Weight, %
Ukraine	UAH	21.38162641
Romania	RON	21.05031987
Russian Federation	RUR	20.66624455
Italy	EUR	8.78678942
Germany	EUR	8.52213383
Belorussia	BYR	5.46723930
Turkey	TRY	4.61107211
Poland	PLN	3.91049590
China	CNY	2.97903706
United Kingdom	GBP	1.80128388
Kazakhstan	KZT	0.82375767
-	-	100.00

The weighting scheme used is as follows. Moldova's main trading partners were ordered by trade share and the first 11 countries, covering about 80% of Moldova's trade in goods, were selected. The weight of each country was computed, based of the share of that country in Moldova's total exports and imports during 2005–2009. The resulting weights are presented in Table 7. Though two countries (Germany and Italy) use the same currency, it was necessary to disaggregate them in order to take into account the difference in their price levels. Their combined shares do not include Moldova's trade with the other euro-zone countries.

The nominal effective exchange rate (NEER) was computed according to the following formula:

$$NEER_t = \prod_i (\frac{E_{it}}{E_{i0}})^{w_i} \tag{5}$$

where E_{it} is the bilateral exchange rate between the currency of partner i and the MDL in month t, E_{i0} is the exchange rate in the base period, and w_i is the weight of the respective currency. All bilateral exchange rates are in indirect quotation, i.e. the price of one unit of the MDL in terms of foreign currency. The resulting NEER index shows a change in the value of the MDL vis-à-vis a weighted basket of foreign currencies from the base period. Values higher than unity mean a nominal effective appreciation of the MDL, while values lower than unity mean a nominal effective depreciation. For illustrative purposes, the base period is set to coincide with the beginning of the dataset (end of November 2005), so that the NEER and REER for November 2005 are equal to unity.

As to the real effective exchange rate, it is obtained by deflating the NEER according to the following formula:

$$REER_t = NEER_t \frac{P_t}{\sum_i w_i P_{it}} \tag{6}$$

where P_{it} is the CPI of partner i in month t, and P_t is the CPI of Moldova in month t. The resulting REER index shows the real average value of the MDL, relative to Moldova's partner countries. Values higher that unity mean a real effective appreciation of the MDL, and vice versa. CPI was chosen as the basis to construct the NEER deflator, because it was the only price index available for all countries and for all periods.

6.1.1 MDL's NEER and REER during 2005–2010

The evolution of the Moldovan leu's NEER is presented in Figure 12. Since the beginning of the period the Moldovan leu had been depreciating in nominal effective terms until November 2006. At its trough, the MDL lost 10% of its value from the base period. Starting from December 2006, the depreciation tendency reversed itself: during 2007 and especially during 2008 the MDL gained almost 40% in value. At its peak, in February 2009, it was priced about 44% more then in the base period. Subsequently, the MDL generally followed a depreciation trend, but remained higher than it was in the base period.

The movements of the REER for the most part reflect the movements of the NEER (see Figure 12). However, large fluctuations from November 2005 to February 2009 were much less pronounced given the compensating changes in the EER deflator: whenever the currency depreciated, the domestic prices rose more quickly, while the reverse held true when it appreciated.

As a result, between November 2005 and the beginning of 2009, the domestic prices changed almost in proportion to the trading partners' prices. During the rest of the period, the domestic prices did not deviate much from the foreign prices, and, as a consequence, all changes in the REER reflected the changes in the NEER.

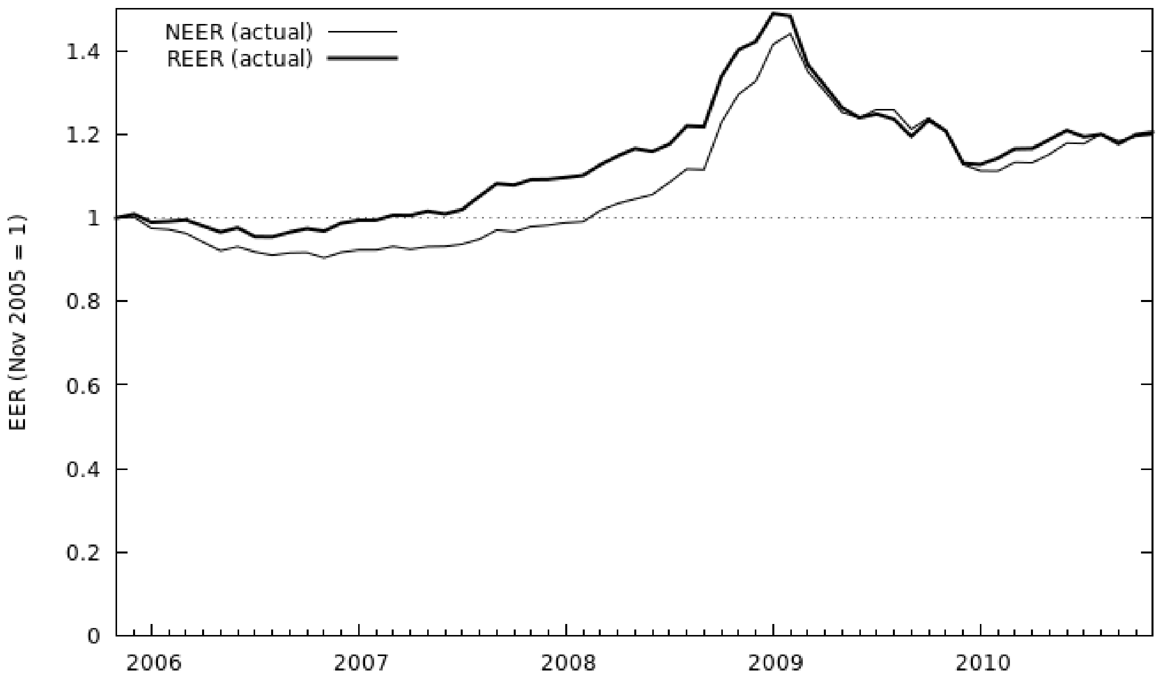

Figure 12: The monthly effective exchange rates of the MDL, November 2005 to November 2010 (November 2005 = 1.00, higher values mean MDL appreciation)

6.2 Nominal exchange rate under a hypothetical peg to EUR

In this section we analyze the effect of exchange rate regime choice on the value of the MDL under alternative scenarios. Given the structure of Moldova's foreign trade, a peg to the EUR seems to be a viable alternative. Since the NBM was successful in maintaining a peg to the US dollar, we assume it should be able to maintain a **fixed peg to the EUR** as well.

We also assume that changing the exchange rate regime of the MDL does not influence the value of other currencies, the price levels in the trading partners or the structure of Moldova's trade. Thus, the nominal exchange rate of the MDL under a fixed peg to the EUR is influenced solely by the bilateral exchange rates between the EUR and other trading partners' currencies. The evolution of the NEER of the MDL under such a regime is shown in Figure 13.

The NEER under a hypothetical peg to the EUR would have behaved differently from the actual movement of the NEER :

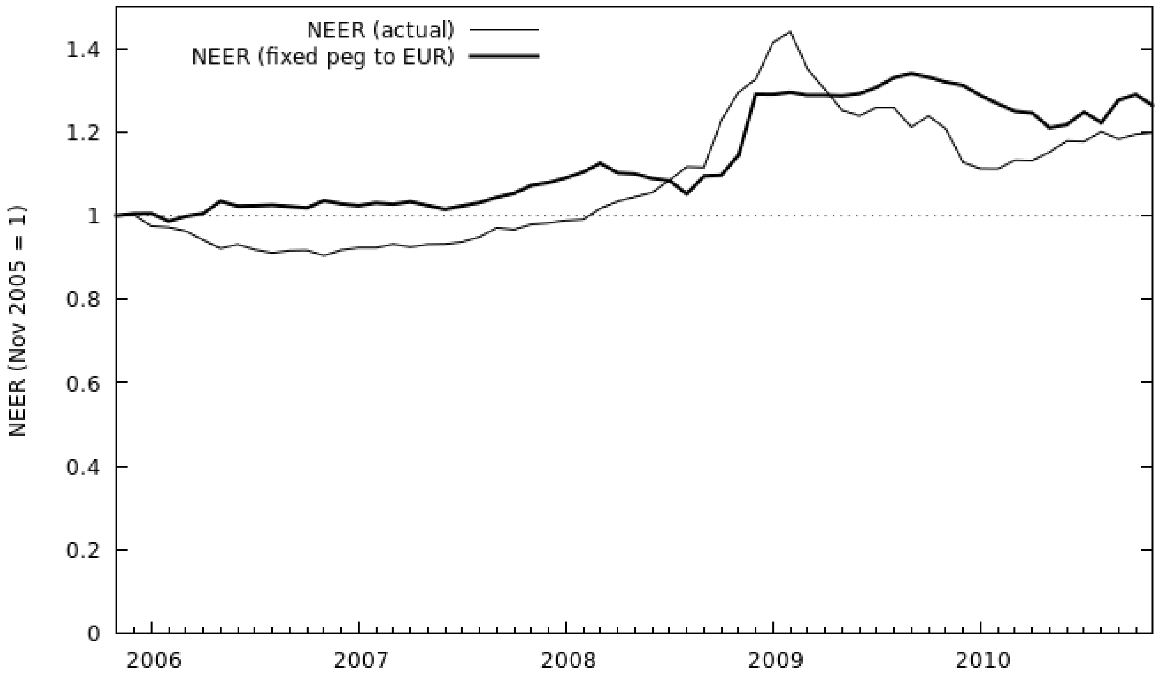

Figure 13: The monthly nominal effective exchange rate of the MDL under a fixed-peg-to-EUR assumption, November 2005 to November 2010 (November 2005 = 1.00, higher values mean MDL appreciation)

* There was no depreciation period. Instead, the nominal value of the MDL remained relatively stable until mid-2007.
* The appreciation was less pronounced. Starting from mid-2007, the MDL generally followed an upward trend against the trading partners' currencies.
* There was no "peak" (a sharp rise followed by a sharp fall) in the value of the MDL.
* In general, the nominal value of the MDL under a hypothetical peg to the EUR was higher than was the case in practice.

6.3 Real effective exchange rate under alternative scenarios

Unlike nominal effective exchange rates, the real effective rates are influenced by prices. This is why in order to assess the influence of the exchange rate regime on the REER, we need to know the behavior of price levels. The large deviations of the REER from unity that took place under the actual regime do not allow us to accept the purchasing power parity hypothesis (at least in its simplest form) and calls for a set of assumptions about the relationship between Moldova's prices and bilateral exchange rates, as well as between domestic and foreign prices.

The economy of the Republic of Moldova is much smaller than any of its trading partners, so we assume that foreign prices are exogenous. As to the factors influencing domestic prices, we start by assuming that they are exogenous. We will therefore use actual data. In what follows we consider two alternative counterfactuals: (i) a rigid peg to the EUR with an invariant CPI, and (ii) a crawling peg to the EUR with an invariant CPI

6.3.1 A rigid peg to EUR with an invariant CPI

First, we rely on the assumption that all CPIs are invariant to the value of the MDL. The REER computed in this way for a fixed peg to the EUR is presented in Figure 14. Unlike under the actual regime, under a hypothetical peg to the EUR there would have been no initial downward swing in the real effective rate, though we see a stable appreciation tendency from the beginning of the period until the beginning of 2008. The first half of 2008 recorded a decline (not observed under the actual regime) followed by a sharp rise in the real value of the MDL in the second half of the year. After reaching the maximal value of 1.38 at the end of 2008, the REER exhibited a slightly downward trend until the end of the period, still remaining well above unity. Thus, the actual regime resulted in a less stable real effective value of the MDL, while it remained undervalued most of the time.

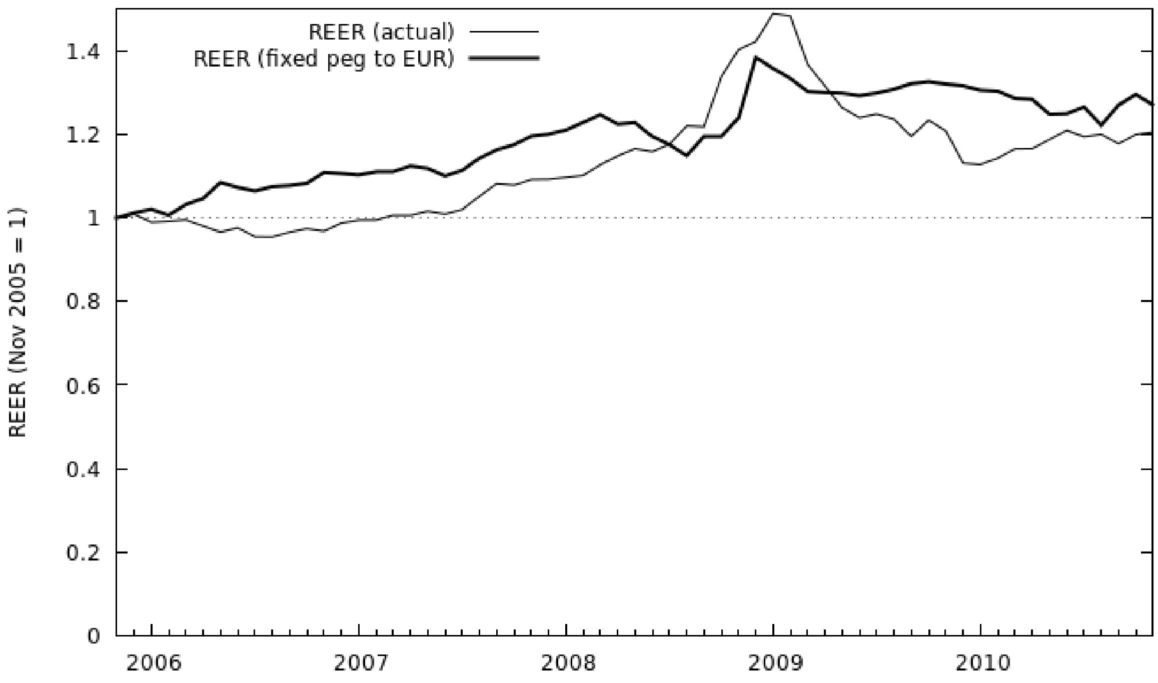

Figure 14: The monthly real effective exchange rate of the MDL under a fixed-peg-to-EUR assumption, November 2005 – November 2010 (November 2005 = 1.00, higher values mean MDL appreciation)

6.3.2 A crawling peg to EUR with an invariant CPI

We now assume the alternative scenario of a crawling peg to the EUR, setting the rate of change in the value of the MDL against the EUR (the crawling pace) to be equal to the actual rate of appreciation of MDL against the USD, adjusted for the actual depreciation of the USD against the EUR.

Between November 31, 2005 and November 30, 2010 the Moldovan leu gained 5.67% while the EUR gained 11.17% against the US dollar. This means that, under a hypothetical crawling peg to EUR, the real effective value of MDL would have depreciated by 1.1% per year (Figure 15), a pattern very similar to the one actually observed under the dollar peg. In summary, switching to a crawling peg to euro would have produced a similar movement in the real value of the Moldovan currency to the actual path observed, although it would have provided lower volatility.

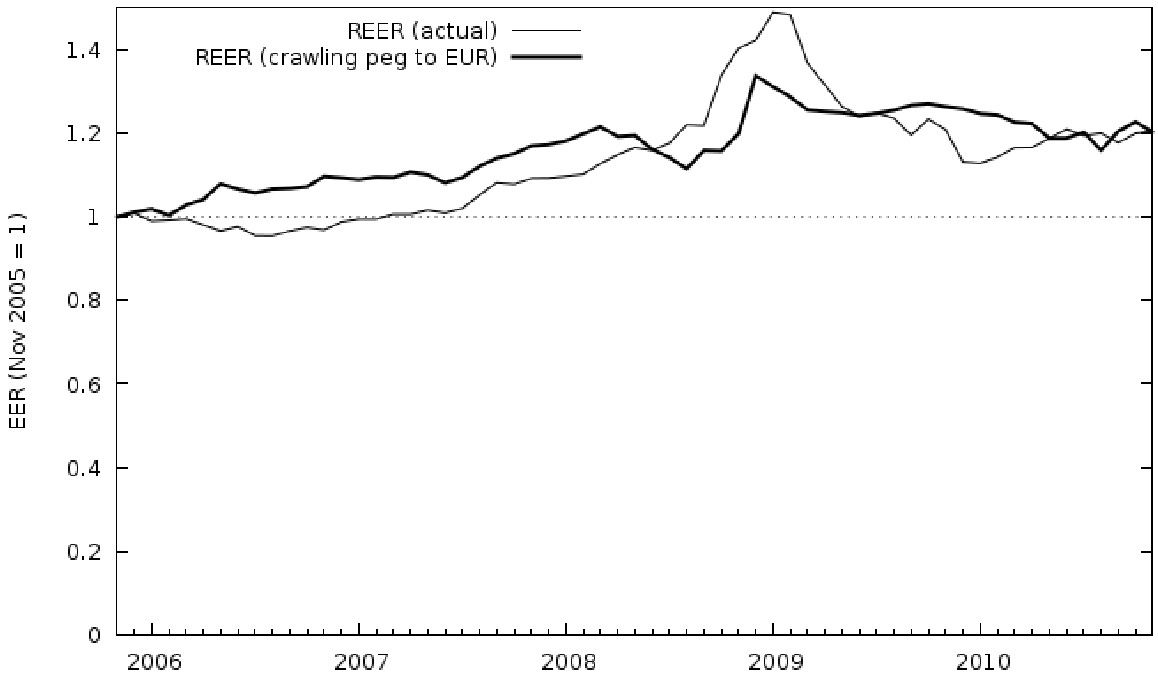

Figure 15: The monthly real effective exchange rate of the MDL under a crawling-peg-to-EUR assumption, November 2005 – November 2010 (November 2005 = 1.00, higher values mean MDL appreciation)

6.4 Assessment of exchange rate volatility

In order to assess the effect of exchange rate regime choice on the volatility of the MDL, we consider the counterfactual paths of the exchange rate under two alternative counterfactual arrangements: (i) a hypothetical peg to a basket of currencies, composed of the US dollar and the euro with equal weights, and (ii) a hypothetical peg to the euro. For the exchange rate path under each alternative, we employ a Monte Carlo simulation method to generate multiple data series in order to examine their properties. To ensure comparability, the alternative pegs are constructed so as to preserve as many features of the original exchange rate regime as possible. Specifically, the average rate of depreciation[6] and the residual term (β_0 and $u(t)$ from the Frankel-Wei regression, see equation (1)) are preserved in the simulation.

The data generation procedure in the Monte Carlo simulation takes the following steps. First, we set the sample size. In our case, this is the same as the sample size of our dataset. Second, we model the data generation process by specifying a parametric model. In our case, this means specifying the weights of basket currencies. In the first alternative regime the weights are 0.5 for the USD and 0.5 for the EUR, while in the second they are 1.0 for the EUR and 0 for the USD. Third, we specify a probability distribution for the unobserved components. In particular, we assume that the error terms follow a normal distribution. Fourth, we generate values for errors, $u(t)$, by means of a random number generator. Fifth, we compute the dependent variable (the exchange rate of MDL vis-à-vis the chosen numeraire(s)). In our case it means generating a synthetic time series for (the log first difference of) the MDL exchange rate. Finally, we estimate the model and obtain the volatility of the synthetic exchange rate.

Because the error terms are generated randomly, we have different series of the MDL exchange rate every time we repeat this procedure. By doing this a large number of times (i) we ensure that we obtain a statistically meaningful value for the standard deviation of the series (our proxy for volatility), and (ii) we can set the upper and lower boundaries of the confidence interval. In total, the Monte Carlo simulation was repeated 3200 times (400 runs for 2 alternative regimes and 4 numeraire currencies). The overall results are reported in Table 8.

Comparing the results under alternative regimes, we observe that pegging to a basket would have resulted in lower exchange rate volatility for the MDL, regardless of the choice of numeraire. Pegging to the EUR would have also resulted in lower volatility (except when the JPY was used as numeraire), as indicated by Figures 42 through 49 in the Appendix.

[6]If we estimate equation (1) subject to the constraint that the weights add up to unity, the exact rate of depreciation will be slightly different from the figure reported in Tables 3 and 4.

Table 8: Standard deviations of $\Delta\ln(MDL)$ under a Monte Carlo simulation

Numeraire	Regime		
	Actual	A hypothetical peg to an equally weighted basket of USD and EUR	A hypothetical peg to EUR
CHF	0.0080715	0.0041661	0.0049012
AUD	0.015424	0.0097794	0.010014
SDR	0.0042295	0.0012941	0.0032031
JPY	1.0843	0.89813	1.1001

7 Conclusions

Between December 2005 and November 2010, the movement of the Moldovan leu reflected the varying weights of foreign currencies with varying degrees of flexibility. While this is broadly consistent with the IMF's classification of Moldova's exchange rate regime as "a managed float with no predetermined path for the exchange rate," a detailed look at how the exchange rate was managed from day to day revealed a different picture of the country's de facto regime. In fact, the regimes could be better described as a soft peg to the US dollar, with its weights ranging between 0.9 and unity. The weight of the Russian ruble was also significant, but only during the first part of the sample period and its weight was never large. In contrast, and somewhat surprisingly, the weight of the euro was never statistically significant, despite the large share of euro-denominated transactions in the Moldovan exchange market, and an even larger share of euro-denominated assets. This puzzle is yet to be resolved.

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Appendix

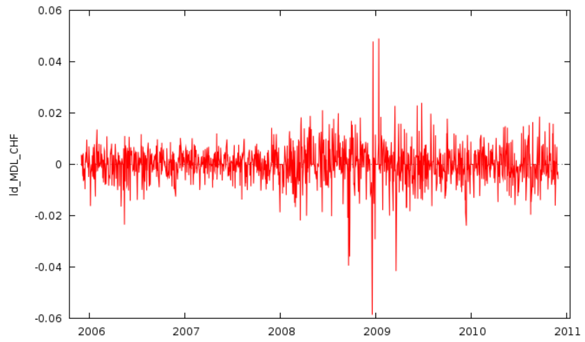

Figure 16: MDL/CHF log returns

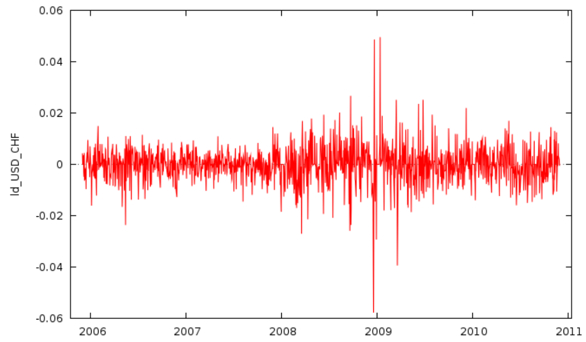

Figure 17: USD/CHF log returns

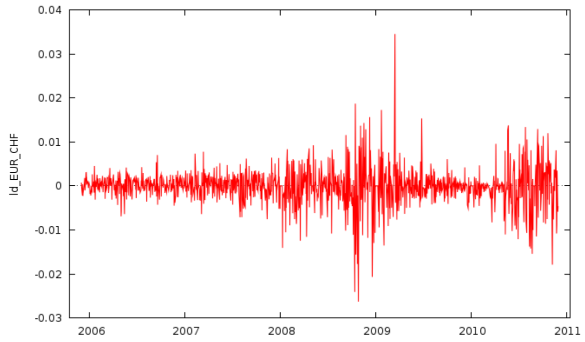

Figure 18: EUR/CHF log returns

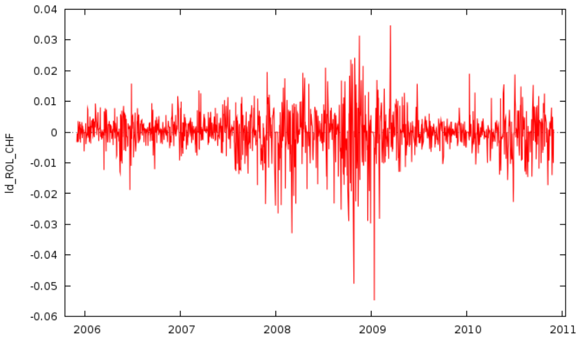

Figure 19: ROL/CHF log returns

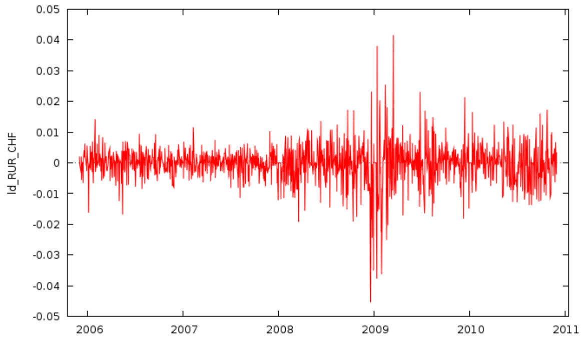

Figure 20: RUR/CHF log returns

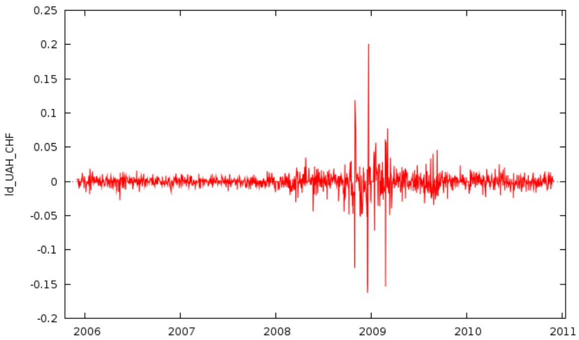

Figure 21: UAH/CHF log returns

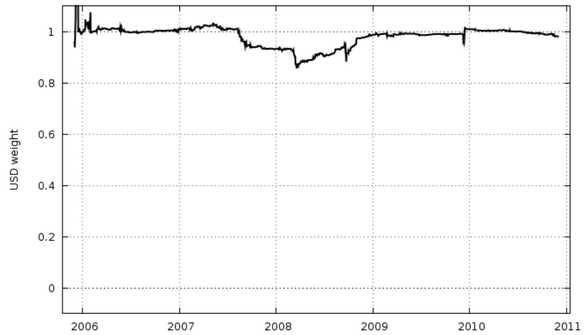

Figure 22: The weight of USD (numeraire: SDR)

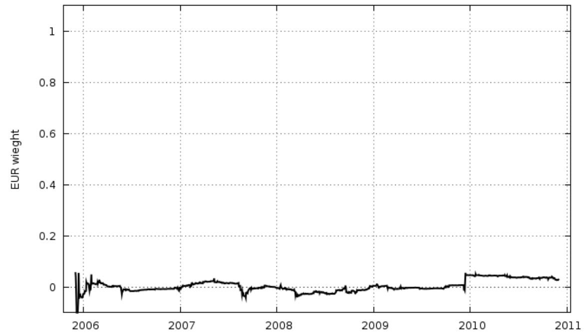

Figure 23: The weight of EUR (numeraire: SDR)

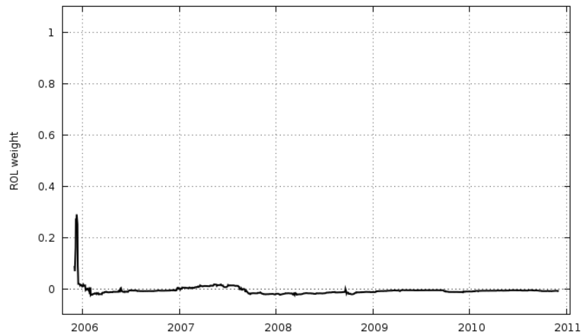

Figure 24: The weight of ROL (numeraire: SDR)

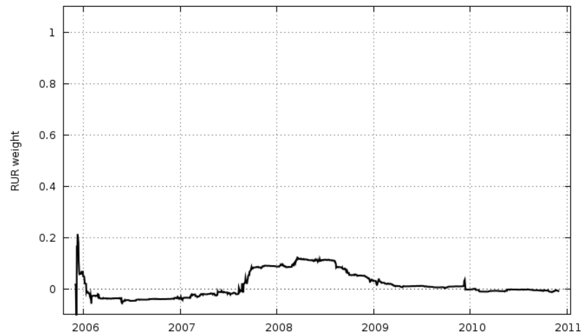

Figure 25: The weight of RUR (numeraire: SDR)

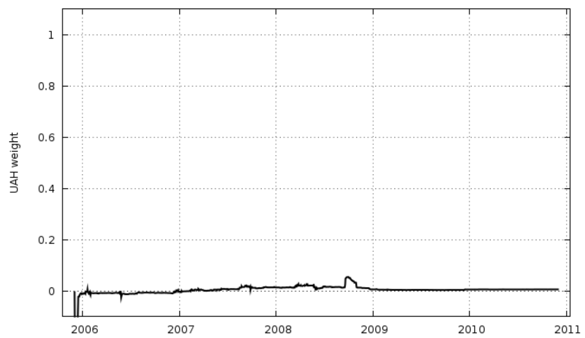

Figure 26: The weight of UAH (numeraire: Swiss franc)

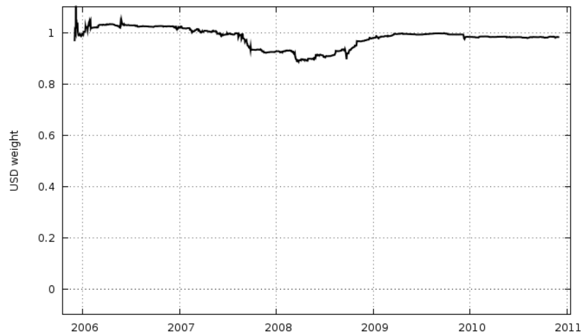

Figure 27: The weight of USD (numeraire: Australian dollar)

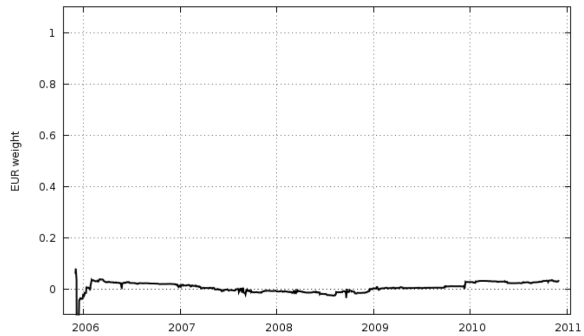

Figure 28: The weight of EUR (numeraire: Australian dollar)

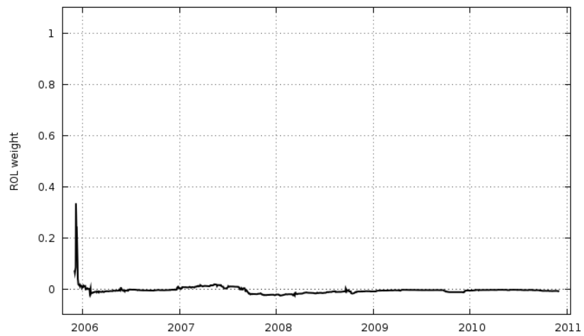

Figure 29: The weight of ROL (numeraire: Australian dollar)

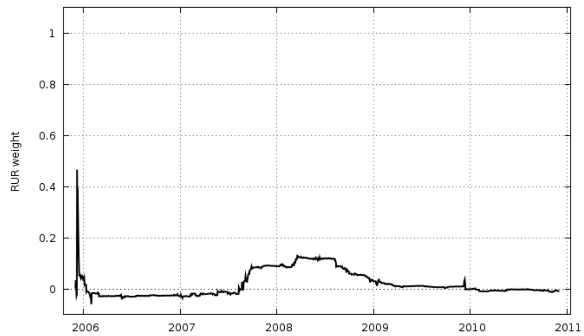

Figure 30: The weight of RUR (numeraire: Australian dollar)

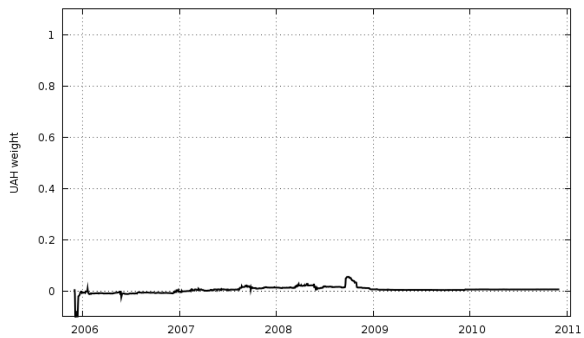

Figure 31: The weight of UAH (numeraire: Australian dollar)

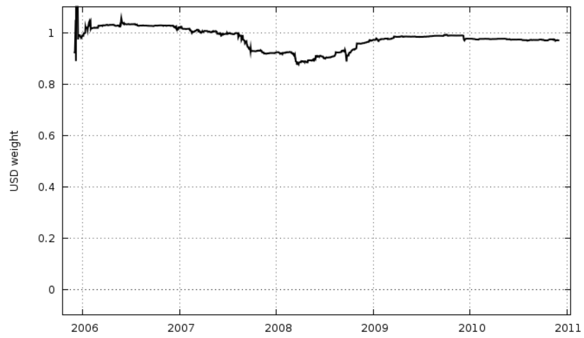

Figure 32: The weight of USD (numeraire: Japanese yen)

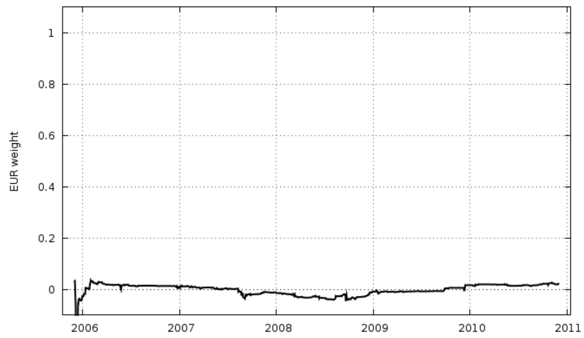

Figure 33: The weight of EUR (numeraire: Japanese yen)

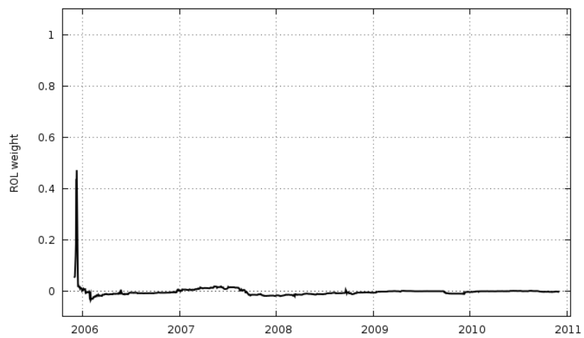

Figure 34: The weight of ROL (numeraire: Japanese yen)

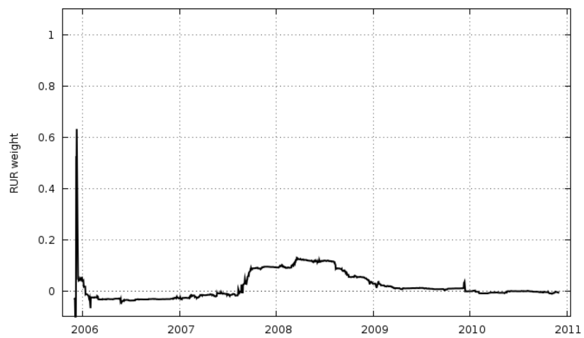

Figure 35: The weight of RUR (numeraire: Japanese yen)

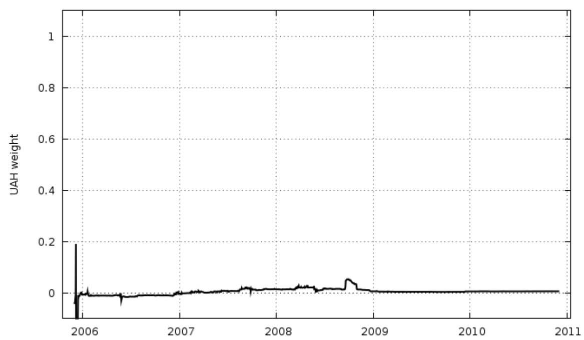

Figure 36: The weight of UAH (numeraire: Japanese yen)

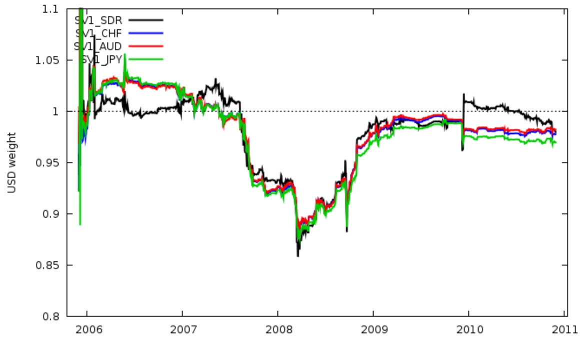

Figure 37: The weight of USD (all numeraires)

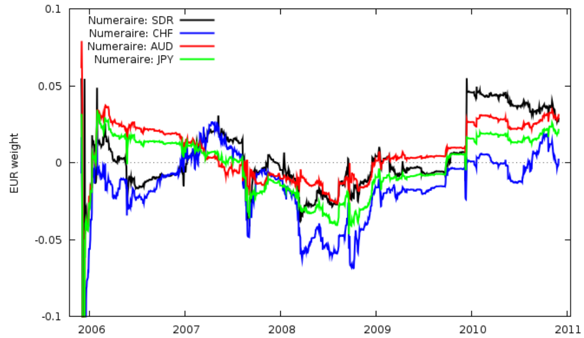

Figure 38: The weight of EUR (all numeraires)

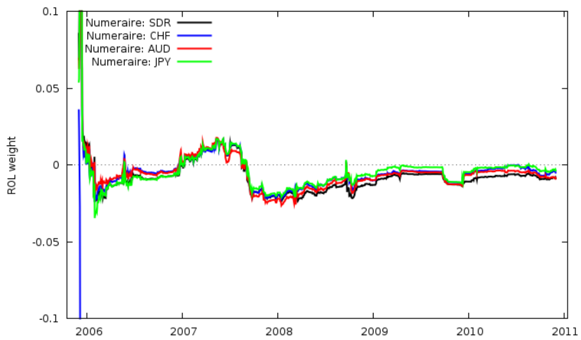

Figure 39: The weight of ROL (all numeraires)

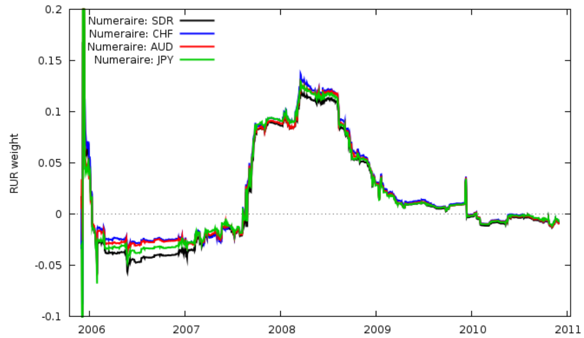

Figure 40: The weight of RUR (all numeraires)

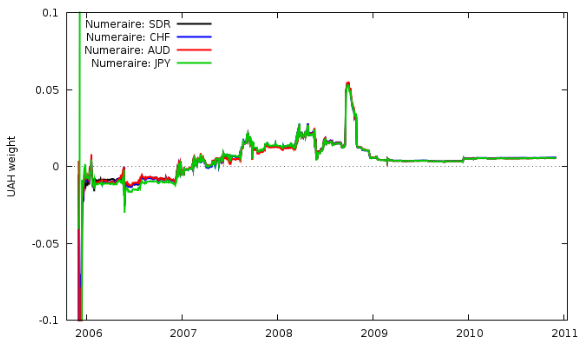

Figure 41: The weight of UAH (all numeraires)

Figures 42 to 45 depict the simulation results for a hypothetical peg to the equally weighted basket of USD and EUR, where the middle red line represents the most likely path, and the upper and lower lines represent the upper and lower boundaries of the 50% confidence interval. Likewise, Figures 46 to 49 depict the same thing for a hypothetical peg to the EUR.

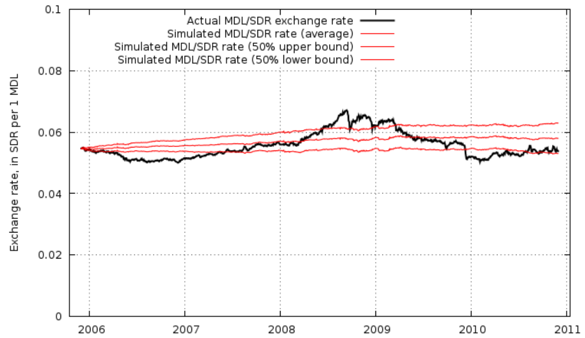

Figure 42: Simulation of a “50:50” currency basket (numeraire: SDR)

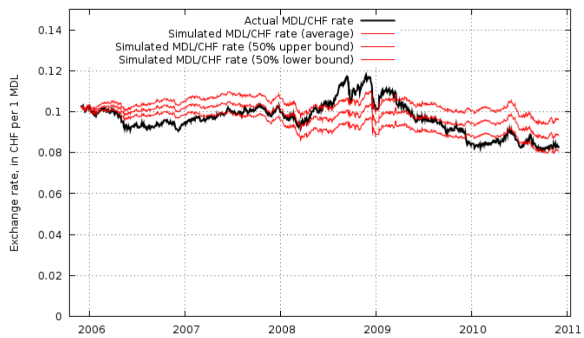

Figure 43: Simulation of a “50:50” currency basket (numeraire: CHF)

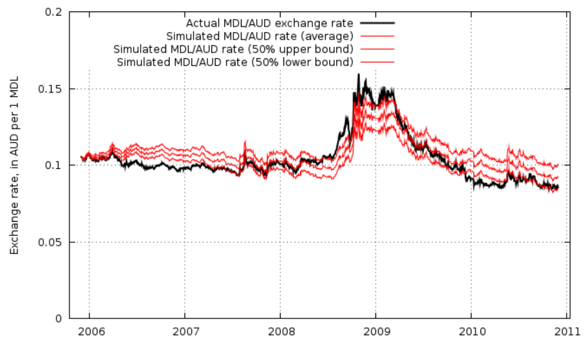

Figure 44: Simulation of a “50:50” currency basket (numeraire: AUD)

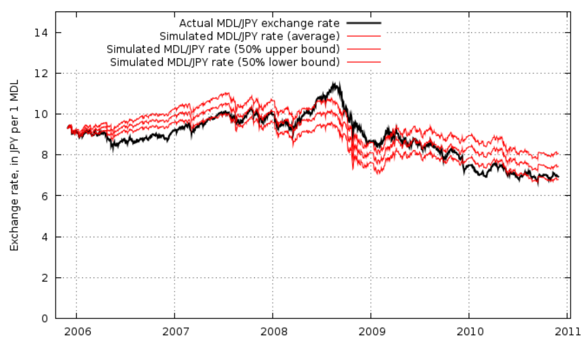

Figure 45: Simulation of a “50:50” currency basket (numeraire: JPY)

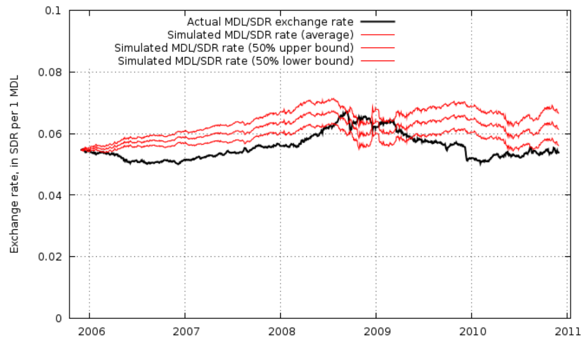

Figure 46: Simulation of a peg to the euro (numeraire: SDR)

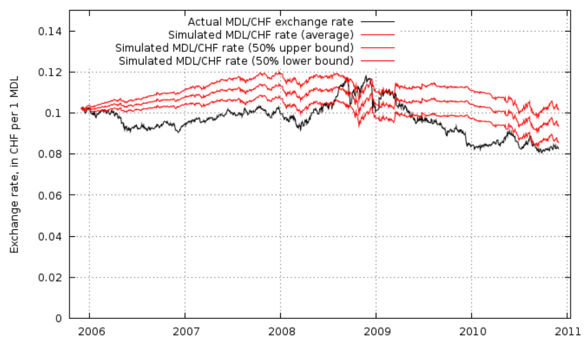

Figure 47: Simulation of a peg to the euro (numeraire: CHF)

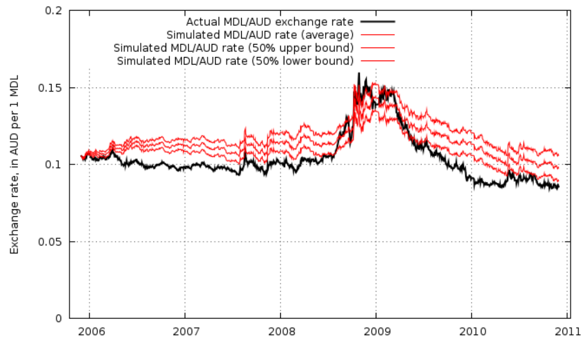

Figure 48: Simulation of a peg to the euro (numeraire: AUD)

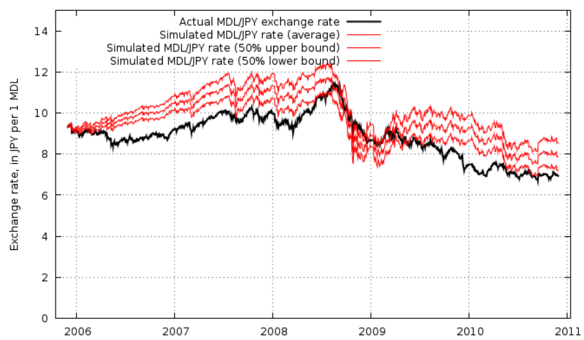

Figure 49: Simulation of a peg to the euro (numeraire: JPY)