Revista de Análisis Económico, Vol. 15, N° 1, pp. 47-59 (Junio 2000)

DOMESTIC CURRENCY EMERGING MARKET BONDS PRICING AND RISK MANAGEMENT ASPECTS

SALIH N. NEFTCI*
University Center of CUNY
University of Reading, U.K.

Abstract

Domestic currency emerging market bonds form an indirect way of trading currency and credit risk. It is true that unlike eurobonds or Bradys, domestic currency emerging market bonds have no default risk *in a classical sense. These bonds are issued by local governments and can be paid one way or another by newly issued currency, if need be. Instead, they carry a significant "devaluation risk". In this paper we discuss the environment that supports such bonds, introduce the main parameters and risks, and compare some ways of modelling and pricing these instruments. The paper illustrates that a non-parametric interest rate modelling will be more appropriate for pricing local currency emerging market bonds.*

I. Introduction

Domestic currency emerging market bonds are fascinating instruments. They form a separate class, with special characteristics within the high-yield bond sector. In addition, they offer promising alternatives and opportunities for investments in credit derivatives, a mix of various interesting aspects.

Many countries have primary and secondary domestic currency bond markets where the latest on-the-run issues are often fairly liquid and trade at relatively

* The author is at the Graduate School, University Center of CUNY, and at ISMA Centre, University of Reading, U.K.

low spreads. High returns, high volatility and recent possibilities of hedging currency risk, have made this class of bonds perhaps the second most important asset class in the emerging market fixed income sector after the Bradys'.[1]

In this paper we discuss the environment that supports such bonds, introduce the main parameters and risks, and compare some ways of modeling and pricing these instruments.

The domestic currency emerging market bonds are by definition denominated in local currency. But we claim that investors in these bonds, whether they are locals or foreigners, see themselves invariably as "dollar-based". These bond markets have in general developed in economies with large budget deficits and with a past history of chronic inflation. These economies are also prone to periodic financial crises. All these in fact make these bonds some sort of indirect way of trading currency and credit risk.

Unlike the emerging market eurobonds or Bradys, domestic currency emerging market bonds have no *default risk* in a classical sense. These bonds are issued by local governments and can be paid one way or another by newly issued currency, if need be. Instead, from the point of view of every player in the market, these bonds contain a significant "devaluation risk", whether the player is a local or a foreign investor. At first, this may appear to be incorrect from the point of view of local investors. Locals have liabilities in the local currency, and a once-and-for-all devaluation will affect domestic currency bonds and the corresponding liabilities in an identical fashion, eliminating the currency risk. But, as will be argued below, in a closer examination, even portfolios with local currency funding will be significantly exposed to a "devaluation event" due to special characteristics of such markets.

Normally, the valuation equations for domestic bonds contain no foreign exchange variable where a potential devaluation can be modeled and this way included in the pricing formulae. Yet, as argued below, the devaluation risk for domestic currency emerging market bonds can be modeled as a jump event in the interest rate process. A casual justification for this is as follows.

The characteristics of the emerging bond markets we are concerned with are such that, during an attack on the currency, the central bank will raise the overnight rates sharply to defend the currency. Thus, episodes of once-and-for-all devaluations are at the same time episodes of jumps in overnight rates. In other words, devaluations and spot rate jumps are essentially one and the same event. By buying domestic currency emerging market bonds, even the local players are, essentially, *pricing the probability* that there will be a devaluation, or a big jump in overnight rates until maturity. The fact that these bonds have short maturities and that they are zero coupons, simplifies this task. In this paper we discuss ways of modelling this pricing attempt.

In particular, the paper illustrates why a non-parametric interest rate modelling will be more appropriate for pricing local currency emerging market bonds.

The devaluation probability creates some unstable dynamics and classical interest rate modelling will be unable to take this into consideration. Yet, drift terms derived from Kernel estimators following Ait-Sahalia (1996), (1995) captures this dynamics very easily.

These points are illustrated for the Russian GKO bonds. The estimates obtained from pre-devaluation period display how these unstable interest rate dynamics can be crucial for GKO pricing and risk management.

II. Modelling

What type of model would one adopt to price such emerging market bonds or any structured products derived from these bonds? We discuss, heuristically, the essential elements that a model for emerging market bond pricing should capture. But first we warn the reader that our definition of emerging local currency bond market is very narrow. We are basically limiting our attention to the secondary market for local currency bonds with characteristics similar to those in Russia (GKOs), China (T-bills), Turkey (T-bills), and Brazil (T-bills). Clearly, these markets have very different aspects as well, yet there are also many similarities. The main parameters of such environments are summarized in the appendix. We begin with some generalities.

The main advantage of the HJM framework,[2] where the whole term structure can be modelled as a k-dimensional Markov process, is the concentration on modelling the volatility rather than getting involved in determining the correct drift parameters of the processes under consideration. In contrast, models based on the "spot rate" appear often awkward, inconvenient and even inaccurate due to the violation of Markovness assumption.[3] We believe that HJM trees is the natural setting for credit spreads and bonds in general. But in the case of domestic currency bonds of emerging economies, it might be preferable to proceed with short rate modelling. We explain this briefly.

Domestic currency emerging market bonds are traded in environments where it makes little sense to talk about a *yield curve* beyond some very short maturities.[4] Maturities over one year rarely trade actively. Most trading is concentrated in Bills of maturities ranging from 1 month to 3 months.

Thus, in the case of domestic currency emerging market bonds, one would be working with the very short end of the yield curve. This means that most of the movements one observes are, essentially, parallel shifts in the "yield curve." What is more, these shifts are almost always caused by observed movements in the O/N rate, where the latter also proxies for *severe* exchange rate movements. Hence, a modelling effort based on one or two underlying processes may be less objectionable.

Our second point was mentioned above. Even "locals", who invest in domestic currency bonds consider themselves as dollar-based investors. This is either because of past financial crises and the existence of chronic inflation, or simply because they fund their local currency bond portfolios with *short positions* in foreign exchange. This means that the exchange rate plays a crucial role in valuing these securities. Short-rate modelling will facilitate dealing with devaluation risk, simply because sudden jumps in the short-rate can in fact be taken as a proxy for possible devaluations, as will be argued below.

Our third point has to do with an interpretation of the spot rate movements in such an environment. In developed financial markets, changes in the spot rate are, in general, interpreted as just that. At times, they may also signal switches in monetary policy and hence may introduce some non-linearity in modeling. In developed financial markets the spot rate carries information about the whole term structure.[5] But, in case of domestic currency emerging market bonds, spot rate movements carry at least *two* separate pieces of information, that are *equally* important. One is on the interest rate environment-funding costs, liquidity movements, etc. But, more importantly, during some special periods, spot rate movements contain information about possible devaluation of the currency. In fact, the players know that when the currency comes under attack, the central bank will intervene by raising the O/N rate sharply. Paradoxically, the steepness of the interest rate hike may be positively correlated with a once-and-for-all devaluation.

We can make an even stronger statement. The central banks in such economies are often willing to maintain a large spread between the O/N rate and the T-bill rates. Hence, the "normal" interest rate movements are in fact less relevant from the point of view of players. They already have a good idea about the expected return from short-term funding of these bonds in the overnight market, *as long as there is no attack on the currency*. This information may often be *implicit* in the bond market.

But under these conditions, the spot rate modeling may involve some additional difficulties. The devaluation of the domestic currency will exhibit itself as a jump in the spot rate and will signal an end to any implicit guarantees given on "reasonable" funding costs. The relevant stochastic differential equations would then need to have jump process driven diffusion components as well. Also, the drift of the spot rate dynamics would contain, among other effects, the (conditional) probability that the exchange rate "peg" would snap.

All these could make the modelling effort highly *nonlinear.*[6] It may also significantly complicate the process of estimating the market prices of risk for pricing purposes.

III. An Alternative Justification

We can give more than a casual explanation for suggesting that investors in domestic currency emerging market bonds consider themselves dollar-based.

In a developed market, bonds carry an *interest rate risk*. For example, it is even possible for the funding cost of a bond (via the repo or O/N market) to exceed the yield at issue of the relevant maturity.[7] On the other hand, if there is no maturity mismatch, the domestic currency bonds will carry no exchange rate risk.

In an emerging local currency bond market, the reverse may be true. The central bank may offer a "guaranteed" minimum spread between the funding cost and the yield at issue. This reduces the standard interest rate risk. Yet, during attacks on the currency, the central banks will be incapable of maintaining the "promised" spread between O/N funding and the bond yields. Thus, a *devaluation event* is regarded as much riskier, especially if one considers the maturity mismatch between local currency assets and liabilities, which is a major characteristic of such markets.

The main idea is that a satisfactory hedging of local currency bonds in emerging markets is, in general, *not possible*. The institutions that carry these bonds in their portfolios do so by running significant maturity mismatches. Here is why.

In these economies the individual investor will not hold these instruments even at unreasonably high rates of return. The devaluation risk is just too big. The recent case of Russian devaluation is a good example. Yet, given the large budget deficits and the need to finance them, the authorities have to sell an increasing quantity of bonds. How is this going to be accomplished?

Consider the following setup. The central bank "guarantees" a spread between the yield of the bonds and the cost of funding through overnight, or better, repo markets. This implicit guarantee may last as long as the "peg" holds.

It is true that, if the peg snaps, the spot rates will jump and the institution carrying the local currency bonds will be significantly exposed. Yet, due to *moral hazard* considerations and given the right spread, the risk may be worth taking from the point of view of the institution, whereas small investors will be *fully* exposed to such risks.

Hence, the local currency bonds will be held in institutional portfolios and will be, say, repo-ed out to individual investors. This creates the maturity mismatch. During attacks on currencies, interest rates raise sharply and, as a result, significant losses become a possibility. Thus, instead of the standard interest rate risk, the players are more concerned with the (conditional) probability of a devaluation.

IV. The Pricing Problem

Thus, the spot rate process relevant to domestic currency emerging market bonds will be given, with some generality by:

$$dr_t = [a\,(r,\,t) + \lambda\,(X_t,\,t)\alpha]\;dt + b\,(r,\,t)\,dW_t + \sigma\,(X_t,\,t)dJ_t, \qquad (1)$$

where the parameters $\{a(r,\,t),\ \lambda\,(X_t,\,t),\ \alpha,\ b\,(r,\,t),\ \sigma\,(X_t,\,t)\}$ and the processes $\{W_t,\,J_t\}$ are as follows. The $a\,(r,\,t)$ and the $\lambda\,(X_t,\,t)$ are respectively, the drift of the diffusion and jump components of the SDE. The dW_t is a Wiener type random term capturing unexpected "small" routine events. The dJ_t is a jump process that captures unexpected big jumps in the devaluation probability. By definition, these latter are rare events and are related to central bank's attempts to defend the currency regime. The $b(r, t)$, $\sigma(X_t, t)$ are the volatility parameters that correspond to these two random disturbances.

The pricing problem can then be defined as follows.

Let $B(t, T)$ denote the observed price, at time t, of a liquid zero coupon bond with maturity $t < T$.[8] Suppose also that in the market, there are a range of *illiquid* zero coupon bonds $\{B(t, T_1), \ldots, B(t, T_n), T_i < T\}$, with maturities less than T. Finally, assume that either a liquid interbank overnight money market, or an overnight *repo* market exists with the relevant spot rate given by r_t. The dynamics of r_t obey the stochastic differential equation (3).

Within this context, the problem of pricing domestic currency emerging market bonds reduces to the following task: Given the process $\{r_t\}$ and the $B(t, T)$, what is the best way to price the $\{B(t, T_i), T_i < T\}$?

We next discuss a possible approach.

V. Risk-Neutral Valuation

We argue that interest rate modelling within the world of risk-neutral valuation may be more practical in case of local currency emerging market bonds. In particular, we propose following the steps outlined below.

1. First realize the nature of the market price of risk for the jump process, J_t. As we argued earlier, the devaluation event has a probability close to zero most of the time. Even for periods during which economic fundamentals could imply a high likelihood of devaluation, seasonal considerations may drive this probability very close to zero. At other times, during the aftermath of IMF packages for example, even economic fundamentals eliminate the possibility of an immediate devaluation. Also, note that the *possibility* of devaluation is a recurrent event with fairly homogenous risk premia across time.
2. Following up on this logic, split the available sample data into two subsamples, one for periods with no devaluation risk, the other where devaluation risk was high. For periods of low devaluation probability, assume that the market price of devaluation risk is zero and calibrate the parameters of the short rate process in a straightforward manner. Then estimate the γ^W as a function of the spot rate.
3. Then, consider the periods of high devaluation probability, and use the already estimated γ^W and the observed yield curve data to calibrate the market price of devaluation risk, γ^J.
4. Given that historical data is used to obtain the relevant parameters, utilize a continuous-time, non-parametric estimation for obtaining the estimates for the relevant drift and diffusion parameters of the short-rate equation.

Following these steps will yield an *arbitrage-free* model for the short rate. This model can be used to price illiquid domestic currency bonds.

To illustrate some of the difficulties one may face during this process, we consider an example from Russian GKO market. This example has the purpose of illustrating the non-linear nature of the drift components that emerging market short rate processes have.

VI. Non-parametric Drift Estimation for GKO's

To illustrate this approach we consider the Russian ruble-denominated GKO market. For the spot rate r_t, we chose the overnight interbank rate. The data for period 1996-1998 are shown in Figure 1.

We intend to illustrate, using non-parametric methods, that the drift of a general SDE for the spot rate is highly nonlinear for the Russian markets. That a non-parametric approach is more appropriate can be justified in many ways. One obvious reason for the present case is the possibility that the drift term is highly nonlinear due to a devaluation event.

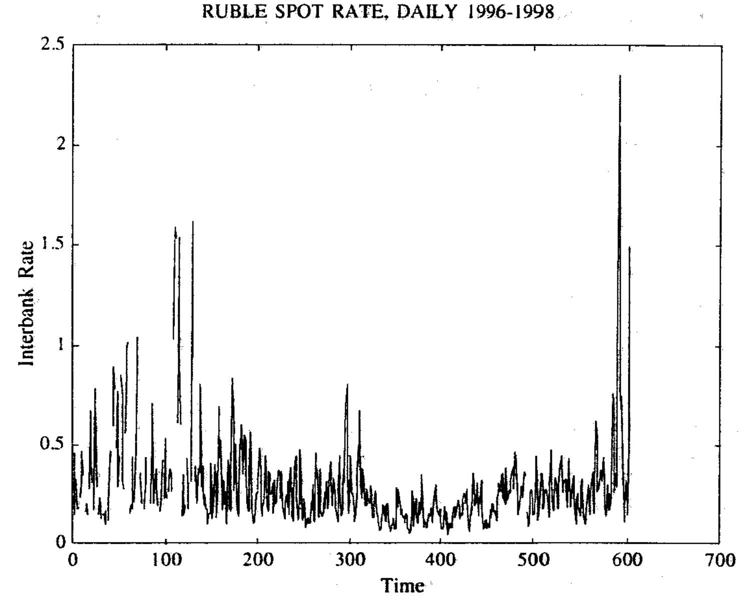
In particular, following Ait-Sahalia (1996), we let the spot rate follow the SDE

$$dr_t = [a_o + a_1 rt + a_2 r_t^2 + a_4 \frac{1}{r_t}]dt + \sigma\, r_t dW_t, \tag{2}$$

where $\{a_i, \sigma i = 1, ..4\}$ are parameters to be estimated.

FIGURE 1

RUBLE SPOT RATE, DAILY 1996-1998



Assuming that the driving term W_t is a Wiener process and that r_t is stationary, gives the following density of the spot rate as a function of the drift and diffusion parameters:

$$f(u) = \frac{1}{\sigma_u} e^{\int_{u_0}^{u} \frac{2\mu(s)}{\sigma_s} ds},$$

where $u_o \geq 0$ is the minimum possible spot rate.

We also define a non-parametric Kernel estimator of this density using the Gaussian Kernel $K(u)$:

$$K(x) = \frac{1}{\sqrt{2\pi}} e^{-.5\frac{(x-u)^2}{h}},$$

where h is the bandwidth parameter. The non-parametric estimator of $f(u)$ using this Kernel function is given by:

$$\hat{f}(u) = \frac{1}{N}\frac{1}{h}\sum_{i=1}^{N} K(\frac{u-r_i}{h})$$

where r_i are observed spot rate data. The N is the total number of observations, equalling 573 in this particular case.

The estimates for the unknown parameter vector θ,

$$\theta = \{a_0, a_1, a_2, a_4, \sigma\},$$

can then be obtained by minimizing the distance between the $f(u, \theta)$ and $\hat{f}(u)$.

That is,

$$\hat{\theta}^N = \arg\min_{\theta}[\int_{u_0}^{\infty} [f(u,\theta) - \hat{f}(u)]^2 du].$$

This minimization will give consistent estimates of the *continuous time* drift and diffusion parameters in θ.

6.1 Numerical considerations

The results displayed in Figures 2 to 6 were obtained using Matlab.

The m-files needed for the calculation of the drift and diffusion parameters and the resulting non-parametric Kernel estimators are straightforward. The major step here is the specification of the bandwidth parameter h, which in this case was selected as .028 by trial and error. Small variations of this parameter make little difference in the estimates.

The choice for bandwith h could be increased a bit more in order to smooth out the wiggles in the estimated right hand tail of the density. But, given the hypothesized jump process, we wanted to detect specifically any bimodal behavior of the density especially at the tails. Hence the relatively non-smooth behavior of the right-hand tail.

The major step in estimation is the minimization routine. We use two minimization routines to obtain the estimates. The internal Matlab routine FMINS

FIGURE 2

ESTIMATED AND ACTUAL NON-PARAMETRIC DENSITIES

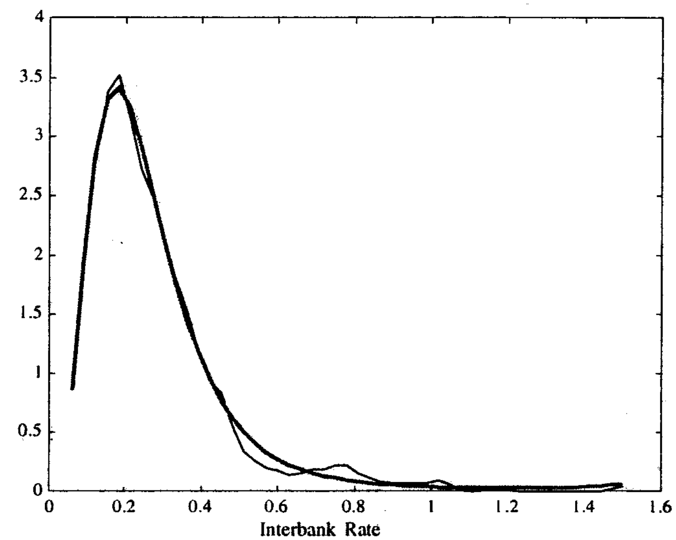


FIGURE 3

ESTIMATED CONTINUOUS TIME DRIFT, O/N INTERBANK

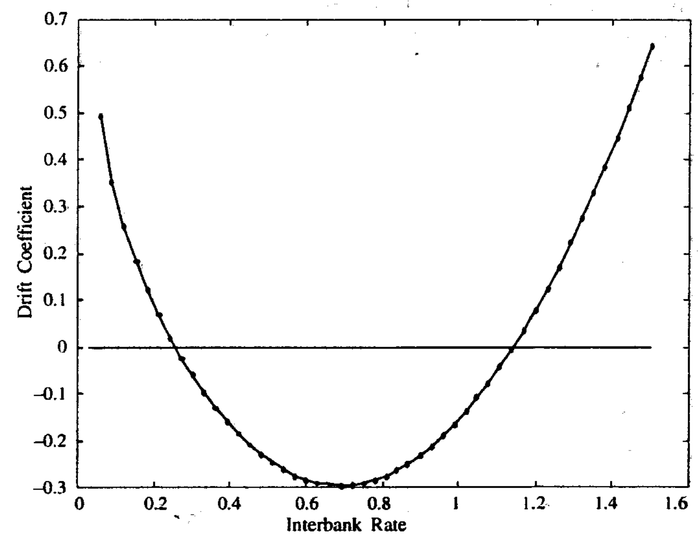
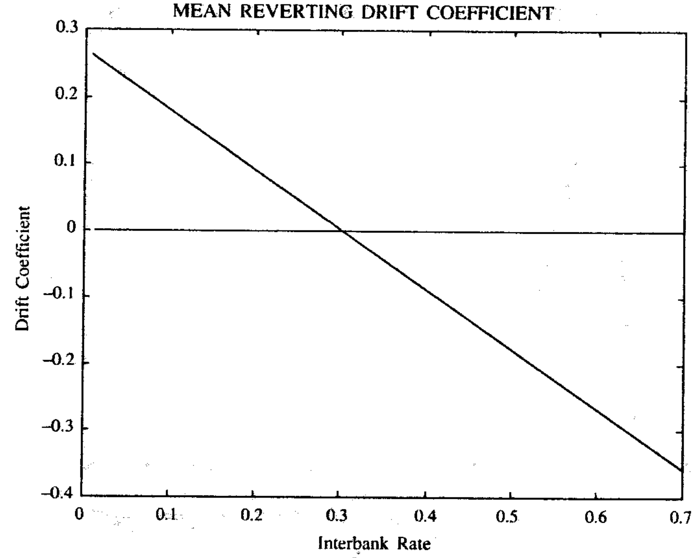


FIGURE 4

MEAN REVERTING DRIFT COEFFICIENT



appears to work. But a modified version of the minimization routine CSMINWEL written by Chris Sims seems to be more adequate in these cases. CSMINWEL is a Matlab M-file that has internal switches to introduce perturbations in case the surfaces under consideration are flat. Our experience is such that for similar non-parametric estimation in continuous time these flat surfaces are often encountered.

Also, in order to obtain adequate convergence an appropriate initial guess of the Hessian is quite helpful.

VII. Results

The results of this minimization are shown in two sets of figures that emphasizes the power of the non-parametric approach in capturing the devaluation risk. In the first set, we use the data on Russian overnight rates until the month of June. These data contain the increases in the overnight rates that were due to the run on the ruble but *not* the devaluation itself. Thus, these data should in principle contain some hints concerning the July-August events that led to the eventual ruble devaluation. These results are in Figures 2-3.

The second set of results are in Figure 5-6. Here we exclude the last few days of data that contain the jumps in overnight rates preceding the ruble devaluation. The resulting interest rate model is very different and does not price the eventual devaluation. Hence, our main point that *a few days of data are suficient to dramatically change the non-parametric model*. It turns out that this is the case, since

FIGURE 5

NON-PARAMETRIC DENSITIES. TWO SAMPLES

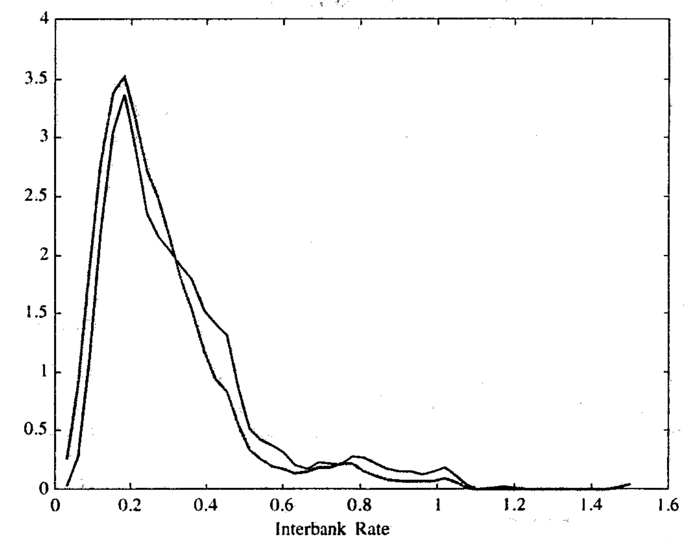
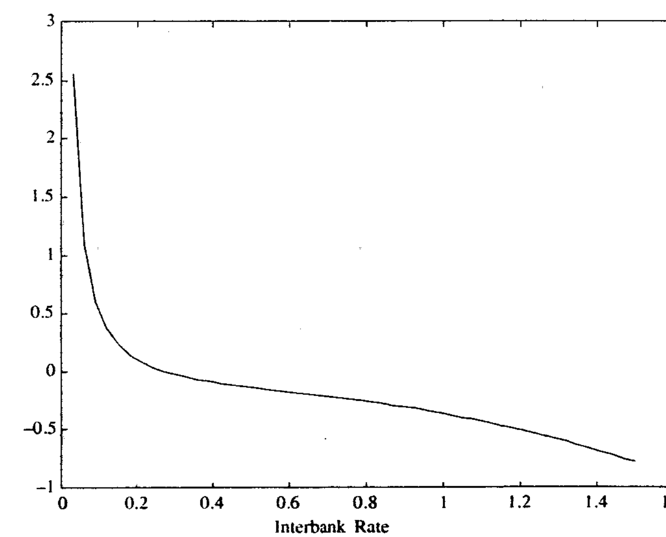


FIGURE 6

DRIFT WITH THE 1996-1997. 6 DATA



the non-parametric approach is very flexible and permits such sudden and non-linear changes in the parameters.

We now study the results in more detail. Figure 2 displays the true and the estimated non-parametric densities superimposed on each other when we use the whole sample. Here we see the problematic behavior of the estimated tails clearly. Any pricing procedure that does not take into account these heavy tails will in all likelihood result in dramatic pricing and risk management errors.

Figure 3 is the plot of the drift implied by the Kernel estimator. We would like to comment on this estimate. First note that a typical spot-rate method for pricing assets will be based on the so-called mean reverting model given by:

$$dr_t = \kappa\,(\mu - r_t)\,dt + \sigma r_t dW_t$$

where the κ, μ, and σ are respectively the speed of mean reversion, the long run mean and the percentage volatility coefficients. The W_t is a standard Wiener process.

In such a model the drift coefficient will have the shape shown in Figure 4. Essentially as r_t increases, the drift decreases. At $r_t = \mu$ the drift is equal to zero, and for higher levels of r_t it becomes negative. But, the important point is that the drift is *linear*.

Now consider the non-parametric drift shown in Figure 3. Here we see that for Russian GKO's the drift can indeed be approximated fairly closely by a downward sloping line as long as r_t stays between 0 and 64%. Yet, as r_t approaches 70%, the drift becomes upward sloping. That is to say for the region:

$$70\% < r_t$$

The mean "reversion" starts to have the wrong sign and the interest rate gets on an *explosive* path. Obviously such a path has to end violently, which it did, with the infamous Russian devaluation of 1998.

It is interesting that, these result which use data before the Russian devaluation of 1998 could capture the unavoidability of the Russian devaluation. Indeed during 1998, one the overnight rates hit 70%, the market became unstable and the currency regime eventually collapsed.

Now consider what happens when we re-estimate the same non-parametric drift using a sample that leaves out the last 10 observations. We obtain a new kernel estimator for the density that is shown in Figure 5. The new estimator is significantly different from the one obtained from the whole sample, especially at the tails. Something, a parametric method would have failed to capture.

Yet, the real difference is shown in the new drift which is shown in Figure 6. Here we see that the drift term for Russian overnight rates is not very different than the ones for US interest rate as reported in Ait-Sahalia (1995). Essentially, they leave out the devaluation risk. Such a result may mistakenly lead an analyst to use the mean-reverting model as a first approximation, but this would be a significant mis-pricing of the devaluation risk.

VIII. Conclusions

These results indicate that at least in this particular case, the non-parametric spot rate models will be capable of incorporating devaluation possibilities into the pricing problem, indirectly and very conveniently. Of course, the existence of unstable regions in drifts estimated with non-parametric methods, can only be a first approximation to formal ways of modelling the devaluation as a jump process, but it certainly is a better approximation than the standard mean-reverting model.

Notes

1 Eurobonds issued by emerging markets issuers form in some cases a larger class, but they are not as liquid and they trade at wider spreads.
2 See Heath-Jarrow-Morton (1989).
3 Given a bivariate Markov process, the implied univariate processes are rarely Markov.
4 We have in mind cases such as Russia and Turkey.
5 One exception is the EMS crisis of 1992. During the crisis, spot rate movements in Nordic economies could have been interpreted as carrying information about potential devaluation of the underlying currencies.
6 By nonlinear, we mean processes with drifts depending nonlinearly on the observed spot rate.
7 An example, is the possibility of an inverted yield curve.
8 It should be kept in mind that within our framework, the T is perhaps 3 or at most 6 months.

References

AIT-SAHALIA, Y. (1996). "Non-Parametric Pricing of Interest Rate Derivative Securities," *Econometrica*, 64 (3), pp. 527-560.
AIT-SAHALIA, Y. (1995). "Interest Rate Models", *The Review of Financial Studies*, 9, pp. 385-426.
HEATH D., R. JARROW and A. MORTON (1992). "Bond Pricing and Term Structure of Interest Rates: A New Methodology for Contingent Claim Valuation", *Econometrica*, 60 (1), pp. 77-105.
MUSIELA, M., and M. RUTKOWSKI (1997). *Martingale Methods in Financial Modelling*, Springer-Verlag.
NEFTCI, S. (1999). "Short FX Positions and Financial Crises". Manuscript.