Crisis Dynamics of Implied Default Recovery Ratios: Evidence From Russia and Argentina

John J. Merrick, Jr.*

November 1999

*Stern School of Business, New York University. The author thanks Ed Altman, John Boschen, Stephen Figlewski, Anthony Saunders, Suresh Sundaresan, and Charles Webster for comments at an earlier stage, and both Barclay Investments, Inc. and Ellen Mathias of Salomon Smith Barney for graciously providing the data. The usual disclaimer applies.

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Abstract

The Russian GKO default crisis provides a unique window into the impact of changing default probabilities and recovery ratio assumptions on credit-sensitive sovereign bond prices. This paper introduces a joint implied parameter approach to extract both the expected recovery ratio and the default probability term structure. The methodology is applied to both Russian Federation and Republic of Argentina US dollar-denominated Eurobonds before and after the GKO crisis. For the Russian bonds, the sample paths suggest a two-phase revaluation. Shifts in default probabilities account for most of the initial price collapse. Marked decreases in the projected default recovery ratio dominate the continued Russian bond price declines. The "contagion effect" impact of the default crisis on the Argentine Eurobond market actually resembles the Russian case much more than the raw price data indicate. The crucial Argentine distinction is that investors never cut recovery value assumptions.

1. Introduction

Russia's August 1998 default on its ruble-denominated GKO debt obligations precipitated a severe revaluation of credit risk throughout the global financial markets.[1] This default was extraordinary, and punished investors who had assumed that a government with access to the monetary printing press would always honor its home currency obligations.[2]

Of course, investors have always imputed default risk to *foreign currency* sovereign debt, especially for emerging market issuers. Echoing this point, the ratings agencies afford less-than-AAA status for many such sovereign bonds. As of year-end 1998, Standard & Poor's rated Russia's US dollar-denominated debt BBB and similar Argentine debt BB. The yield premiums over US Treasury yields demanded for foreign issuers' US dollar-denominated debt compensate the holders for bearing default risks. Such yield premiums fluctuated wildly during the Russian GKO default crisis as default scenario contagion spread to the markets for emerging market countries' dollar-denominated debt.

While the extreme price volatility generated by the Russian crisis was painful to many investors, it provides a unique window into the impact of changing default probabilities and recovery ratio assumptions on credit-sensitive sovereign bond prices. This paper introduces a *joint* implied parameter approach to sovereign bond pricing to extract market assumptions about *both* the expected recovery ratio and the default probability term structure by applying a consistent valuation framework to a cross-section of market prices on outstanding bond issues. Previous empirical analyses of U.S.

corporate bond pricing such as Fons (1987) and Jarrow, Lando and Turnbull (1997) exogenously specify default recovery rate parameters based upon previous careful studies of U.S. historical default experience. In the emerging sovereign debt markets, no such recovery histories based upon previous defaults are available for reference. Moreover, sovereign default crises are necessarily fluid situations generating possibly major revisions in investor expectations.

This paper's empirical section applies the methodology to both Russian Federation (the catalyst country) and Republic of Argentina (a contagion-effect country) US dollar-denominated Eurobonds during the GKO crisis. The empirical strategy aims to answer a sequence of outstanding questions to fully understand the price dynamics of the emerging markets debt crash. First, what were the market's initial recovery rate assumptions on these Russian and Argentine Eurobonds? Second, in both of these markets, what implied default rate term structures did the cross-section of prices initially reflect? Third, how did these assumed recovery ratio and default rate term structure parameters change throughout the GKO default crisis? Finally, did shifts in expected recovery values distort observations of default rate contagion effects?

The implied recovery ratio approach is particularly useful for these Russian and Argentine applications. Far from being a typical default, this home-currency Russian GKO bond default catalyzed a global review of credit risks. Of course, the most direct impact of such a watershed event would be on other classes of Russian debt. Moreover, unlike Brady Bonds, Russian Federation Eurobonds carry no attached collateral. By scrutinizing market reactions via the price fluctuations on the five outstanding Russian Eurobond issues during the crisis, the analysis can trace the path of revisions to market expectations regarding both the recovery ratio and Eurobond default probabilities. Argentina's Eurobond issues also suffered severely from the revaluing of credit risks, but subsequently recovered most of their losses. A comparative analysis of the Argentine bond price data gives a broader context for recovery ratio assumptions. The Argentine analysis also permits a direct characterization of default crisis contagion effects.

The empirical analysis leads to the following conclusions: First, the pre-crisis implied recovery ratio for Russian Eurobonds is lower than the level that previous researchers have estimated for US corporate debt. In contrast, Argentina's debt embodies standard US corporate debt recovery ratio assumptions. Second, during the crisis, the implied default probability on Russian debt rose sharply during the week prior to the GKO default announcement and then rose again afterwards. Third, the implied Russian recovery ratio – reasonably stable prior to the GKO default – fell sharply upon the actual default announcement. Fourth, significant downward revisions in this implied recovery ratio continued even after the default probability stabilized at its higher value. For the post-GKO default announcement sample period, market prices imply an average recovery value for Russian Eurobonds of only ten cents on the dollar. Finally, because of the divergence between recovery value shifts during this sample period, bond price comparisons alone understate the depth of the default contagion effect on Argentina.

The remainder of this paper is organized as follows. Section 2 reviews the recovery value concept and details the pricing framework. The framework incorporates a discounted expected cash flow methodology utilizing the now familiar equivalent martingale technique. Section 3 discusses the data. Section 4 discusses the estimation strategy. Section 5 presents results for the Russian Federation Eurobonds. Section 6 presents the results for the Republic of Argentina Eurobonds. Section 7 discusses contagion crisis depth. Section 8 concludes.

2. A Pricing Framework

In principal, risky sovereign debt valuation should proceed along lines similar to valuation for risky corporate debt. Except for Brady Bonds (see below), the sovereign debt default event is couched under a forced "rescheduling" agreement that exchanges the originally promised cash flow stream for new, more lenient terms. From the investor's perspective, the value of the involuntarily-exchanged new security is less than that of the original debt. In a sovereign default, as the Russian GKO exchange package negotiations showed, power – not the issuer's actual ability to pay – may be the most important determinant of whatever value the investor may recover.

As with risky corporate debt, assumptions about the default recovery ratio – the percentage of bond par value recovered by the investor after a default – crucially affect sovereign foreign currency debt valuation. For different classes of US corporate debt, investors can utilize a well-documented default experience history to help predict potential default recovery rates. For example, Altman and Eberhart (1994) examine a sample of 91 US firms that filed for and emerged from Chapter 11 between 1980 and 1992. The authors estimate bondholder recovery by actual post-emergence bond market value. The sample's average recovery rate is about 50%, with significant differences among seniority classes. Using a much larger sample over the 1978-1998 period, Altman *et al* (1999) estimate the weighted average recovery rate of US corporate debt defaults to be 40% of face value.

Unlike the US domestic corporate debt markets, the sovereign foreign currency bond markets offer no rich default experience histories for reference. A large portion of such debt exists under the Brady Bond structure, where repayment of principal and a rolling component of the coupon stream is secured by zero-coupon US Treasury Note collateral. Through the Treasury collateral, the Brady Bond structure ameliorates the investor's problem of reliably estimating a default recovery ratio.[3] In the absence of such Brady Bond guarantees, a default crisis scenario for unsecured sovereign debt is destined to be a fluid situation.

There are four components in the valuation methodology for a specific N-period maturity bond. The first is the bond's notional (i.e., promised) cash flow stream consisting of coupons and principal value. Denote the date t coupon payment by C_t and the maturity date N principal repayment by F_N. The second component is an assumed specific salvage or recovery value, R, paid to the bondholder immediately upon the event of default. In the default portion of the event tree, this immediate substituting payment of R replaces any remaining cash flows (i.e., the remaining coupons and principal) from the initially promised stream. This recovery value represents the default date present value of the bond's payment rescheduling. The third component is the adjusted *risk-neutral* payments probability distribution under the equivalent martingale measure of Harrison and Kreps (1979). Denote the (adjusted) probability of default during the specific date t-1 to date t period as p_t. Denote the (adjusted) probability of a timely payment of the promised date t cash flow as P_t. Since each coupon payment has a "cross-default" provision with every subsequent coupon, P_t represents the cumulative probability of no default occurring from issue date through date t.[4] Thus, the effect of recovery value is spread out across the event tree. The fourth valuation component is the risk-free present value discount factor for a time t cash flow, denoted as f_t.

Equation (1) expresses the bond's current value, V_0, as the expected discounted cash flow relation:

$$V_0 = \sum_{t=1}^{N} [P_t * f_t * C_t] + [P_N * f_N * F_N] + \sum_{t=1}^{N} [p_t * f_t * R] . \tag{1}$$

As in Jonkhart (1979) and Fons (1987), equation (1) views the bond's current value as a probability-weighted sum of three components: coupon flows, principal repayment and recovery value. However, following Leland and Toft (1996), the probability distribution used here is reinterpreted as the implied risk-neutral distribution.

Finally, cross-default provisions with other coupon-paying bonds may also exist. In this case, recovery value realization on a particular bond may occur even on a date where no coupon payment is scheduled. Careful treatment of recovery value as a separate flow component involves analyzing the specific institutional cross-default framework.

Denote the date t term risk-neutral default probability rate as δ_t. The probability of timely payment of a future date t cash flow follows as:

$$P_t = (1 - \delta_t)^{t}. \tag{2}$$

Previous empirical research on expressions such as equation (1) by Fons (1987) and Bhanot (1998) consider only a constant probability of default ($\delta_t = \delta$). Here, assume instead that the term default rate applying for a period t cash flow can be expressed as a linear function of time:

$$\delta_t = \alpha + \beta * t, \tag{3}$$

where the parameters α and β are restricted to values ensuring that P_t is less than or equal to unity for all t. A flat default rate term structure ($\beta = 0$; $\delta_t = \alpha$) would imply identical forward default rates for all periods. During a crisis, default rates for deferred periods – which apply to default probabilities in future periods conditional on the sovereign's ability to successfully avoid an earlier default – might be lower than near-term default rates. Equation (3) attempts to improve upon the specifications of previous research to capture such a default rate curve in a parsimonious manner.[5]

In sum, the framework incorporates three unknown parameters: R, α and β. The risk-free discount factors and the bond's notional cash flows are known. Since $p_t = (P_{t-1} - P_t)$, equation (4) embodies an estimable form of the bond valuation expression.

$$V_0 = \sum_{t=1}^{N} [\,(1 - \alpha - \beta*[t]\,)^{t} * f_t * C_t] + (1 - \alpha - \beta*[N]\,)^{N} * f_N * F_N$$

$$+ \sum_{t=1}^{N} [\,(\,(1 - \alpha - \beta*[t-1])^{t-1} - (1 - \alpha - \beta*[t])^{t}\,) * f_t * R\,]\,. \tag{4}$$

3. The Data

As of year-end 1998, the Russian Federation had five bullet US dollar-denominated Eurobond issues outstanding: the 9.25% 11/27/01 (Russia-01); the 11.75 6/10/03 (Russia-03); the 8.75% 7/24/05 (Russia-05); the 10% 6/26/07 (Russia-07); and the 11% 7/24/18 (Russia-18).[6] Thus, from the inception of the GKO crisis, the five bonds' maturity spectrum spanned between two and twenty years. The total par value of all of Russia's Eurobond issues is approximately $13.7 billion. These bonds are the unsecured debt obligations of the Russian Federation and are governed by the laws of England. Each bond's cross-default provision is triggered should the Russian Federation default on any of its other Eurobonds or other public external indebtedness.

For the same period, the Republic of Argentina also had five bullet US dollar-denominated Eurobond issues outstanding: the 9.25% 2/23/01 (Arg-01); the 8.375 12/20/03 (Arg-03); the 11% 10/9/06 (Arg-06); the 11.375% 1/30/17 (Arg-17); and the 9.75% 9/19/27 (Arg-27). Thus, from the inception of the GKO crisis, the five Argentine bonds' maturity spectrum spanned between two and thirty years. The total par value of all of these fixed-rate Argentine Eurobond issues is approximately $11.5 billion. These bonds are the unsecured debt obligations of the Republic of Argentina and are governed by the laws of England.

The bonds of both issuers trade in an over-the-counter dealer market. As might be anticipated, the August crisis triggered important changes in the structure of the Russian market. Prior to August, about twenty firms acted as market-makers, though only about ten could be relied upon to supply liquidity on a consistent basis. In the aftermath of the crisis, only about one-half of these firms continued to participate as dealers. The crisis also changed the mix of customer order flow, as hedge funds and Russian trading firms exited the market. Average trading volume shrank from pre-crisis levels of approximately $10 billion per day to no more than $500 million (in March 1999). Markets are made in all five bonds, but the longer-term issues exhibit greater liquidity.

This study's bond price data are mid-market bond prices collected once each day off of dealer-contributed Reuters bond pricing pages for each date in the sample. Because of the substantial market disarray during the period, even screen-collected prices may be suspect. Indeed, the sample contains no Russian bond prices for August 17th, the day the screens went blank. Nevertheless, these collected Eurobond prices passed a reliability cross-check with the closing bid-side marks of a major bond dealer. The mid-market prices used reflect bond values more accurately than bid-side prices, since bid-asked spreads widened precipitously during the heat of the crisis. The study's sample period starts on July 23, 1998 and ends on December 14, 1998. Corresponding risk-free discount factors applying to each cash flow date were imputed from daily closing Treasury yield curve data.

Table 1 presents a descriptive overview of the Russian and Argentine bonds, including their outstanding par value, initial settlement date, and price and yield ranges over the sample period.

<Insert Table 1>

Figure 1 plots the Russia-18's and Argentina-17's market prices between July 23rd and December 14th. The Russian bond price – initially stable during the halcyon last week of July – fell steadily from August 5th through August 14th as the global markets as the markets began to get nervous; plummeted in response to the August 17th GKO default announcement; dropped sharply once again later during the last week of August; and then stabilized for the rest of the sample period. The Argentine bond price tracked the Russian market during its August decline, but then recovered. However, even at the deepest point of the crisis, the Argentine bond never marked less than 70 price points. The lowest Russian bond mark was 12.5 price points.

<Insert Figure 1 Here>

4. Empirical Analysis

To repeat, he empirical investigation focuses on four questions. First, what were the market's initial recovery rate assumptions on these Russian and Argentine Eurobonds? Second, in both of these markets, what implied default rate term structures did the cross-section of prices initially reflect? Third, how did these assumed recovery ratio and default rate term structure parameters change throughout the GKO default crisis? Finally, did shifts in expected recovery values distort observations of default rate contagion effects?

For each market, the estimation strategy proceeds as follows. Recall equation (4), the expression for bond value. Define a bond's "model value," $\hat{V}_0$, by substituting the estimates α, β and R into equation (4). Now, at date 0, consider a cross-section of I outstanding issues indexed by the subscript i with a common cross-default provision. Define the sum of squared residuals across the I outstanding issues on date 0 as

$$SSR_0 = \sum_{i=1}^{I} (V_{i,0} - \hat{V}_{i,0})^2 \tag{5}$$

where $V_{i,0}$ is now interpreted as the date 0 market value for the i^{th} bond. Estimates of the date 0 implied model parameters can be derived by choosing values for

$\hat{\alpha}$, $\hat{\beta}$ and $\hat{R}$ that minimize SSR_0 in equation 5 while simultaneously constraining the average of the cross-sectional bond pricing residuals to equal zero:[7]

$$(1/I) \sum_{i=1}^{I} (V_{i,0} - \hat{V}_{i,0}) = 0. \tag{6}$$

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Implementing the strategy requires the following steps. For each day in the sample, construct the cash flow event tree for each of the I bonds.[8] Next, apply equation (4) representing each bond's value as the sum of its discounted probability-weighted cash flows. Finally, using initial guesses for the unknown parameters R, α, and β, search for the values that minimize that day's sum of squared cross-sectional bond pricing residuals while setting the cross-sectional average error to zero.

Parameter estimates are computed using an algorithm for nonlinear optimization subject to nonlinear constraints.[9] The convergence algorithm does not guarantee that the final estimates are global solutions. This is a general problem with search algorithms in nonlinear optimization. Some experimentation with alternative initial guesses showed that starting points generally did not make a crucial difference to the estimation results. Of course, another index to the credibility of an estimation procedure is the reasonableness of its results.   These are presented below.

5. Results for Russian Federation Eurobonds

Table 2 reports summary statistics for the Russian market's time series of daily parameter estimates over the full sample. The average implied recovery ratio for these Russian bonds was estimated at 13.1%, significantly lower than the 40%-50% *ex post* ratios cited above for US corporate defaults. The average default rate term structure parameters – base rate of 0.37; slope of .0176 per year – implied average payment probabilities of 36% for a 2-year-ahead date; 5% for a 5-year date; and 0% for a 10-year date. All three model parameter series exhibited substantial daily variation.

Table 3 reports similar Russian market results for two sub-samples partitioned into pre-August 17, 1998 and post-August 17 periods. As might be anticipated, there are large differences in the default rate term structure parameter estimates across the two sub-samples. The average post-announcement base default rate more than doubled its pre-announcement level (from .17 to .41). In both sub-samples, the estimate slope coefficient was positive. However, the correlation between the default function intercept and slope parameters was negative.

Unlike the case of the default rate parameters, a stylized credit crisis need not predict shifts in the implied default recovery ratio. A default recovery ratio only takes on meaning conditional upon the occurrence of the default event. Its value could be independent of changes in the probability that the event occurs, unless relevant news is changing both simultaneously. Thus, there is no theoretical reason why the implied recovery rate need change in a crisis. However, the Table 3 estimates clearly show that a dramatic fall did occur in the post-announcement sub-sample. The pre-announcement average recovery ratio estimate was 27.3%. Thus, even the pre-crisis Russian recovery value estimate is lower than the 40%-50% average historical levels cited above for US corporate *ex post* default recovery experience. For the post-announcement period, the implied recovery ratio estimate was 10.4%. In Russia's case, the rise in default probability was accompanied by a significant downward revision in assumed recovery value.

Table 3 also reports test statistics that strongly reject the null hypothesis that the Russia Eurobond recovery ratio and the default rate function intercept were constant across the August 17th break point.

<Insert Tables 2 and 3 here>

Figure 2 plots the daily estimates of the implied recovery ratio (R) and the default rate function's intercept coefficient (α). The plot provides additional depth to the nature of the Russian Eurobond market crash. From the viewpoint of the base default rate, the crisis had completed a good deal of its repricing by August 14th. The annualized default rate function intercept rose from below 0.10 to about 0.30 as the markets became increasingly apprehensive about Russia's finances. In response to the August 17 GKO announcement, the base default rate jumped overnight to near 0.40 – essentially its average value for the remainder of the period. Yet, as Figure 1 showed, bond prices continued to fall throughout the rest of the month. The estimates reveal that further downward revisions in the implied recovery ratio accounted for the continued market declines. In particular, the estimated recovery ratio collapsed 8.25 points overnight on August 25th (from $23.0 to $14.75 per $100 of par value), and fell another 13.45 points from the 25th to its $1.3 low on October 14th.

<Insert Figure 2 here>

Figure 3 displays the quantitative value significance of these recovery ratio revisions by comparing the Russia-18's model price at the estimated recovery ratio against a *counterfactual* simulated Russia-18 price. The point of this exercise is to show how much market revisions to recovery value mattered during the crisis: to quantify recovery revaluation effects on prices as distinct from default probability revision effects. Table 3 computes its counterfactual simulated price by applying the sample estimates for α and β, but only after keeping the recovery ratio parameter fixed at 25% throughout the sample (R=$25 per $100 of par value). The gap between the true and counterfactual prices increases as the implied recovery ratio falls. Indeed, the post-GKO default announcement sample's average difference was about 13.5 price points. The largest difference occurred on October 14th, when the gap rose to 21.9 price points. The period between August 18th and October 15th was particularly interesting. The implied payment probability prospects actually brightened – α in Figure 2 decreased and the counterfactual R = 25 price in Figure 3 rose – while market bond prices continue to fall significantly.

<Insert Figure 3 here>

6. Results for Republic of Argentina Eurobonds

Table 4 reports summary statistics for the Argentine market's time series of daily parameter estimates over the full sample. The average implied recovery ratio for these Republic of Argentina bonds was estimated at 49.6%, in line with the 40%-50% average *ex post* ratios cited above for US corporate defaults. The average default rate term structure parameters – base rate of 0.128; slope of .0023 per year – implied average payment probabilities of 75% for a 2-year-ahead date; 47% for a 5-year date; and 19% for a 10-year date.

Table 5 reports similar Republic of Argentina Eurobond market results for the two sub-samples partitioned into pre-August 17, 1998 and post-August 17 periods. As with the Russian market data, there were large differences in the default rate term structure parameter estimates across the two sub-samples. The average post-announcement base default rate quadrupled its pre-announcement level (to .148 from .034). And as with Russia, while the estimate slope coefficient was positive in both sub-samples, the correlation between the default function intercept and slope parameters was negative.

Table 5 also reports test statistics for the null hypothesis that the Argentine Eurobond recovery ratio and the default rate function parameters were constant across the

August 17th break point. In contrast to the results for Russian bonds, the constant recovery ratio hypothesis cannot be rejected. Nevertheless, the hypotheses of constant default rate function parameters – both intercept and slope – can be rejected at standard levels of significance. Figure 4 plots the daily estimates of the implied recovery ratio (R) and the default rate function's intercept coefficient (α) for these Republic of Argentina Eurobonds.

<Insert Tables 4 and 5 here>

<Insert Figure 4 here>

7. Crisis Depth

Perceived gains from diversifying an emerging market investment allocation across a wide set of different country credits depend on the correlations among country bond markets. If asset correlations tend to rise in times of crisis, much of the originally perceived benefits from diversification is negated. In the emerging fixed income markets, the rising correlations during credit crises are termed "contagion effects." An increase in the implied probability of default of one sovereign issuer's debt (e.g., Russia) causes corresponding implied default probability increases for others (e.g., Argentina) as emerging market investors simultaneously rush to shrink their portfolio exposures.

But in the current context, interpreting even the most basic data concerning the relative depths of the GKO default crisis among different emerging markets is problematic. As depicted in Figure 1, while Argentine Eurobond prices followed Russian bond prices down from mid-August to mid-September, the crash in Argentine bond prices was significantly less severe.

Yet, a very different picture of the relative depths of the crisis appears in Figure 5. This figure plots the estimated payment probability for a 5-year horizon cash flow date in each market. The implied five-year Argentine payment probability began August at 75%. It collapsed to an average of 21% for the first-half of September. Thus, the true default crisis in the Argentine market actually resembled Russia much more than the raw price data indicates. Default crisis contagion effects from Russian to Argentine Eurobonds were extremely strong. The crucial distinction between the two bond markets is that investor perception of the Argentine recovery value floor never buckled. In contrast, recovery value under a Russian default was essentially written off. The lesson for Argentina: default crisis contagion effects are very real. What saved the Argentine market from a more severe crash was ongoing investor confidence in being treated fairly under a potential default scenario.

8. Conclusions

The results here support the hypothesis that significant downward revisions in the market's assessment of default recovery ratios played a significant roll in the 1998 crash of Russian Federation Eurobond prices. What caused these substantial downward revisions? The most likely factor was the unveiling of the first Russian government proposals for restructuring the defaulted ruble-denominated GKO debt. These first proposals, released the week after the default, lacked clear details on the pricing of a proposed ruble-into-dollar debt swap. The details regarding possible trading restrictions on either the new ruble or new dollar security alternatives were also sketchy. More clarity about the situation did not appear until early December 1998. Major international banks deemed the initial plan – along with several revisions – unacceptable. However, one conclusion was clear: investors would fare worse than they had originally anticipated. This GKO outcome most certainly influenced the continued price declines in the Russian Eurobond market.[10]

While the extreme price volatility generated by the Russian crisis was painful to many investors, it provides a unique window into the impact of changing default probabilities and recovery ratio assumptions on credit-sensitive sovereign bond prices. This paper's findings highlight difficulties portfolio managers and, especially, market makers face assessing and hedging credit-sensitive sovereign bond price risks. Clearly, hedge ratios designed using standard spread duration measures are inappropriate for hedging credit risk dimensions when recovery ratio revaluation plays a role. And as the Russian Eurobond case presented here reveals, market recovery ratio perceptions are fragile. Moreover, shifts in recovery ratio perceptions can be as quantitatively important for bond prices as shifts in default probabilities.

Interpreting the estimates of market recovery ratio assumptions for Russia (pre-crisis: 27%) and Argentine (about 50%) may be fertile ground for political economists. Certainly, these estimates give some perspective to the deeper question: what is an appropriate recovery value for sovereign debt? Much to the dismay of the international banks involved in the GKO default negotiations, raw bargaining power – not reserve levels, net exports or other cash flow factors – may be the true fundamental.

Finally, the implied recovery value approach is not only applicable to emerging market sovereign debt. The methodology can also be exploited to further understand the pricing of US corporate debt markets. Substantial historical data exists on US corporate bondholder *ex post* recovery experience. Applying this paper's technique may help define whether such recoveries have been high or low relative to *ex ante* market assessments; whether recovery prospects for US corporate debt are subject to major periodic shifts; and whether – as in Russia's case – dramatic downward revisions are conceived in crisis.

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Footnotes

[1] GKOs – Gosudarstvennye Kratkosrochnye Obyazatel'stva – are ruble-denominated state treasury bills. The Russian Federation defaulted on its GKOs in the domestic debt restructuring plan announced on August 17, 1998.

[2] Standard and Poor's reports seven previous instances of a sovereign's default on home currency debt. See Chambers [1997].

[3] See Claessens and Pennachi [1996] and Bhanot [1998] for empirical analysis of Brady bonds.

[4] Hence, the probability of receiving the recovery value R on any date t, p_t, can be written as $p_t = (P_{t-1}-P_t)$, the probability of default during the specific date t-1 to date t period. Alternatively, P_t, the probability of receiving a promised date t coupon payment can be expressed as $P_t = 1 - \sum_{s=1}^{t} p_s$.

[5] Absent recovery value (R=0), equation (3) would imply a simple term structure for pure default credit yield spreads. In fact, if $\beta = 0$, all zero coupon bonds would share the same yield spread over the risk free yield. The introduction of a lumpy positive recovery value alters this result, and breaks down the pure correspondence between yield spread and default rates.

[6] Another Russian issue, the 11% 7/24/28 containing a 7/24/08 par put provision, was excluded from consideration. The $13.7 billion total Eurobond issuance size quoted below includes $2.5 billion of this 2028 maturity bond.

[7] The estimation procedure also restricts the recovery ratio and all bond cash flow date payment probabilities to be nonnegative. An earlier draft also reported Russian model estimates for a case without the current nonnegativity constraint on the recovery ratio, but where the model priced the longest maturity issue (the Russia-18s) exactly. That case's results were broadly consistent with those reported here, but negative values for the recovery ratio were estimated during a two-week global liquidity crisis episode during the October 1998.

[8] We assume that default occurs only on a bond cash flow date. Because of cross-default provisions, a default on any one of an issuer's bonds triggers a default on every issue.

[9] The GRG2 (generalized reduced gradient) algorithm for nonlinear optimization subject to nonlinear constraints was used. This algorithm is generally available through Microsoft's Excel software package.

[10]GKO rescheduling negotiations and revisions dragged on until the major international banks began agreeing to terms in March 1999.

Table 1
Russian Federation and Republic of Argentina Eurobond Descriptions

					Sample Statistics July 23, 1998 - December 14, 1998			
			Initial	Par Value	Price Range		Yield Range	
Issue	Coupon	Maturity	Settlement	($000s)	Max.	Min.	Min.	Max.
Russia-01	9.25	11/27/01	11/27/96	$ 1,000,000	88.8	25.0	13.2%	73.2%
Russia-03	11.75	6/10/03	6/10/98	$ 1,250,000	89.2	15.0	14.4%	92.5%
Russia-05	8.75	7/24/05	7/24/98	$ 2,968,968	71.4	13.0	15.1%	73.5%
Russia-07	10	6/26/07	6/26/97	$ 2,400,000	75.2	17.0	14.6%	61.1%
Russia-18	11	7/24/18	7/24/98	$ 3,446,671	71.2	12.5	15.4%	86.3%
Arg-01	9.25	2/23/01	2/23/96	$ 1,200,000	103.5	74.9	7.7%	23.3%
Arg-03	8.375	12/20/03	12/20/93	$ 1,800,000	102.1	71.3	7.9%	16.8%
Arg-06	11	10/9/06	10/9/96	$ 1,300,000	109.1	74.5	9.4%	16.9%
Arg-17	11.375	1/30/17	1/30/97	$ 3,875,000	110.1	70.4	10.2%	16.5%
Arg-27	9.75	9/19/27	9/19/97	$ 3,350,000	96.8	61.9	10.1%	15.9%

Table 2
Russian Eurobond Implied Recovery Ratio and Default Rate Function Estimates

Full Sample Estimates: July 23, 1998 - December 14, 1998

	Recovery Ratio (R)	Default Rate Intercept (α)	Default Rate Slope (β)
Sample Mean	*13.0*	*0.368*	*0.0176*
Std. Dev.	*3.7*	*0.054*	*0.0191*
Maximum	*31.3*	*0.593*	*0.0404*
Minimum	*1.3*	*0.084*	*-0.0130*
Correlation	1.00	-0.56	-0.23
Matrix		1.00	-0.15
			1.00

Implied Horizon Payment Probability

2-Year	5-Year	10-Year
36%	5%	0%

Table 3
Russian Eurobond Implied Recovery Ratio and Default Rate Function Estimates

Pre-GKO Default Subsample: July 23, 1998 - August 14, 1998

	Recovery Ratio (R)	Default Rate Intercept (α)	Default Rate Slope (β)
Sample Mean	*27.3*	*0.166*	*0.0072*
Std. Dev.	*3.0*	*0.078*	*0.0103*
Maximum	*31.3*	*0.306*	*0.0404*
Minimum	*20.7*	*0.084*	*-0.0048*

	R	α	β
Correlation	1.00	-0.28	0.16
Matrix		1.00	-0.13
			1.00

Implied Horizon Payment Probability

2-Year	5-Year	10-Year
67%	32%	7%

Post-GKO Default Subsample: August 17, 1998 - December 14, 1998

	Recovery Ratio (R)	Default Rate Intercept (α)	Default Rate Slope (β)
Sample Mean	*10.3*	*0.406*	*0.0196*
Std. Dev.	*5.8*	*0.054*	*0.0183*
Maximum	*29.5*	*0.593*	*0.0345*
Minimum	*1.3*	*0.318*	*-0.0130*

	R	α	β
Correlation	1.00	0.25	-0.07
Matrix		1.00	-0.80
			1.00

Implied Horizon Payment Probability

2-Year	5-Year	10-Year
31%	3%	0%

Chi-Square Statistics: Tests of Equality of Means Across Subsamples

Recovery Ratio (R)	Default Rate Intercept (α)	Default Rate Slope (β)
73.7	104.7	6.0

Table 4
Republic of Argentina Eurobond Implied Recovery Ratio and Default Rate Function Estimates

Full Sample Estimates: July 23, 1998 - December 14, 1998

	Recovery Ratio (R)	Default Rate Intercept (α)	Default Rate Slope (β)
Sample Mean	*49.6*	*0.128*	*0.0023*
Std. Dev.	*5.4*	*0.009*	*0.0021*
Maximum	*86.7*	*0.668*	*0.0111*
Minimum	*34.5*	*0.023*	*-0.0142*

	R	α	β
Correlation	1.00	0.48	-0.06
Matrix		1.00	-0.81
			1.00

Implied Horizon Payment Probability

2-Year	5-Year	10-Year
75%	47%	19%

Table 5
Republic of Argentina Eurobond Implied Recovery Ratio and Default Rate Function Estimates

Pre-GKO Default Subsample: July 23, 1998 - August 14, 1998

	Recovery Ratio (R)	Default Rate Intercept (α)	Default Rate Slope (β)
Sample Mean	*51.2*	*0.034*	*0.0063*
Std. Dev.	*2.7*	*0.011*	*0.0015*
Maximum	*54.0*	*0.056*	*0.0109*
Minimum	*44.7*	*0.023*	*0.0044*
	R	**α**	**β**
Correlation	1.00	-0.18	-0.19
Matrix		1.00	-0.13
			1.00
Implied Horizon Payment Probability			
	2-Year	5-Year	10-Year
	91%	71%	36%

Post-GKO Default Subsample: August 17, 1998 - December 14, 1998

	Recovery Ratio (R)	Default Rate Intercept (α)	Default Rate Slope (β)
Sample Mean	*49.3*	*0.148*	*0.0014*
Std. Dev.	*10.2*	*0.103*	*0.0042*
Maximum	*86.7*	*0.668*	*0.0111*
Minimum	*34.5*	*0.045*	*-0.0142*
	R	**α**	**β**
Correlation	1.00	0.58	-0.10
Matrix		1.00	-0.78
			1.00
Implied Horizon Payment Probability			
	2-Year	5-Year	10-Year
	72%	43%	17%

Chi-Square Statistics: Tests of Equality of Means Across Subsamples

Recovery Ratio (R)	Default Rate Intercept (α)	Default Rate Slope (β)
0.4	16.0	15.4

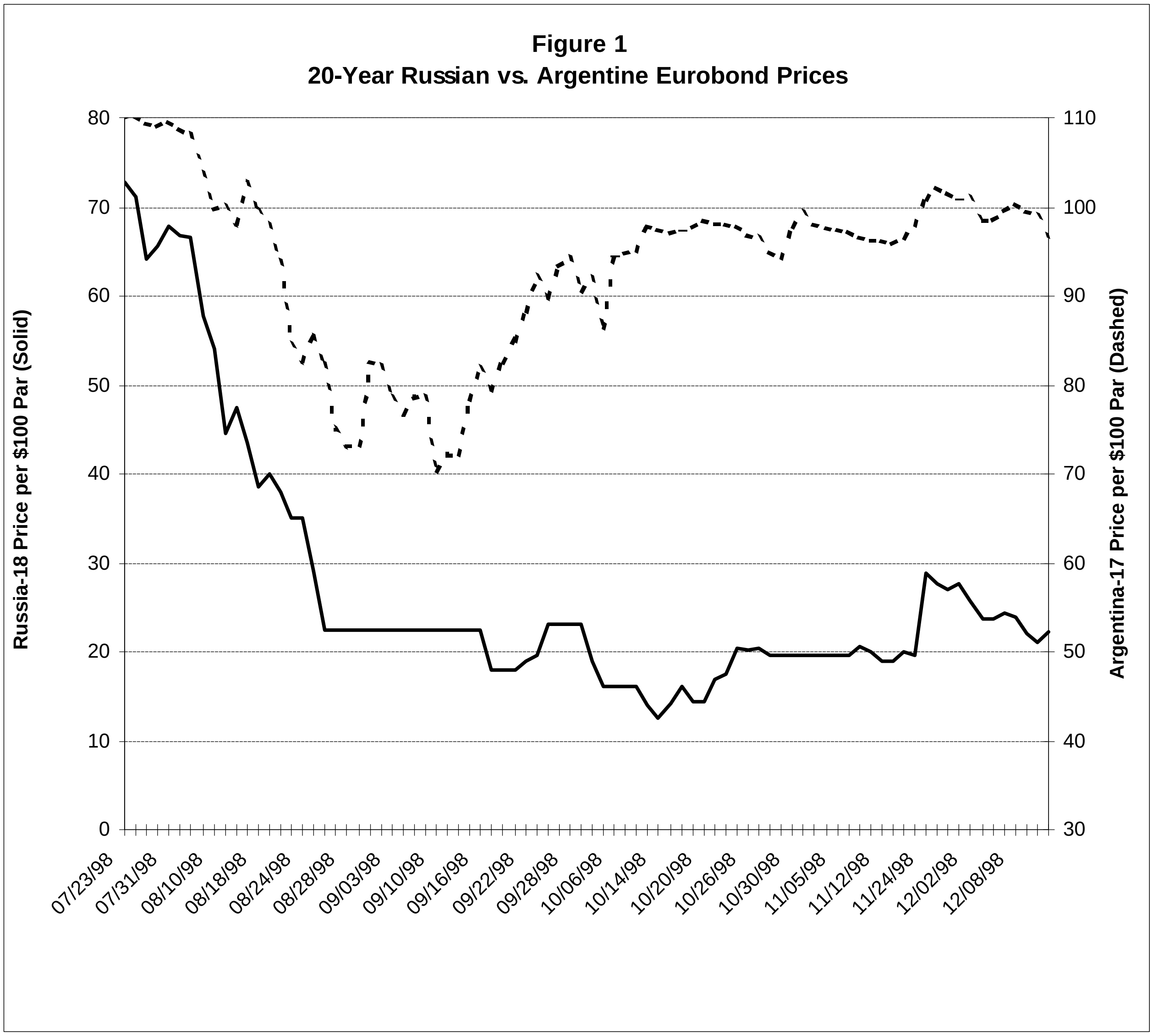
Figure 1
20-Year Russian vs. Argentine Eurobond Prices
Russia-18 Price per $100 Par (Solid)
Argentina-17 Price per $100 Par (Dashed)
0
10
20
30
40
50
60
70
80
30
40
50
60
70
80
90
100
110
07/23/98
07/31/98
08/10/98
08/18/98
08/24/98
08/28/98
09/03/98
09/10/98
09/16/98
09/22/98
09/28/98
10/06/98
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12/02/98
12/08/98

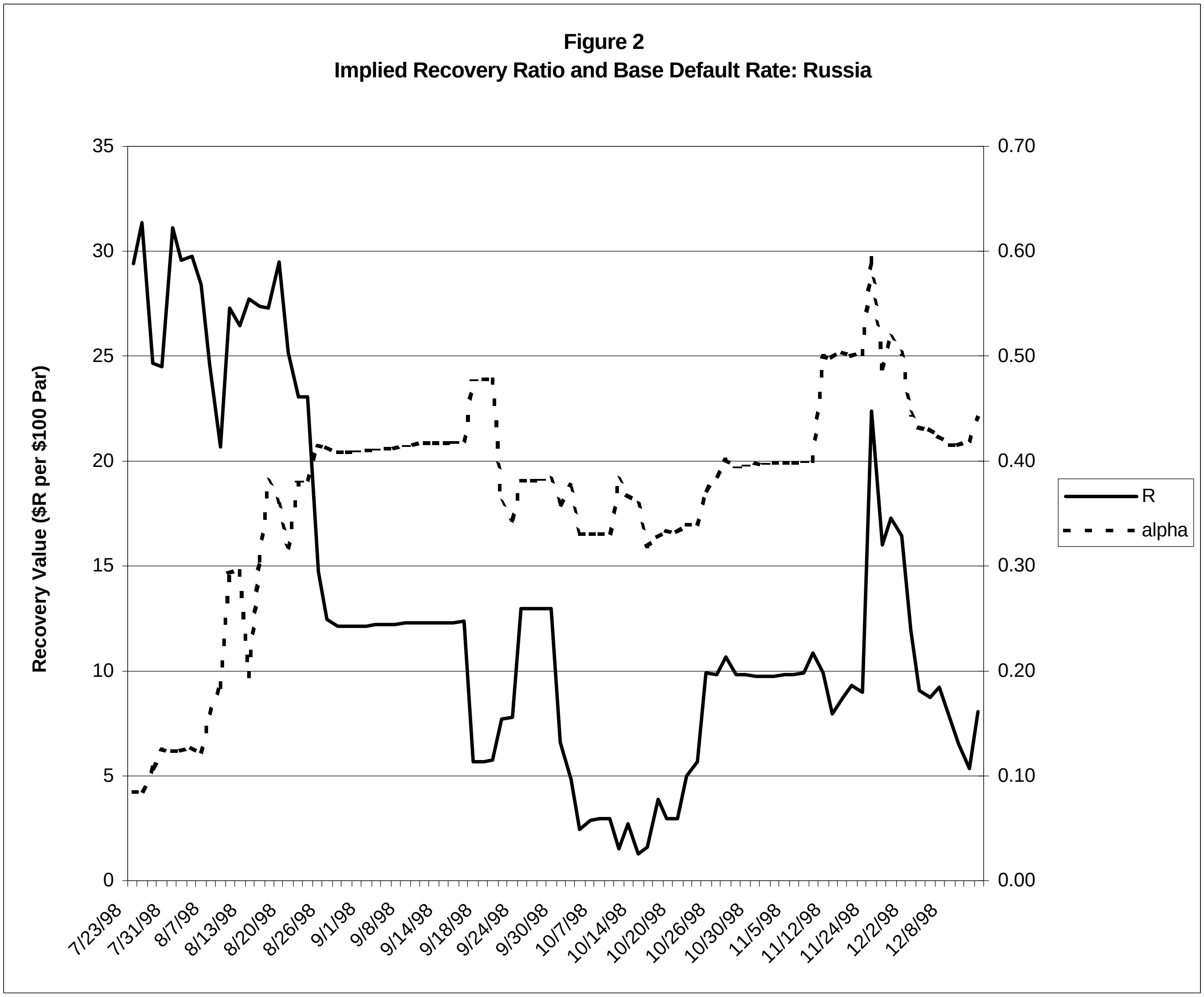
Figure 2
Implied Recovery Ratio and Base Default Rate: Russia
Recovery Value ($R per $100 Par)
35
30
25
20
15
10
5
0
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
7/23/98
7/31/98
8/7/98
8/13/98
8/20/98
8/26/98
9/1/98
9/8/98
9/14/98
9/18/98
9/24/98
9/30/98
10/7/98
10/14/98
10/20/98
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12/2/98
12/8/98
R
alpha

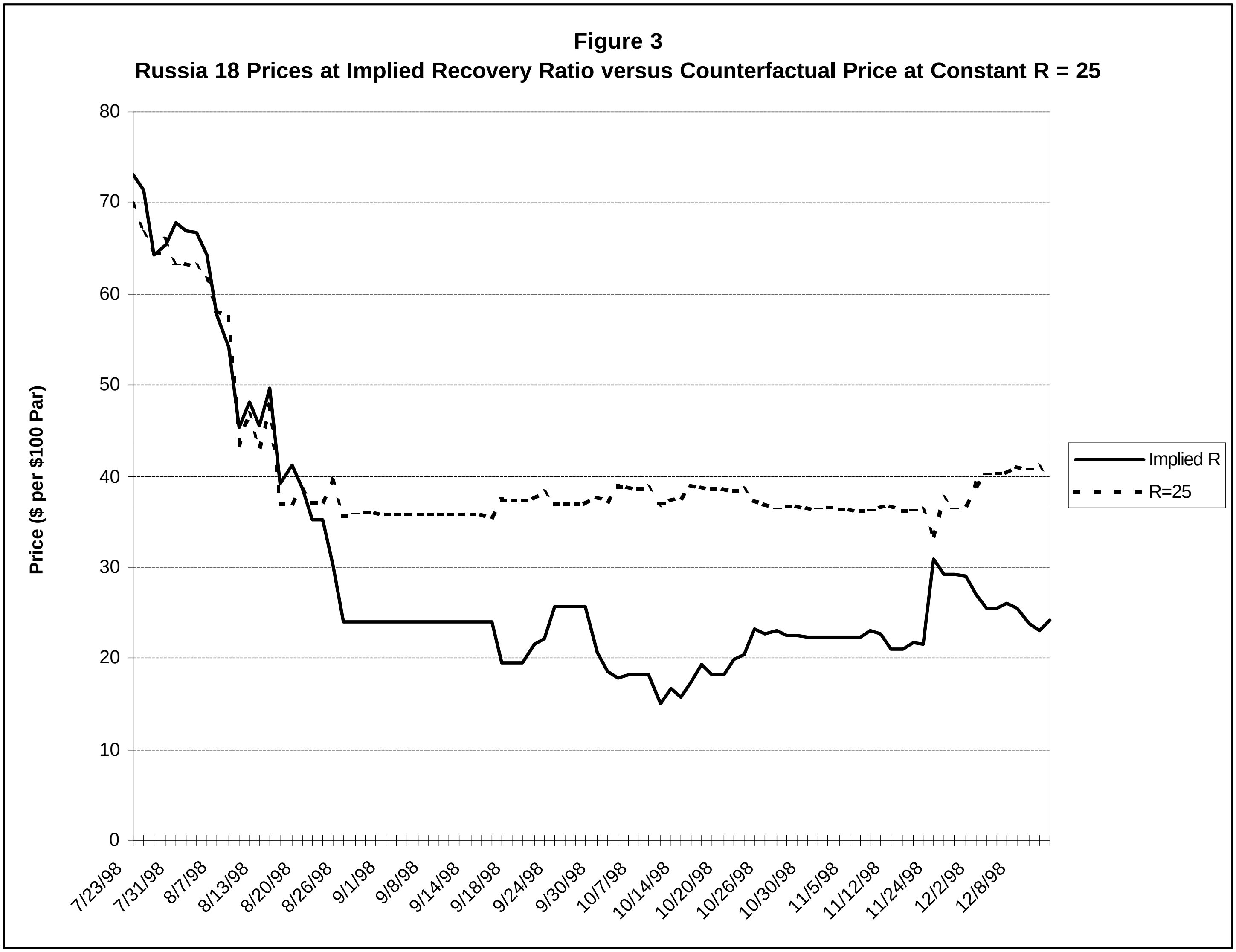
Figure 3
Russia 18 Prices at Implied Recovery Ratio versus Counterfactual Price at Constant R = 25
Price ($ per $100 Par)
80
70
60
50
40
30
20
10
0
7/23/98
7/31/98
8/7/98
8/13/98
8/20/98
8/26/98
9/1/98
9/8/98
9/14/98
9/18/98
9/24/98
9/30/98
10/7/98
10/14/98
10/20/98
10/26/98
10/30/98
11/5/98
11/12/98
11/24/98
12/2/98
12/8/98
Implied R
R=25

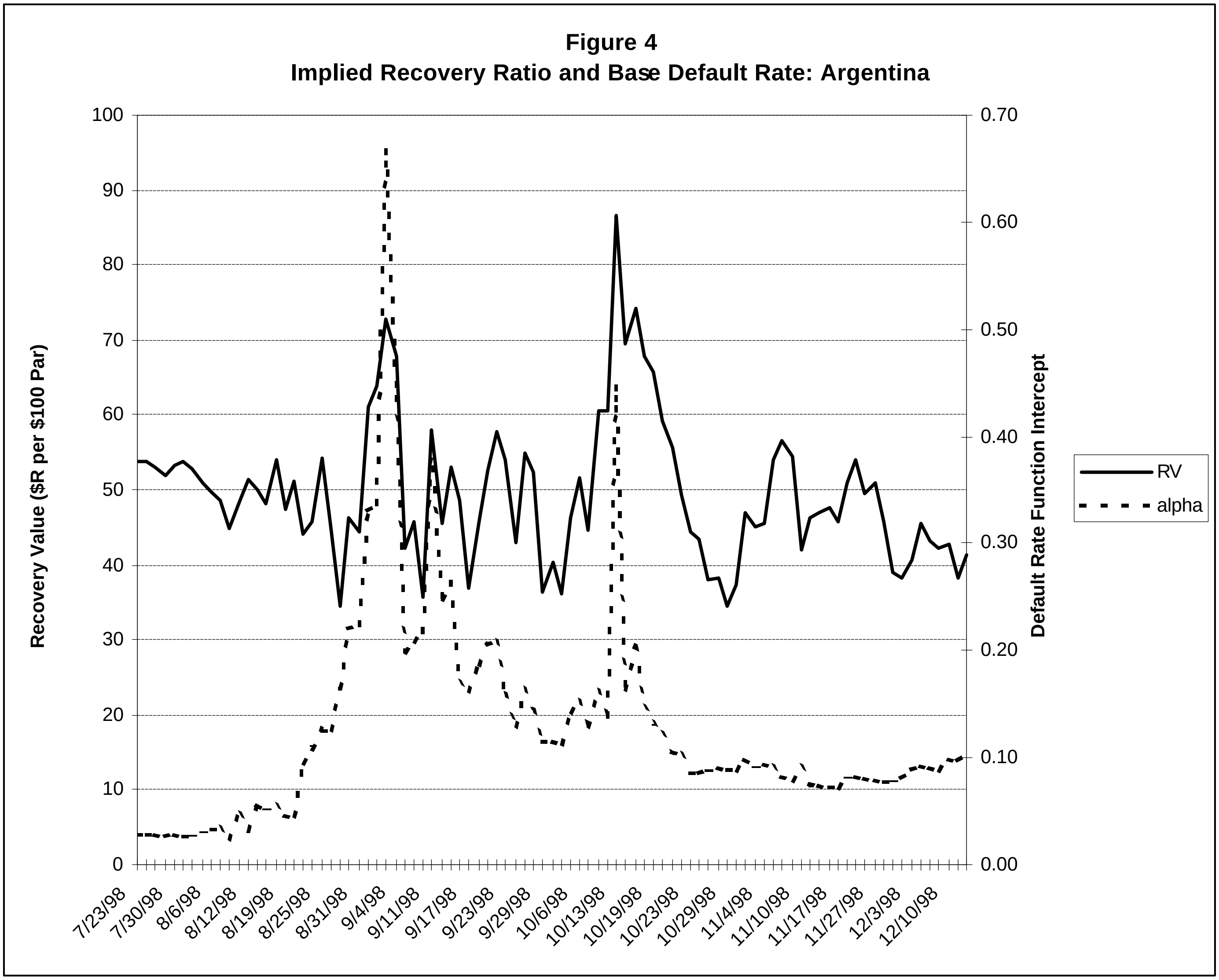
Figure 4
Implied Recovery Ratio and Base Default Rate: Argentina
Recovery Value ($R per $100 Par)
Default Rate Function Intercept
RV
alpha
0
10
20
30
40
50
60
70
80
90
100
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
7/23/98
7/30/98
8/6/98
8/12/98
8/19/98
8/25/98
8/31/98
9/4/98
9/11/98
9/17/98
9/23/98
9/29/98
10/6/98
10/13/98
10/19/98
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11/27/98
12/3/98
12/10/98

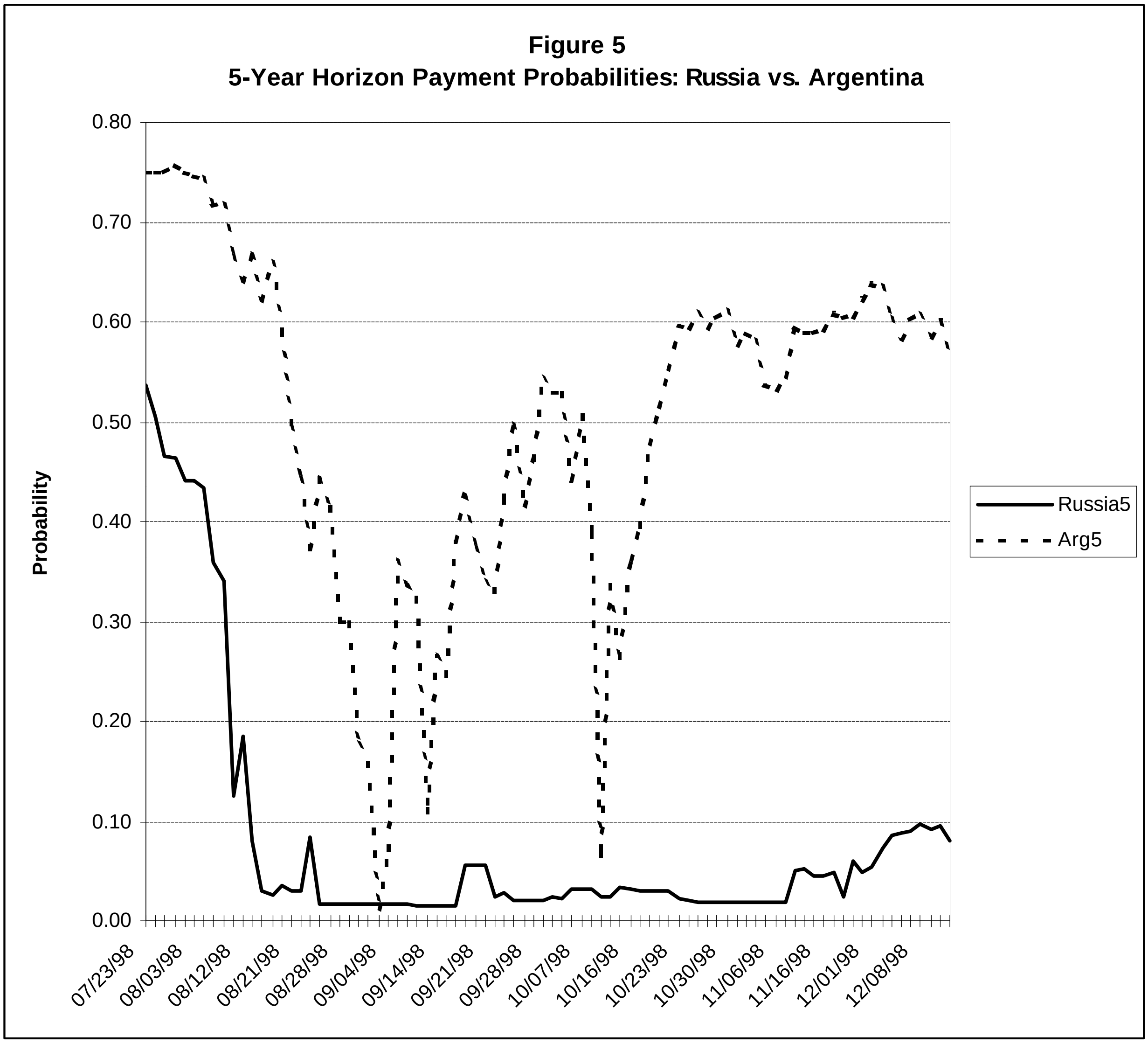

Figure 5
5-Year Horizon Payment Probabilities: Russia vs. Argentina
Probability
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
07/23/98
08/03/98
08/12/98
08/21/98
08/28/98
09/04/98
09/14/98
09/21/98
09/28/98
10/07/98
10/16/98
10/23/98
10/30/98
11/06/98
11/16/98
12/01/98
12/08/98
Russia5
Arg5