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Crisis dynamics of implied default recovery ratios: Evidence from Russia and Argentina

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Abstract

This paper extracts both the implied default recovery ratio and the risk-neutral default probability term structure for Russian Federation and Republic of Argentina US dollar Eurobonds during the 1998 Russian default crisis. This crisis provides a unique window into the impact of changing default probabilities and recovery ratio assumptions on credit-sensitive sovereign bond prices. For the Russian Eurobonds, the sample paths suggest a two-phase crisis revaluation. Shifts in default probabilities account for most of the initial price collapse. Marked decreases in the implied default recovery ratio dominate the second phase. Investors never cut their recovery value assumptions for Argentine debt. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

Pricing bonds subject to the risk of default requires understanding both default probabilities and recovery value. Previous empirical analysis of US

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corporate bond valuation such as Fons (1987) focuses on the dynamics of fluctuations in default probabilities. In emphasizing default probability shifts, this work abstracts from considering changes in expected default recovery rates as an important component of bond price risk. Typically, such research exogenously specifies default recovery rate parameters based on the average US historical corporate default recovery experience. Altman and Eberhart (1994) and Altman et al. (1999) detail this default recovery history for US corporate bonds.

This paper uses a joint implied parameter approach that simultaneously extracts the market's implied recovery ratio as well as the adjusted risk-neutral default probability term structure by applying a consistent valuation framework to a cross-section of outstanding bond issues. The analysis is applied to valuing risky sovereign emerging market bonds during the period of extreme price volatility generated by the August 1998 Russian Gosudarstvennye Kratkosrochnye Obyazatel'stva (GKO) default crisis. [1]

The Russian crisis provides a unique window into the impact of changing default recovery ratio assumptions on credit-sensitive sovereign bond values. Importantly, in the emerging sovereign debt markets, no Altman-like recovery histories based upon previous defaults are available for reference. Thus, this paper's implied parameter approach is particularly relevant for emerging market debt applications. Indeed, interpreting pre-crisis implied recovery ratios for different sovereign issuers may be fertile ground for political economists. Moreover, sovereign default crises are necessarily fluid situations possibly generating major revisions in investor expectations. Thus, the impact of potential changes in recovery ratio assumptions may be most important in precisely these situations.

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 questions about 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 each of these markets, what implied default rate term structures did the cross-section of prices initially reflect? Finally, how did these assumed recovery ratio and default rate term structure parameters change throughout the GKO default crisis?

The implied recovery ratio approach is particularly useful for these Russian and Argentine applications. Far from being a typical default, this home-cur-

[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 17 August 1998.

rency 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. These estimates provide a basis to understand what recovery ratio assumptions the market used in valuing bonds during the crisis. Of course, as implicit parameters derived from observing market prices, these data differ in content from the Altman-type estimates based upon actual experience. For researchers examining the aftermath of the crisis, these estimates permit tests of specific hypotheses concerning the role of recovery ratio assumption revisions on bond prices. But the analysis could also have practical value for market participants utilizing the information content of prices. In real time, extracting the implicit parameters would generate information for uninformed investors, while also generating trading opportunities for those investors specializing in predicting true recovery prospects.

Argentina's Eurobond issues also suffered severely from the revaluation of credit risks, but subsequently recovered most of their losses. A comparative analysis of the Argentine bond price data gives this study 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 after 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 10 cents on the dollar.

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 presents pricing results for individual issues. Section 8 concludes the paper.

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. [2] 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 ini-

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

tially 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 joint probability of no default occurring from issue date through date t.[3] 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.

Eq. (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), Fons (1987), and Hurley and Johnson (1996), Eq. (1) views the bond's current value as a probability-weighted sum of three components: coupon flows, principal repayment and recovery value.[4] Following Leland and Toft (1996), the probability distribution used here is interpreted as the implied risk-neutral distribution. If risk premiums exist, implied risk-neutral default probabilities will be larger than the objective probabilities of default (see Wu, 1991). Thus, any default probabilities estimated from market data will need to be interpreted with care. Nevertheless, casting the model in terms of risk-neutral probabilities permits unbiased estimation of the model's key recovery ratio parameter.

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

[3] 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.

[4] The specific form of the valuation equation need not correspond to (1). For example, Hurley and Johnson (1996) assume that bond recovery in a default takes a special form: a known fraction of what the bond's value would be if no default had occurred. Such a form would be hard to motivate in the current application. Each issuer's Eurobonds contain cross-default provisions and maintain equal standing in default regardless of coupon or remaining term to maturity. Hurley and Johnson (1996) also assume a constant default rate (see below).

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

Previous empirical research on expressions such as Eq. (1) by Fons (1987) and Bhanot (1998) work with a constant default rate ($\delta_t = \delta$). 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 or at least negatively correlated with near-term default rates. Eq. (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 $p_t = (P_{t-1} - P_t)$, Eq. (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

[5] Absent recovery value ($R = 0$), Eq. (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.

GKO crisis, the five bonds' maturity spectrum spanned between 2 and 20 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 2 and 30 years. The total par value 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 20 firms acted as market makers, though only about 10 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 17th August, 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.

As detailed above, the price data used in this study derive from the best first-hand source (the Reuters screens). But there is no accompanying data on volume or market depth. On certain days during this period, even on-the-run US Treasuries traded on an order-only basis. For much of the crisis, large price movements on light volume characterized activity in the emerging sovereign bond markets. Nevertheless, as the price graph fluctuations below show, participants were not shy about revaluing these bonds.

The study's sample period starts on 23 July 1998 and ends on 14 December 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.

Fig. 1 plots the Russia-18s and Argentina-17s market prices between 23rd July and 14th December. The Russian bond price – initially stable during the

Table 1
Russian Federation and Republic of Argentina Eurobond descriptions. Sample statistics: 23 July 1998–14 December 1998

Issue	Coupon	Maturity	Initial settlement	Par value ($000s)	Price range		Yield range (%)	
					Max.	Min.	Min.	Max.
Rus-01	9.25	11/27/01	11/27/96	$1,000,000	88.8	25.0	13.2	73.2
Rus-03	11.75	6/10/03	6/10/98	$1,250,000	89.2	15.0	14.4	92.5
Rus-05	8.75	7/24/05	7/24/98	$2,968,968	71.4	13.0	15.1	73.5
Rus-07	10.0	6/26/07	6/26/97	$2,400,000	75.2	17.0	14.6	61.1
Rus-18	11.0	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	11.0	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

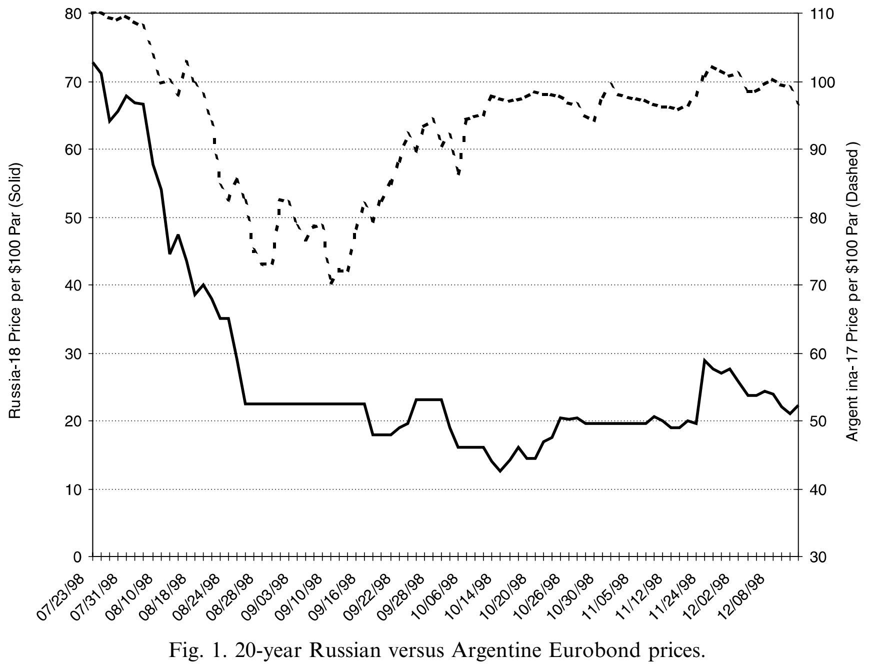

Fig. 1. 20-year Russian versus Argentine Eurobond prices.

halcyon last week of July – fell steadily from 5th August to 14th August as the global markets as the markets began to get nervous; plummeted in response to the 17th August 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.

4. Empirical analysis

To repeat, the empirical investigation focuses on three 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 risk-neutral 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?

For each market, the estimation strategy proceeds as follows. Recall Eq. (4), the expression for bond value. Define a bond's model value, $\hat{V}_{0,}$ by substituting the estimates $\hat{\alpha}, \hat{\beta}$ and $\hat{R}$ into Eq. (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

$$\mathrm{SSR}_0 = \sum_{i=1}^{I} (V_{i,0} - \hat{V}_{i,0})^2, \tag{5}$$

where $V_{i,0}$ is now interpreted as the date 0 market value for the ith bond. Estimates of the three implied model parameters for each date 0 can be derived by choosing the values for $\hat{\alpha}, \hat{\beta}$ and $\hat{R}$ that minimize SSR_0 in Eq. (5) while simultaneously constraining the average cross-sectional bond pricing residual to equal zero: [7]

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

[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 October 1998.

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 Eq. (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 did not make a crucial difference to the estimation results. [10] 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

The study's sample period starts on 23 July 1998 and ends on 14 December 1998. Table 2 reports summary statistics for the Russian market's time series of daily parameter estimates for two sub-samples partitioned into pre-17 August and post-17 August 1998 periods. For the initial pre-default period, the average risk-neutral default rate term structure parameter estimates – base rate of 0.17; slope of 0.0072 per year – implied average risk-neutral payment probabilities of

[8] Default occurs only on a bond cash flow date. Because of cross-default provisions, 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] The estimation routine requires initial parameter guesses. For this study, the parameter estimates from the previous day were used as sensible starting values for the next day's estimation procedure. To see what differences the estimates might show using an alternative set of starting values, a formal sensitivity experiment was conducted. Instead of using the previous day's result as reported in the paper, substitute a fixed set of starting values: $R = 27.3; \alpha = 0.166; \beta = 0.0072$ for the Russian data. (As Table 2 will detail, these are the average Russian estimates extracted for the pre-GKO default period.) Since the key hypothesis is whether the true R collapses in the post-default period (as found and reported in Table 2), this new set of starting values makes the convergence routine work harder. The parameter estimates are virtually identical. The average R in the post-default sample differs by one-tenth (10.2 versus 10.3 as reported); the average α differs by 6000 (0.400 versus 0.406 as reported); and the average β differs by 1000 (0.0206 versus 0.0196). Thus, even using "poor" starting values, the routine is able to find estimates consistent with those derived using the "good" previous day estimates.

Table 2
Russian Eurobond implied recovery ratio and default rate function estimates

	Recovery ratio (R)	Default rate intercept (α)	Default rate slope (β)
Pre-GKO default sub-sample: 23 July 1998–14 August 1998			
Mean	27.3	0.166	0.0072
S.D.	3.0	0.078	0.0103
Test	Mean = 40	Mean = 0	Mean = 0
Chi-square statistic	42.4	24.8	5.8
P-value ( )	(*)	(*)	(0.016)
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 sub-sample: 17 August 1998–14 December 1998			
Mean	10.3	0.406	0.0196
S.D.	5.8	0.054	0.0183
Test	Mean = 40	Mean = 0	Mean = 0
Chi-square statistic	245.5	299.6	54.8
P-value ( )	(*)	(*)	(*)
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%
Tests of equality of means across sub-samples			
Chi-square statistic	73.7	104.7	6.0
P-values ( )	(*)	(*)	(0.014)

* < 0.0001.

67% for a two-year-ahead date; 32% for a five-year date; and 7% for a 10-year date.

The average implied recovery ratio for these Russian bonds prior to the GKO default is estimated at 27.3%. This value is significantly lower than the 40–50% ex post ratios cited above for US corporate defaults. Table 2 presents a formal test rejecting the hypothesis that the implied Russian recovery rate equals 40%.

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 0.17 to 0.41). This post-crisis sample's average estimates imply payment probabilities of 31% for a two-year-ahead date; 3% for a five-year date; and 0% for a 10-year date. In both sub-samples, the estimated slope coefficient was positive and significantly different from zero at standard levels of significance.

Thus, allowing a nonflat default rate term structure is a useful relaxation of the typical empirical restriction. 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 needs to change in a crisis. However, the Table 2 estimates clearly show that a dramatic fall did occur in the post-announcement sub-sample. Recall that the pre-announcement average recovery ratio estimate was 27.3%. For the post-announcement period, the implied recovery ratio estimate fell to 10.3%. Thus, in Russia's case, the rise in the implied risk-neutral default probability was accompanied by a significant downward revision in assumed recovery value.

The third panel of Table 2 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 17th August break point.

Fig. 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

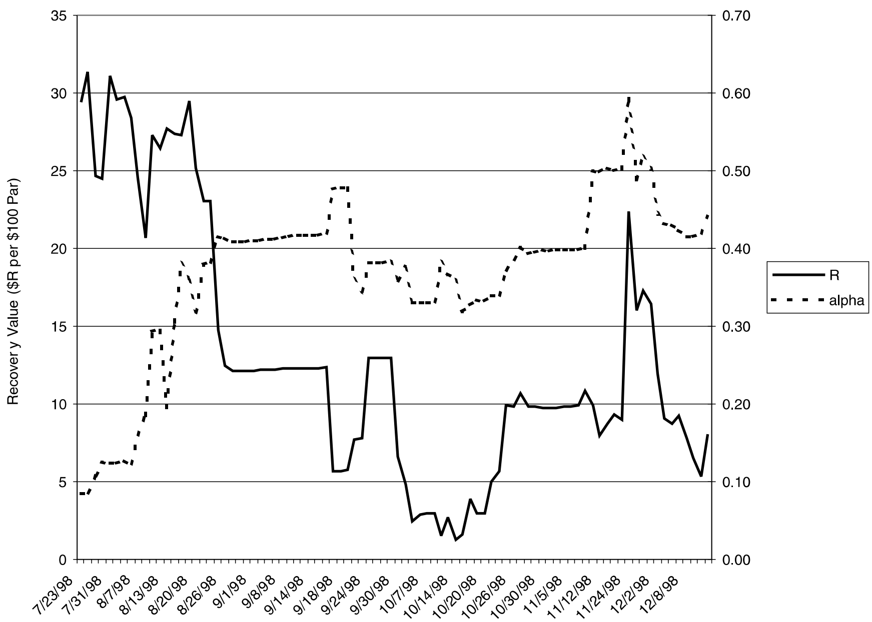

Fig. 2. Implied recovery ratio and base default rate: Russia.

of the base default rate, the crisis had completed a good deal of its repricing by 14th August. 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 17th August GKO announcement, the base default rate jumped overnight to nearly 0.40 – essentially its average value for the remainder of the period. Yet, as Fig. 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 25th August (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 14th October.

The nature of the second-phase of the Russian bond market crisis becomes clear from the change in the model estimates between 19 August and 14 October. Over this post-GKO default period, the price of the Russia-18s fell from 40.0 to 12.5. Model estimates for α and β are nearly identical. In contrast, the implied recovery ratio fell from 29.5 to 1.3.

6. Results for Republic of Argentina Eurobonds

Table 3 reports summary statistics for the time series of daily parameter estimates derived from the Republic of Argentina Eurobond market results for the two pre- and post-17 August sub-samples. For the initial pre-default period, the average default rate term structure parameter estimates – base rate of 0.034; slope of 0.0063 per year – implied average payment probabilities of 91% for a two-year-ahead date; 71% for a five-year date; and 36% for a 10-year date.

The average implied recovery ratio for these Argentine bonds prior to the GKO default is estimated at 51.2%. This value is right in line with the 40–50% average ex post ratios cited above for US corporate defaults. A formal test finds no evidence to reject the hypothesis that $R = 50\%$ for Argentine Eurobonds.

As with the Russian market data, there are large differences in the Argentine implied risk-neutral default rate term structure parameters across the two sub-samples. The average post-announcement base default rate quadrupled its pre-announcement level (from 0.034 to 0.148). This post-crisis sample's average estimates imply payment probabilities of 72% for a two-year-ahead date; 43% for a five-year date; and 17% for a 10-year date.

And as with Russia, the estimated default term structure slope coefficient is positive in both sub-samples and significantly different from zero at standard levels of significance. Again, the correlation between the default function intercept and slope parameters is negative.

Table 3 also reports test statistics for the null hypothesis that the Argentine Eurobond recovery ratio and the default rate function parameters were constant across the 17th August break point. In contrast to the results for Russian

Table 3
Republic of Argentina Eurobond implied recovery ratio and default rate estimates

	Recovery ratio (R)	Default rate intercept (α)	Default rate slope (β)
Pre-GKO default sub-sample: 23 July 1998–14 August 1998			
Mean	51.2	0.034	0.0063
S.D.	2.7	0.011	0.0015
Test	Mean = 50	Mean = 0	Mean = 0
Chi-square statistic	2.7	36.8	40.7
P-value ( )	(0.100)	(*)	(*)
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 sub-sample: 17 August 1998–14 December 1998			
Mean	49.3	0.148	0.0014
S.D.	10.2	0.103	0.0042
Test	Mean = 50	Mean = 0	Mean = 0
Chi-square statistic	0.3	85.5	10.1
P-value ( )	(0.584)	(*)	(0.001)
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%
Tests of equality of means across sub-samples			
Chi-square statistic	0.4	16.0	15.4
P-values ( )	(0.527)	(*)	(*)

* < 0.0001 .

bonds, the constant recovery ratio hypothesis cannot be rejected. The post-crisis recovery ratio estimate of 49.3 is quite close to the pre-crisis level of 51.2. Nevertheless, the hypotheses of constant default rate function parameters – both the intercept and slope coefficients – can be rejected at standard levels of significance. Fig. 3 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. [11]

[11] The Argentine results graphed in Fig. 3 reveal two obvious "spikes". The 3 September 1998 spike was a one-day "fluke" where the 2002 bond fell more than the 2017 and 2027 issues, but then reversed the next day. The 13 October 1998 spike reflects a three point gain in the 2027 issue versus nearly unchanged prices in the front three issues. Those front issues"caught up" over the next two days.

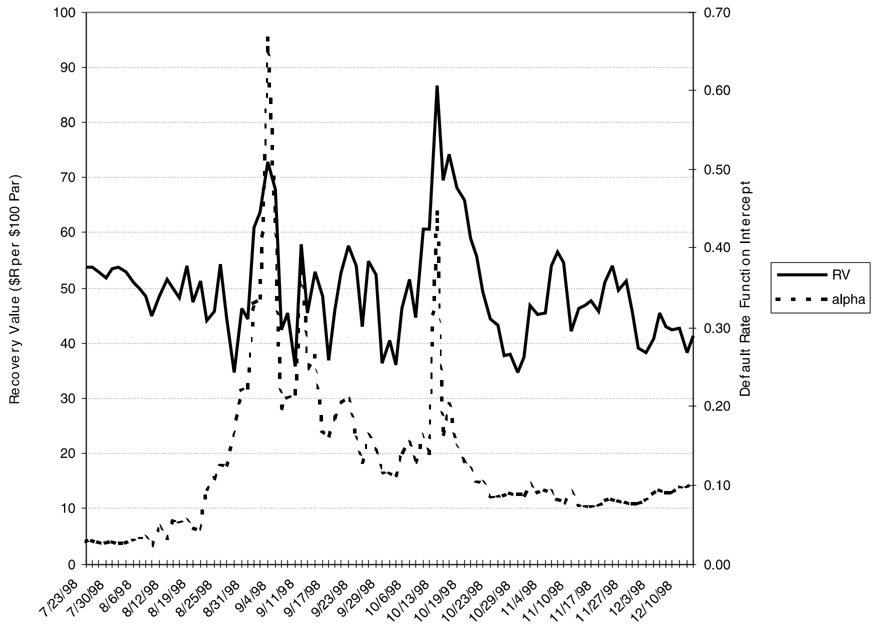

Fig. 3. Implied recovery ratio and base default rate: Argentina.

7. Analysis of individual bond pricing

This study's focus has been on the crisis dynamics of implied recovery ratio and default rate term structure parameters. The daily estimates of the model's parameters were constructed to produce unbiased and minimum variance errors for the daily cross-section of bond prices. However, a look at individual issues might also yield some insights into how well the simple model of Section 2 performs as a valuation framework during the volatile crisis period.

Coincidently, recent empirical research by Elton et al. (1999) has exposed significant valuation biases in cross-sections of high-grade US corporate bonds. That study reveals that a simple "corporate spot yields" relative value framework explains a large part of the variation in bond values for bonds grouped by risk ratings classes. Nevertheless, their model's pricing errors contain significant biases related to (1) coupon levels and (2) an age/liquidity variable. Thus, the Elton et al.'s study indicates that while simple models explain a great deal about bond valuation, further work is needed to characterize issue-by-issue differences among even US corporate bonds.

Tables 4 and 5 here present sample average pricing errors (market price minus model price) as well as time series bond price regressions at the individual bond level for each of the five Russian Federation and five Republic of

Table 4
Market versus model price regressions: Russian Federation Eurobonds. Sample period: 23 July 1998–14 December 1998

Market–model price			Price level regressions				Change in price levels regressions			
Issue	Average	S.D.	Intercept	Slope	R^2	S.E.	Intercept	Slope	R^2	S.E.
Rus-01	0.46	0.51	0.579	0.997	0.999	0.51	0.001	1.022	0.982	0.42
			(0.135)	(0.003)			(0.046)	(0.015)		
Rus-02	−0.74	0.92	−1.359	1.018	0.998	0.86	−0.010	0.978	0.958	0.69
			(0.196)	(0.005)			(0.076)	(0.022)		
Rus-05	−0.27	0.74	0.597	0.969	0.999	0.56	−0.006	0.962	0.970	0.48
			(0.121)	(0.004)			(0.053)	(0.018)		
Rus-07	2.33	0.89	3.332	0.965	0.998	0.72	0.015	1.004	0.978	0.43
			(0.162)	(0.005)			(0.047)	(0.016)		
Rus-18	−1.79	0.95	−3.294	1.051	0.999	0.59	−0.011	1.020	0.978	0.41
			(0.142)	(0.004)			(0.044)	(0.016)		

Table 5
Market versus model price regressions: Republic of Argentina Eurobonds. Sample period: 23 July 1998–14 December 1998

Market–model price			Price level regressions				Change in price levels regressions			
Issue	Average	S.D.	Intercept	Slope	R^2	S.E.	Intercept	Slope	R^2	S.E.
Arg-01	−0.88	1.41	−12.936	1.127	0.977	1.13	0.010	1.050	0.777	1.02
			(1.726)	(0.018)			(0.108)	(0.059)		
Arg-03	1.68	1.60	9.329	0.914	0.964	1.44	−0.046	0.795	0.708	1.00
			(1.646)	(0.018)			(0.105)	(0.054)		
Arg-06	−0.62	1.22	6.837	0.922	0.990	0.93	−0.002	0.852	0.838	0.86
			(0.928)	(0.010)			(0.091)	(0.040)		
Arg-17	0.60	0.73	−0.998	1.017	0.995	0.72	−0.005	1.051	0.928	0.77
			(0.740)	(0.008)			(0.081)	(0.031)		
Arg-27	−0.79	0.82	−4.380	1.042	0.992	0.75	0.004	0.965	0.932	0.74
			(0.869)	(0.010)			(0.078)	(0.028)		

Argentina issues used in this study. These regressions explain each individual bond market price series as a function of an intercept term and the previously fitted model price series. Tables 4 and 5 present these price regressions in both level and first-differenced forms.

The individual bond sample average pricing error values, as well as the statistically significant nonzero intercept terms in the price level regressions, indicate that some issues traded "cheap" on average during the sample period, while others traded "rich". For example, from Table 4, the market price of the Russia-07s averaged 2.33 points more than its fitted model value during the sample period. In contrast, from Table 5, the market price of the Argentina-01s averaged 0.88 less than its respective fitted model value. Abstract from these individual bond effects by moving to the market-versus-model price regressions for the first-differenced data. Each model price change series explains a large percentage of the variation in each issue's market price change. The regression R^2 are greater than 95% for the Russian Federation Eurobonds, and greater than 70% for the Republic of Argentina Eurobonds. Furthermore, the estimated slope coefficients are quite close to unity except in two Argentine Eurobond cases.

Nevertheless, the results reported here suggest that more work needs to be done at the individual bond level. For example, one reason why a bond may trade rich relative to companion issues is because of its special value as collateral in the repurchase agreements market. Thus, the average richness of the Russia-07s may be traceable to repurchase agreement market conditions during this period.

8. Conclusions

This paper's results support the hypothesis that significant downward revisions in the market's assessment of default recovery ratios played a significant role 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. [12]

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

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

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.

The diverse estimates of market recovery ratio assumptions for Russia (pre-crisis: 27%) and Argentine (about 50%) 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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