Emerging Market Sentiment: Evaluating Pricing Signals from the Bond Markets

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Abstract

This chapter analyzes emerging market yield spreads utilizing a step-by-step approach designed to be accessible to a general audience including policy specialists, market practitioners and debt market students. The discussion highlights the roles of investor perceptions regarding bond default probability and default-state recovery value in bond valuation. The core framework for interpreting yield spreads as signals of default probabilities is developed within a series of examples. These examples reflect the important effects of alternative recovery value assumptions on yield spreads. First, the standard sovereign spread computation is related to per period default probability under the special assumption of 0% recovery of face value in default. Next, the "stripped" sovereign spread concept – applicable to issues like Brady bonds that have 100% collateral against face value – is explained and related to the perceived default rate. Finally, the general case where recovery value is greater than 0% but less than 100% of par value is considered. In this case, yield spread determination is shown to be more complex.

This analysis provides a simple resolution to the Brady bond-Eurobond spread gap puzzle. In particular, the framework explains why stripped sovereign spreads from Brady issues *should* be larger than the calculated sovereign spreads from the same issuer's Eurobonds. A divergence should occur between the two spreads even though both reflect an identical default probability. The analysis suggests the definition of a special "stripped-of-recovery-value" yield spread.

Finally, a more formal emerging market bond valuation model is applied to value US dollar-denominated Eurobonds issued by the Republic of Argentina. This model, based upon a discounted expected cash flow approach, is a variant of that presented in Merrick's (2001) study of Russian and Argentine Eurobond pricing during the Russia GKO default crisis of August 1998. The model implemented here values a cross-section of fifteen outstanding Republic of Argentina Eurobond bonds in the midst of that country's 2001 debt market crisis. The results are contrasted with those from the standard yield-based sovereign spread analysis.

1. Introduction

The explosive growth of sovereign emerging market foreign currency debt issuance in the 1990s has generated substantial interest in the underpinnings of fair valuation for these bonds. Domestic and international investors, investment banks, securities dealing firms, the issuing governments themselves, and international financial institutions (IFIs) share an interest in understanding the forces governing value in these markets. Investors, investment banks and dealing firms must decide upon proper debt security portfolio allocations. Issuing governments must structure sustainable fiscal and debt management policies that permit continued access to international sources of funds. IFIs must develop policies that promote the international capital market stability. In all cases, effective decision-making necessitates a clear understanding of emerging market bond valuation.

In recent years, academic research has also expanded rapidly into emerging markets, especially those for foreign currency debt.[1] A number of studies have analyzed the structure of emerging market debt yields. Standard macroeconomic variables like economic growth rates, inflation rates, and budget and trade deficits– the "fundamentals" – explain the cross-section of sovereign spreads during normal periods quite well. However, one crucially important finding emerges from this work: *shifts* in such fundamental variables explain very little of the short-run variation in emerging market yield spreads during times of crisis (see e.g., Eichengreen and Mody, 1999). Instead, unexplained variation in "market sentiment" – perhaps reflecting shifts in risk aversion or herd behavior on the part of investors or managers – accounts for an outsized component of the emerging market yield spread movement. This finding that fluctuations in yield spreads cannot be adequately explained by movements in the standard fundamental macroeconomic variables is disappointing. Moreover, this result clearly leads policymakers to begin focusing more attention toward acquiring a clear understanding of the "story" that bond yield spreads tell about issuer default prospects as well as possible contagion effects.

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[1] For example, see Durbin and Ng (1999), Eichengreen and Mody (1999), Kamin and von Kleist (1999), Mauro, Sussman, and Yafeh (2002) and Sy (2001) for general studies of bond yields and spreads, and Merrick (2001) and Duffie, Pedersen and Singleton (2002) for studies of individual markets.

Yield spreads on risky emerging market debt produce important signals regarding the market's consensus of prospective issuer default probabilities. Policymakers may find such information extremely valuable in assessing the proper policy response to a crisis episode. However, these market-based signals are sometimes confusing and need to be interpreted with care. For example, the literature has identified one specific sovereign yield spread puzzle: the persistent gap between spreads on Brady bonds and Eurobonds with equivalent sovereign risk. A number of studies have raised questions as to whether these securities are priced appropriately and why these differentials have not been arbitraged (see, e.g., IMF, 1997).

This chapter analyzes emerging market yield spreads utilizing a step-by-step approach designed to be accessible to a general audience including policy specialists, market practitioners and debt market students. The discussion highlights the roles of investor perceptions regarding bond default probability and default-state recovery value in bond valuation. The core framework for interpreting yield spreads as signals of default probabilities is developed within a series of examples. These examples reflect the important effects of alternative recovery value assumptions on yield spreads. First, the standard sovereign spread computation is related to per period default probability under the special assumption of 0% recovery of face value in default. Next, the "stripped" sovereign spread concept – applicable to 100% collateralized issues like Brady bonds[2] – is explained and related to the perceived default rate. Finally, the general case where recovery value is greater than 0% but less than 100% of par value is considered. In this case, yield spread determination is shown to be more complex.

Importantly, this analysis provides a simple resolution to the Brady bond-Eurobond spread differential puzzle. In particular, our framework explains why stripped sovereign spreads from Brady issues *should* be larger than the calculated sovereign spreads from the same issuer's Eurobonds. The is because the quoted Eurobond spread "blends" the true (high spread) sovereign yield used to discount the risky cash flows and the (zero spread) risk-free yield used to discount the bond's assumed recovery value.

[2] Brady issues were created in the 1990s as part of the debt restructurings of defaulted emerging market sovereign loans. A key component of the Brady bond structure was that each issue is partially collateralized by zero-coupon US Treasury bonds. Typically, the zero-coupon Treasury collateral covers the entire principal amount and a rolling portion of the remaining coupon interest.

Thus, a divergence should occur between Eurobond and unblended ("stripped") Brady spreads even though both reflect an identical default probability. The analysis here suggests the definition of a special "stripped-of-recovery-value" yield spread.

This chapter also applies a more formal emerging market bond valuation model to valuing US dollar-denominated Eurobonds issued by the Republic of Argentina. This model, based upon a discounted expected cash flow approach, is a variant of that presented in Merrick's (2001) study of Russian and Argentine Eurobond pricing during the Russia GKO default crisis of August 1998.[3] The model implemented here values a cross-section of fifteen outstanding Republic of Argentina Eurobond bonds in the midst of that country's 2001 debt market crisis. The results are contrasted with those from a standard yield-based sovereign spread analysis.

The remainder of this chapter is organized as follows. Section 2 briefly surveys previous empirical academic research on the structure of emerging market debt yields. Section 3 presents a simple analytical framework for interpreting yield spreads for risky sovereign debt in terms of per period default rates and recovery value assumptions. Section 4 develops and applies a recovery value-enhanced valuation model to Republic of Argentina Eurobonds during that country's 2001 debt market crisis. Section 5 summarizes and concludes.

2. Sovereign debt yield spreads: basic concepts and hypotheses

A bond's yield-to-maturity is defined as the internal rate of return computed from the bond's current market price using its promised future cash flows.[4] As such, a bond's yield is inversely related to its market value. A yield "spread" measures the difference in quoted yields on two bonds. An emerging market bond's yield does not represent a true expected return measure because the promised cash flows may never materialize – the issuer may default. Therefore, the (positive) yield spread of a US dollar-denominated

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

[4] By convention, this internal rate of return calculation assumes that all scheduled coupon and principal payments are paid in full to the investor and that the coupon payments are reinvested until the bond's maturity date at the same rate of return. Thus, as is well known, the conventional yield-to-maturity concept does not properly handle coupon reinvestment risk.

emerging market sovereign bond versus its US Treasury counterpart reflects a valuation discount attributable to expected default losses.[5]

Market observers use an emerging market debt issue's spread versus the yield on a benchmark market counterpart to summarize the state of pricing at any particular time. Expressing the valuation discount for an emerging market bond in terms of yield-to-maturity and yield spread follows standard market practice for quoting other bonds subject to default risk such as both investment grade and high-yield US corporate bonds. A bond's "initial offering spread" or "issuance spread" reflects its pricing at the time of issue. A "secondary market spread" reflects the state of the bond's pricing as a seasoned issue trading in the dealer market after issuance. The spread on a collateralized issue such as a Brady bond can be computed as a "stripped sovereign spread" by adjusting for the valuation impact of the bond's riskless collateral.

Figure 1 plots a monthly history of JP Morgan's Emerging Market Bond Index (EMBI) of stripped sovereign spreads on Brady bonds of various emerging market issuers versus US Treasuries beginning December 1990 and ending December 2001. This spread index averaged about 800 basis points during this period. As this graph reveals, EMBI spreads were also extremely volatile. The maximum observed spread was 1,555 basis points. The minimum spread was 350 basis points. The EMBI's standard deviation was about 250 basis points. Two yield spread "spikes" appear during this time period. The first, beginning in December 1994 and peaking in March 1995, represents the market sell-off in the Mexican credit crisis. The second, beginning in August 1998 and peaking in January 1999, portrays the sector's valuation collapse during the Russian GKO default crisis.

<insert Figure 1 about here>

Understandably, the importance of emerging market debt valuation in a crisis-filled environment has led to a growing number of academic studies of yield and yield spread determination. One can think of spreads as depending upon four types of variables: (i) macroeconomic fundamentals; (ii) debt instrument and country

[5] A portion of the observed spread could also reflect a liquidity difference.

characteristics; (iii) interest rates in the US, Germany and Japan; and (iv) market sentiment. Eichengreen and Mody (1998) conduct a broad examination of initial offering yield spreads on over 1,000 new bond issues in 55 countries over the period from 1991 to 1997.[6] These authors document significant inverse impacts of both issuance size and a credit rating variable on issuance yield spread levels, as well as mixed evidence for a positive relationship between issuance spreads and the level of US interest rates.[7] Perhaps the most important conclusion of the Eichengreen and Mody study is that the short-run variation in spreads appears to be better explained by shifts in market sentiment rather than shifts in economic fundamentals. For example, variation in standard macroeconomic variables explain very little of the short-run variation in spreads associated either with the Mexican crisis or the period of emerging market spread compression during the second half of 1996 and the first of 1997. Such shifts in market sentiment might be more easily understood as reflecting unobservable changes in investor risk aversion. Alternatively, such shifts might be evidence of herd behavior on the part of returns-chasing investors and investment managers.

Kamin and von Kleist (1999) construct a coherent picture of issuance spread behavior over the decade after controlling for deal-specific factors such as issuer home region, creditworthiness, bond maturity, and currency denomination. They document sensible and important impacts on non-Brady bonds and loan issuance spreads of credit ratings, term-to-maturity, currency issue choice, and dummy variables interpreted as year-by-year sentiment shifts. Their regression results again reveal that the general fall in the spreads over the period were dominated by unexplained market sentiment shifts. Kamin and von Kleist also address the possibility that interest rate policies in the major industrial countries – the US, Japan and Germany – significantly affect spreads. Under a view popularized by the financial press, emerging market spreads collapsed in late 1996 and early 1997 because the "appetite for risk" rose as interest rates in the major industrialized countries fell. Despite substantial effort, the authors find scant support for

[6] These authors calculate each bond's offering yield spread as the arithmetic difference between that bond's yield-to-maturity (derived from its issuance price) and the corresponding yield on a riskless sovereign issue of comparable maturity in the currency of issue (i.e., for US dollar issues, the corresponding US Treasury yield). The *compound* spread definition of Section 3 below is easier to apply consistently.

[7] In an investigation of issuance decisions, the authors document a significant inverse relationship between the *volume* of new issues and the level of US Treasury yield. Thus, high US interest rates depress new issuance of emerging market debt.

significant interest rate effects on their emerging market non-Brady bond and loan issuance spreads. Figure 2 here presents an updated scatter graph of the level of the EMBI sovereign stripped spread versus the coincident Treasury bill yield level for the December 1990 to December 2001 period.[8] This graph evinces little support for the hypothesis that spread levels and Treasury bill yields have any correlation at all.[9]

<insert Figure 2 about here>

Kamin and von Kleist's argue that trends in the secondary spreads on Brady debt – the spread data most often previously employed to depict emerging market bond valuation – may not be representative of spread trends for a broader sample of non-Brady credits. Indeed, the authors document that the stripped sovereign spreads on Brady bonds, the primary type of long-term sovereign bond issued in the early 1990s, are significantly higher than the issuance spreads on non-Brady bonds and loans. In focusing on the large difference between spreads on Brady debt versus those on non-Brady debt, the authors echo analysis presented by the International Monetary Fund in their 1997 report (IMF, 1997). In assessing market conditions during 1996, the IMF report states, "[Y]ield spread differentials between the Brady and Eurobond sectors endured, suggesting continued market segmentations…In particular, persistent spread differentials between Brady bonds and Eurobonds with equivalent sovereign risk have raised questions as to whether these securities are priced appropriately and why these differentials have not been arbitraged."[10] In the IMF study's opinion, the suggested explanations for the continuing spread differential remain unconvincing.[11] Mauro, Sussman and Yafeh (2002) also refer to the spread differential as an "anomaly" and concur that proffered explanations seem

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[8] In this "dynamic" scatter graph, a line that traces the period-by-period time path connects the data points.

[9] The popular conception reported by Kamin and von Kleist that spreads were interest rate dependent no doubt reflects the experience of 1991 – when spreads collapsed 500 basis points as short-term US interest rates eased 350 basis points – combined with that of 1994 – when spreads rose more than 1100 basis points as US interest rates tightened nearly 300 basis points.

[10] See IMF (1997), pages 70 and 75.

[11] Such explanations include (1) a "stigma effect" on Brady bonds carried forth from their genesis out of loan restructuring; (2) the implicit costs of "stripping" the collateral from Brady bonds to obtain a pure sovereign spread exposure; (3) the unusual cash flow patterns of Brady bonds; (4) the bearer form of some Eurobonds; (5) the lower volatility of Eurobonds; (6) the call features of Bradys; and (7) repurchase agreement market costs inhibiting arbitrage between the Brady and Eurobond markets.

less than fully satisfying. However, the IMF study also points to certain buyback and/or debt exchange programs that particular emerging market issuers implemented beginning in 1996 to retire ("high spread") Brady debt in favor of newly issued ("low spread") Eurobonds. Mexico, the Philippines, Ecuador, Panama, Poland and Brazil all participated in such programs at that time, and Argentina later followed suit.

More recent research on emerging market bonds has moved on to analyze the valuation aspects of the restructuring process accompanying a potential default. The role of collective action clauses found in some bond indentures has received particular focus.[12] Collective action clauses enable a qualified majority of bondholders to modify key financial terms of the debt agreement and to make decisions binding on all other holders. Such clauses eliminate the risk that any individual investor holds out from the majority's agreement in order to litigate separately to seek full repayment. Collective action clauses can facilitate sovereign restructurings either prior to or after a default. However, clauses designed to facilitate restructurings may also encourage moral hazard on the part of issuers leading to an increased frequency of default.

Eichengreen and Mody (2000) and Becker, Richards and Thaicharoen (2001) examine the empirical impact of collective action clauses on spread determination. In both studies, the empirical strategy exploits the strong correlation between the presence of collective action clauses in a bond indenture and that bond's governing law. Bonds governed under English law, such as Eurobonds issued in London, typically incorporate collective action clauses. In contrast, bonds governed under New York law, such as Brady bonds, typically do not incorporate such clauses. In principle, this governing law/collective action clause effect could explain why New York-based Brady bond yield spreads are larger than London-based Eurobond spreads. Unfortunately, the evidence on the valuation impact of governing law choice is mixed.[13]

[12] See, for example, IMF (2002).

[13] Eichengreen and Mody (2000) report large and different impacts of governing law choice on issuance yield spreads for high-rated versus low-rated issuers. In line with the idea that collective action clauses add value, that study finds that the use of English law by issuers with high credit ratings reduces issuance yield spreads. In contrast, low-rated issuers adopting English law are penalized though higher issuance yield spreads, presumably because of increased moral hazard. In a more recent study incorporating both secondary and issuance spreads, Becker, Richards and Thaicharoen (2001) find that use of English law adds value (spreads tend to be lower), but the effects are often statistically insignificant at standard significance levels. Moreover, they can find no evidence that the use of English law (and, therefore, the presence of collective action clauses) increases yields for low-rated issuers.

A complementary research direction places more intense focus on investor perceptions regarding how much of a bond's value would be recovered in the event of default. Clearly, the relationship between the sovereign yield spread and issuer default probability entails understanding bond payoffs in the default state. A 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. The percentage of the value of the new security to the par value of the original security can be termed the bond's default recovery value.

Assumptions about the default recovery value 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 bankruptcy between 1980 and 1992. The authors estimate bondholder recovery by measuring actual post-bankruptcy emergence bond market values for individual firms.[14] That 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 (1999) estimates the weighted average recovery rate of US corporate debt defaults to be 40% of face value.

However, unlike the US domestic corporate debt markets, the sovereign bonds in emerging markets offer no rich default experience histories for reference. A large portion of such debt initially was issued under the Brady bond structure. A Brady bond's Treasury collateral ameliorates the investor's problem of reliably estimating a default recovery value.[15] However, uncollateralized Eurobond issues have become more important sources of funding in the sovereign emerging markets. In the absence of Brady bond-like guarantees, a default crisis scenario for unsecured sovereign Eurobond debt is destined to be a fluid situation.

Eurobonds are uncollateralized obligations. An emerging market investor discounting the expected cash flows of a Eurobond must jointly estimate recovery value

[14] Altman and Eberhart analyzed the price/payoff of the debt securities upon emergence from Chapter 11.
[15] See Claessens and Pennachi (1996) and Bhanot (1998) for empirical analysis of Brady bonds.

and payment probabilities. Merrick (2001) examined the role of revisions in *implied* recovery value in both Russian Federation and Republic of Argentina Eurobond valuation during extraordinarily volatile Russian GKO-default credit crisis of 1998. The empirical analysis led to a number of conclusions. First, recovery value estimates for Argentine debt embodied a "standard" US corporate debt 50% recovery value assumption. In contrast, the pre-crisis implied recovery value for Russian Eurobonds was much lower. Second, the implied Russian recovery value – reasonably stable prior to and just after the GKO default – fell sharply one week after the actual default announcement. Third, significant downward revisions in Russian Eurobond implied recovery value continued even after the default probability stabilized at its higher value.[16]

Finally, Brady bonds and Eurobonds differ along the recovery value dimension. A Brady bond's principal is fully collateralized by US Treasury zero-coupon bonds of equal face value. Investors have a precise understanding of the market value of this underlying collateral. The impact of this differential recovery concept on quoted yield spreads for Brady bonds versus Eurobonds is significant. Section 3 examines this impact within the context of a full analysis of the relation between recovery values and yield spreads.

3. Interpreting yield curves for risky sovereign debt: some simple analytics

This section develops some simple yield spread analytics for emerging market debt. One goal is to relate market yield spreads to investor perceptions regarding both default probability and default recovery value. Perceptions of issuer default probability play a central role in emerging market bond valuation. Many authors have interpreted the yield spread on an emerging market bond as a direct measure of the issuer's per period "default rate" after assuming that default-state recovery value is zero. In contrast, the analysis here will highlight the importance of the assumed default recovery value in yield spread determination. When a more realistic (i.e., positive) recovery value is anticipated, the implied default probability consistent with a given observed yield spread can rise significantly. The important conclusion is that the observed yield spread does not directly measure the issuer's default rate. Thus, recovery value assumptions matter.

[16] The downward revision in implied recovery value occurred as investors digested relevant "news" – the contentious dealings of the Russian government and GKO investors in the aftermath of the GKO default. Russian never did default on its Eurobond obligations.

This section's second goal is to distinguish between the yield spread concepts appropriate for uncollateralized debt (e.g., Eurobonds) versus collateralized debt (e.g., Brady bonds). As discussed earlier, a number of studies have documented that stripped sovereign yield spreads quoted on Brady bonds exceed the yield spreads quoted on Eurobonds of the same issuer. The literature interprets this difference either as an unexplained pricing anomaly or a product of the collective action clauses within the Eurobond indenture. The analysis here offers an alternative explanation. While lacking explicit Brady-type collateralization, a given issuer's Eurobond presumably has positive recovery value in default. Thus, the conventional yield-to-maturity on a Eurobond blends the high discount rates appropriate for the default-sensitive component of expected cash flow with the low discount rate appropriate for the perceived recovery value component. In contrast, the Brady bond's computed stripped sovereign spread is strictly appropriate for the uncollateralized coupon flows where 0% recovery might more reasonably be assumed. Thus, the stripped sovereign yield spreads quoted on Brady bonds *must* be higher than the yield spreads quoted on Eurobonds of the same issuer if nonzero Eurobond recovery value is assumed.[17]

All of the results will be demonstrated through a series of examples based upon two types of discounting analysis. The conventional method discounts the *promised* cash flows of a given bond and, given the bond's market value, generates the bond's quoted yield-to-maturity. This yield is the internal rate of return on the bond's promised cash flows. A second discounting method discounts the bond's *expected* cash flows based upon a specific analysis of default prospects that incorporates particular assumptions about both the issuer's probability of making the scheduled payments and any recovery value should default occur. Side-by-side analysis of these two discounting methods permits understanding of how a bond's quoted yield and spread reflect the key parameters determining expected default losses. This analysis is presented in a series of steps. Section 3.1 presents examples for uncollateralized bonds (e.g., Eurobonds) assuming zero recovery in default. Section 3.2 presents examples for collateralized bonds (e.g., Brady issues) and studies the "stripped spread" yield concept. Section 3.3 analyzes

[17] Assuming some positive value for the Brady's uncollateralized cash flows would complicate the algebra, but not change the general thrust of the result.

the effects of positive default recovery value on uncollateralized bond yield spreads and relates the findings to the Brady-Eurobond excess spread puzzle. Finally, Sections 3.4-3.6 discuss related topics of blended spreads, the Eurobond-Brady spread gap puzzle, and the impact of risk-aversion on implied default rates.

3.1 Yield spreads on uncollateralized bonds assuming zero recovery in default

Consider a simple 1-period example in the spirit of Kamin and von Kleist's analysis linking benchmark country (here, the US) and emerging market country yields. Let V be the market value and let Y be the quoted yield-to-maturity on a 1-period emerging market 10% coupon rate bond per $100 of the bond's par value. Then, the quoted yield, defined as the internal rate of return on the investment when purchased at the current market value, is such that

$$V = \frac{10 + 100}{1 + Y}. \tag{3.1}$$

Practitioners will use the spread between an emerging market debt issue's yield and that of the counterpart benchmark market issue to summarize current market conditions. Thus, practitioners will compare the yield-to-maturity on the emerging market bond ("Y") to the yield on the US Treasury issue of the same maturity (denoted here as "y"). The difference between Y and y reflects a valuation discount attributable to the emerging market issuer's default potential.

For example, suppose that a 1-year US Treasury 0% coupon rate bond were priced at $95.238 per $100 of par value to yield 5% on an annually-compounded basis: ($100/$95.238 = 1.0500 = 1 + y; y = .0500). Furthermore, suppose that an emerging market issuer's 1-year US dollar-denominated 10% coupon rate bond were priced at $96.38 per $100 of par value to yield 14.13% on an annually-compounded basis:

$$V = \frac{10 + 100}{1.1413} = 96.38. \tag{3.1''}$$

Market practitioners might define the emerging market bond's yield spread, s, via the compound form:[18]

$$(1 + Y) = (1 + y)(1 + s). \tag{3.2}$$

Thus,

$$s = \frac{(1 + Y)}{(1 + y)} - 1 \tag{3.3}$$

Here, the emerging market issuer's yield spread could be calculated as

$$s = 1.1413/1.0500 - 1 = .0870 \text{ (8.70\% or 870 basis points).} \tag{3.4}$$

While the yield and spread computations above conveniently summarize current market quotations, they provide little insight. The financial logic behind the setting of V in the market is more usefully described through an equilibrium relationship to the probability of payment, p, and the appropriate discount rate. If the emerging market bond's $100 principal is repaid in full, the investor receives $110 (= $100 of principal plus $10 of coupon interest). However, if the issuer defaults, assume that the investor recovers only R dollars per $100 of par value. Assume that this specific recovery value, R, replaces all other cash flow claims. Then, V can be expressed as the expected discounted value of the two possible end-of-period cash flow outcomes where the outcomes occur with the assumed probabilities, p and 1– p. If investors are risk-neutral, then the risk-free 1-period yield is properly used to discount both state-dependent cash flows:[19]

$$V = p\,\frac{110}{(1 + y)} + (1 - p)\,\frac{R}{(1 + y)}. \tag{3.5}$$

[18] This multiplicative form for the spread is more convenient than an additive form for compounding purposes.
[19] Alternatively, if investors are risk-averse, the payment probability can be thought of as an *adjusted* risk-neutral probability distribution as in Harrison and Kreps (1979). See section 3.4 below.

As in Kamin and von Kleist (1999), assume that the emerging market bond investor recovers nothing (i.e., 0% of par value) in the default state. In this setting, R = 0 and the emerging market 1-period zero-coupon bond is valued as

$$V = p\frac{110}{(1 + y)} + (1 - p)\frac{0}{(1 + y)}. \tag{3.5'}$$

Substituting equation (3.1) into (3.5'), the emerging market bond's quoted yield, Y, can be determined as

$$1 + Y = \frac{1 + y}{p}. \tag{3.6}$$

Combining the expression above with the definition of the multiplicative yield spread produces a particularly convenient interpretation: 1 + s equals the inverse of the bond's payment probability. Thus,

$$1 + s = \frac{1 + Y}{1 + y} = \frac{1}{p} \tag{3.7}$$

and, finally,

$$s = \frac{1 - p}{p}. \tag{3.8}$$

Thus, under the above assumptions, s equals the ratio of the default probability (1 – p) to the payment probability (p). The yield spread rises as default becomes more likely (i.e., s rises as p falls).

The analysis extends naturally to the case of a 2-period coupon-bearing bond paying a per-period coupon of C per $100 of par value. The bond's yield-to-maturity, Y, is defined as

$$V = \frac{C}{(1 + Y)} + \frac{(C + 100)}{(1 + Y)^2}. \tag{3.9}$$

The companion risk-neutral valuation equation must account for all possible cash flow outcomes. For simplicity, assume that the benchmark term structure of zero-coupon yields is flat ($y_1 = y_2 = y$). The probability of being fully paid in both periods is p^2 and the associated discounted cash flow is $[\frac{C}{1+y} + \frac{100+C}{(1+y)^2}]$. The probability of being paid the coupon in period one, but experiencing a default in period two equals $p(1 - p)$, and the associated discounted cash flow is $\frac{C}{1+y}$ (since a recovery value of $R = 0$ is assumed). Finally, the probability of experiencing default in period one is $1 - p$ and the associated discounted cash flow is zero. Thus, under the 0% recovery value assumption, the risk-neutral valuation equation simplifies to

$$V = p^2[\frac{C}{1+y} + \frac{100+C}{(1+y)^2}] + p(1-p)\frac{C}{1+y} \ . \tag{3.10}$$

This can be re-arranged to derive

$$V = \frac{p\,C}{1 + y} + \frac{p^2\,(C + 100)}{(1 + y)^2}. \tag{3.11}$$

Clearly, equation (3.11) is consistent with (3.9) above if

$$1 + Y = (1 + y)(1 + s) = \frac{1 + y}{p}. \qquad (3.12)$$

Hence, as with its 1-period bond counterpart, the spread variable (s) is again determined as the ratio of the per period default probability (1-p) to the payment probability (p):

$$s = \frac{1 - p}{p}. \qquad (3.13)$$

These relationships can also be reverse engineered to uncover *implied* market parameters from bond market prices. For example, suppose that a 2-year 10% coupon rate bond of an emerging market issuer currently sells in the secondary market for $93.21 per $100 of par value. Assume a recovery value of $0. If the annually-compounded yields on 1-year and 2-year zero-coupon US Treasury are each 5%, what is the emerging market bond's yield spread?[20] Moreover, what per period default rate is the market using to price this emerging market issue?

At a market value of $93.21, the emerging market bond's yield-to-maturity (Y) equals 14.13% from equation (3.9):

$$93.21 = \frac{10}{(1.1413)} + \frac{(10 +100)}{(1.1413)^2}. \qquad (3.9')$$

Via equation (3.3), the bond's yield spread equals

$$s = (1+Y)/(1+y) - 1 = (1.1413/1.05) - 1 = .0870 \text{ (or 8.70\%)}. \qquad (3.3')$$

Finally, this 870 basis point spread implies that the market is attributing the issuer a per period payment probability of 0.92. In particular,

[20] All of the examples of this section are based upon flat term structures of risk-free per period discount rates and payment probabilities. The introduction of more general curve shapes necessitates applying appropriate term rates for each payment date and permits analysis of the "forward" default rate curve (see Section 4 below).

$$s = (1 - p)/p = .0870 \qquad (3.8')$$

if and only if p = .92 and (1 – p) = .08. Thus, at a price of $93.21, the bond market's *implied* default rate is 8% per period.

The analysis works for the simple cases of 1-period and 2-period bonds. However, assuming a 0% default recovery value, these yield spread and per period payment rate results also hold for bonds with maturities extending beyond two periods.

3.2 The "stripped spread" yield concept for Brady bonds

Brady bonds, created in the 1990s as part of the debt restructurings of defaulted emerging market sovereign loans, are an important class of emerging market debt. By the middle part of the decade, the Brady market stood as the largest and most liquid emerging debt market sector.[21] The key component of the Brady bond structure is that each issue is partially collateralized by zero-coupon US Treasury bonds. Typically, the zero-coupon Treasury collateral covers the entire principal amount and a rolling portion of the remaining coupon interest. A Brady issue's Treasury collateral is held by the Federal Reserve Bank of New York and provides important protection for investors should the issuing sovereign fail to make timely payment of coupon or principal. But for present purposes, the presence of the collateral complicates the calculation of the appropriate yield spread. The complication arises because all cash flows do not carry equivalent exposures to default. Clearly, the uncollateralized portion of the bond's cash flow stream should be discounted at a default-risk adjusted rate. Investors need to earn a premium on this portion of the bond's promised payment stream to compensate for expected default losses. However, the collateralized portion of the cash flow stream should be discounted at the risk-free rate. No default premium is required on this Treasury-backed portion. Practitioners who reference the standard yield-to-maturity calculation (i.e., a single internal rate of return for all cash flows) for a Brady bond are careful to term the result the "blended yield" since this calculation improperly lumps together cash flows that

[21] Beginning with Mexico in 1996, emerging market sovereigns have retired a significant portion of the outstanding Brady issues via buybacks and debt exchanges for newly issued uncollateralized sovereign Eurobond market issues. For example, $1.8 billion of Brady issues were part of Argentina's June 2001 voluntary debt exchange. By September 2002, about half of the original Brady issues had been retired. Moreover, during 2001, secondary market trading volume in Eurobonds was more than double that of the remaining Brady bond sector. For more details, see IMF (2002b).

differ in underlying risk. A yield spread derived from this blended yield would be artificially low and could not be directly used to accurately characterize sovereign default probabilities via equation (3.13).

The discounting complications that Brady bonds present suggest an adjustment to the spread calculation methodology. Practitioners apply the standard spread calculation as above only after "stripping out" the present value of collateralized cash flow component. The present value of collateralized cash flow component is calculated using risk-free discount rates. As a simple example, consider the definition of s^s, the "stripped spread" on a 2-period, coupon-bearing Brady bond with full collateral against principal and no collateral against either coupon.[22] For the default-free collateralized principal amount, use $1+y$ to discount this default-free cash flow. For the uncollateralized, default-exposed coupon amounts, use the spread-adjusted rate $Y = (1+y)(1+s^s) - 1$. The stripped spread term (s^s) in the discount factor for the uncollateralized coupons would define the "pure" sovereign yield spread.

In practice, this calculation is performed in two steps. First, subtract out the present value of the Treasury collateral from the Brady bond's market value and denote this "stripped value" of the bond as V^*:

$$V^* = V - \frac{100}{(1+y)^2}. \tag{3.14}$$

Second, solve implicitly for Y, the sovereign yield, from the following definition, where C represents the promised (but uncollateralized) coupon payments:

$$V^* = \frac{C}{(1+Y)} + \frac{C}{(1+Y)^2}. \tag{3.15}$$

Given Y, solve for the stripped spread from the definition as before:

[22] In practice, terms for coupon collateralization vary across specific issues. A common structure involves collateralization of the next three coupon payments (on a rolling basis).

$$(1 + Y) = (1 + y)(1 + s^s) \tag{3.16}$$

Assuming 0% recovery for *coupon* payments in default, the risk-neutral valuation equation for this coupon-bearing two-period Brady bond extends to

$$V^* = \frac{p\,C + (1 - p)\,0}{(1 + y)} + \frac{p^2\,C + p(1 - p)\,0}{(1 + y)^2}. \tag{3.17}$$

Furthermore, s^s, the "stripped spread," can be solved for directly by combining equations (3.16) and (3.17):

$$s^s = \frac{1 - p}{p}. \tag{3.18}$$

Suppose that the same per period emerging market issuer payment probability used by the market for the uncollateralized bond (p = .92) is also used for a 2-year, 10% coupon rate Brady bond. From equation (3.18), the stripped yield spread on this bond (s^s) would be .0870 (= [1–.92]/.92). Thus, from equation (3.16), the sovereign yield on this bond would be $Y = (1 + y)(1 + s^s) - 1$ or Y = (1.05)(1.0870) – 1 = .1413. At this sovereign yield, the fair value of the two 10% annual rate coupons is given by[23]

$$V^* = \frac{10}{1.1413} + \frac{10}{(1.1413)^2} = 16.439. \tag{3.19}$$

[23] The valuation for V^* could also have been computed through the risk-neutral discounted expected value of the coupons using p = .92:

$$V^* = \frac{.92\,(10) + (.08)\,0}{(1.05)} + \frac{(.92)^2\,10 + .92(.08)\,0}{(1.05)^2} = 16.439.$$

Next, solve for the fair market value of the collateralized principal. The value of the collateral is found by discounting the bond's par value by the risk-free rate of 5%. Thus, the collateral would be valued at $90.703 (= 100/[1.05]^2). Finally, this 2-year Brady bond's fair market value would be the sum of the two component values, or V = 16.439 + 90.703 = 107.142.

The solution for the "stripped spread" reduces to 870 basis points, the same ratio of default-to-payment probabilities as in the case of s, the spread on non-Brady bonds (s^s = [1 – .92]/ .92 = .870). But a conventionally calculated yield-to-maturity on this bond at a price of $107.142 is 6.099% via equation (3.9):

$$107.142 = \frac{10}{1.06099} + \frac{(10 + 100)}{(1.06099)^2}. \tag{3.9''}$$

Think of this calculated 6.099% as the "blended yield" on this collateralized bond. This blended yield – the bond's internal rate of return conditional on no default – provides little substantive information on the market's implied default probability rate since it mixes the true sovereign yield (relevant to form the discount rate on the risky coupons) and the risk-free yield (relevant for the collateralized principal). Furthermore, the 126 basis point yield spread to Treasuries derived from this computed blended yield (1.26% = .0105 = [1.06099/1.05] – 1) is a "blended spread" that offers a fuzzy picture of the market. Policymakers should be careful to track a Brady bond's 870 basis point stripped sovereign spread, not its 105 basis point blended spread, when attempting a direct read on the market's implied default probability rate. Only the 870 basis point stripped sovereign spread directly reveals the market's true 8% assessment of the issuer's per period default probability.

3.3 Positive recovery values shift yield spreads

The yield spread analysis for non-Brady, uncollateralized emerging market debt in Section 3.1 above invoked the most conservative possible recovery value assumption: 0%. Under this assumption, a bond's yield spread directly reflects the issuer's default probability. However, based upon previous experience with both corporate bond and sovereign loan defaults, investors may expect some positive recovery value to emerge in the default state. *Ceteris paribus*, these same investors would price emerging market bonds higher to reflect this perceived positive recovery value. As the analysis below will detail, the introduction of a positive recovery value shifts the relationship between the yield spread and the default rate.

Assume that a known specific recovery value, R, is paid to the bondholder upon the event of default and replaces all other cash flow claims. To simplify the analysis, assume that this recovery value is actually received only at the bond's maturity date, regardless of when default actually occurs. In the default portion of the event tree, this substituting payment of R replaces any remaining cash flows (i.e., the remaining coupons and principal) from the initially promised stream. In the discounting equation below, a default in period two generates a payment of R; however, a default in period one is attributed a payment of R/(1 + y) – i.e., the period one present value of R actually received in period two. Given these assumptions about the bond's recovery value, the investor values the bond according to the following risk-neutral valuation equation:

$$V = \frac{p\,C + (1 - p)\,[R/(1 + y)]}{(1 + y)} + \frac{p^2\,(C + 100) + p(1 - p)\,R}{(1 + y)^2}. \qquad (3.20)$$

Typically, uncollateralized emerging market bonds (e.g., Eurobonds) are quoted on a yield-to-maturity basis as described by equation (3.9) and repeated here:

$$V = \frac{C}{(1 + Y)} + \frac{(C + 100)}{(1 + Y)^2}. \qquad (3.9)$$

Note that the multiplicative form of the yield spread will no longer reduce to the simple ratio of per period default-to-payment probabilities because of the extra R terms in equation (3.20). The multiplicative yield spread concept will correspond to those previously examined only in two extreme cases. First, if the recovery value equals 0, the analysis reduces to the case initially studied in Section 3.1. Second, if R = 100, the analysis reduces to that for the "stripped spread" case of the Brady bond of Section 3.2. Because neither of these two conditions is likely to hold in practice, yield spread determination is now more complex.

Consider once again US dollar-denominated 10% coupon rate, 1-year and 2-year maturity bonds of an emerging market issuer. However, instead of a recovery value of $0, assume that the market perceives default recovery value to be $50 per $100 of par (R = 50). Again, assume that the equivalent 1-year and 2-year riskless benchmark zero-coupon yields are each 5% and that the issuer's per period payment probability is p = .92. Under these assumptions, the discounted expected cash flow valuation for the 1-year bond follows from equation (3.5):

$$V = .92\,\frac{110}{1.05} + (1 - .92)\,\frac{50}{1.05} = 100.19. \qquad (3.5'')$$

From equation (3.1), the 1-year bond's yield is 9.79%:

$$100.19 = \frac{10 + 100}{1.0979}. \qquad (3.1')$$

Furthermore, from equation (3.3), this bond's yield spread is 456 basis points:

$$s = \frac{1.0979}{1.05} - 1 = .0456. \qquad (3.3')$$

Now turn to the 2-year bond. Assuming R = 50, the discounted expected cash flow valuation for the 2-year bond follows from equation (3.20):

$$V = \frac{.92\,(10) + (1 - .92)\,[50/1.05]}{1.05} + \frac{(.92)^2\,(10 + 100) + .92(1 - .92)\,50}{(1.05)^2}$$

$$V = 100.18. \qquad (3.20')$$

From equation (3.9), this 2-year bond's yield is 9.90%:

$$100.18 = \frac{10}{1.0990} + \frac{(10 + 100)}{(1.0990)^2}. \qquad (3.9')$$

Furthermore, from equation (3.3), this bond's yield spread is 466 basis points:

$$s = \frac{1.099}{1.05} - 1 = .0466. \qquad (3.3'')$$

These answers offer some surprises. With a positive recovery value (R = 50), the yields on the 1- and 2-year bonds are not equal even though the benchmark risk-free yield structure reflects a "flat" 5% curve and the assumed per period payment probability is constant. Moreover, the computed yield spreads no longer equal the ratio of default to payment probabilities as in the R = 0 case.

Table 1 compares bond values and associated yields for 10% coupon rate emerging market bonds from 1 to 10 years in maturity under alternative assumptions for both the level of R and the value of p. The upper panel of Table 1 uses a "normal" value for the payment probability: p = .92. Bond values and associated yields are computed for all 10 issues under three different recovery value assumptions: R = 0, 50 and 100. The R = 0 column reflects valuation as in the examples of Section 3.1. The R = 100 column reflects valuation as in the collateralized Brady bond examples of Section 3.2. The R = 50 column reflects valuation as in the examples of the current section. The lower panel of Table 1 recalculates all bond values and yields under a much lower payment probability: p = .60. Interpret this p = .60 as a "crisis" value for the payment probability.

The impacts of assuming positive recovery value on bond values are easy to understand. Consider the 2-year bond valued under normal market conditions (p = .92) at

93.21 if R = 0 and 100.18 if R = 50. Thus, there is a difference in value of +6.97 moving from the R = 0 column to the R = 50 column in the upper panel of Table 1. This +6.97 change reflects the 15.4% probability that the bond defaults by the end of the 2-year horizon (.154 = 1 – .846 where, from the table, $.846 = .92^2$) multiplied by the discounted value (using the 2-year risk-free discount factor = .907) of the assumed recovery value (R = 50). Thus, aside from rounding error, +6.97 = (.154)(.907)(50). The bond values for all of the other positive recovery value cases (in either the upper or lower panels) versus an R = 0 benchmark can be computed in a similar fashion.

Table 1 reveals that yield levels and yield curve shapes are complex functions of payment probability and recovery value. The complexity reflects bond value impacts that depend on the assumed payment rate and the presented value of the assumed recovery value (see above) as well as on the differing sensitivities of the conventional value/yield translation for long versus short maturity bonds. For example, under the R = 50 assumption, the emerging market issuer's yield curve could be either upward or downward sloping depending upon whether the payment probability is high or low. Furthermore, the same bond value can result from markedly different parameter pairings. The 8-year bond's value is essentially the same under "normal" conditions (p = .92) with 0% recovery as it would be under "crisis" conditions (p = .60) with 100% recovery (Brady-type collateralization). These examples show that bond price level and yield curve shape do not necessarily reveal market expectations regarding issuer default probability. A second key variable – default recovery value – must be simultaneously considered. In this light, emerging market bond yield spreads are quite complex signals of market sentiment.

<insert Table 1 about here>

3.4 Blended yields and blended spreads

Positive recovery value complicates the interpretation of yield spreads as direct indicators of default prospects. One more example based upon the 10% coupon rate, 2-year bond may help clarify the problem and suggest the appropriate adjustment. If recovery value is \$50 per \$100 of par value (R = 50), a bondholder is assured of at least

$50 at maturity even if default occurs in period one. Given an assumed per period payment probability value of .92, the market should be willing to pay $100.18 for this bond as in equation (3.20') and Table 1. At this value, the bond's yield-to-maturity is 9.90% and the quoted yield spread is 466 basis points (= [1.0990/1.05] – 1 = .0466). However, this 9.90% yield-to-maturity and this quoted spread of 466 basis points should be treated as a "blended yield" and a "blended spread," respectively. The blended nature of these yield and spread concepts becomes apparent when the valuation framework is recast in discounted cash flow terms. In particular, the yield and spread logic that flows from the risk-neutral valuation result is best seen after rewriting equation (3.20) in the following forms:

$$V = \frac{p\,C}{(1+y)} + \frac{p^2\,(C+100)}{(1+y)^2} + \frac{[(1-p)+p(1-p)]\,R}{(1+y)^2} \qquad (3.21)$$

and

$$V = \frac{p\,C}{(1+y)} + \frac{p^2\,(C+100-R)}{(1+y)^2} + \frac{R}{(1+y)^2}. \qquad (3.22)$$

Note that while the first two terms of equation (3.22) contain p, the key parameter of the payment probability distribution, the third term does not. Given this insight, it is useful to re-express equation (3.22) as a set of cash flows discounted by two different rates:

$$V = \frac{C}{(1+Y^R)} + \frac{(C+100-R)}{(1+Y^R)^2} + \frac{R}{(1+y)^2}. \qquad (3.23)$$

An amount equal to the recovery value R should be discounted at the riskless rate, y. However, the coupons and the amount of the promised principal payment that exceeds the recovery value should be discounted at the spread-adjusted rate:

$$(1 + Y^R) = (1 + y)(1 + s^R) \quad (3.24)$$

where

$$s^R = \frac{1 - p}{p}. \quad (3.25)$$

In our example, the bond's *true* sovereign yield (Y^R) and sovereign spread (s^R) equal

$$s^R = \frac{1 - p}{p} = \frac{.08}{.92} = .0870 \ (= 8.70\%) \quad (3.26)$$

and

$$Y^R = (1 + y)(1 + s^R) - 1 = (1.05)(1.0870) - 1 = .1413 \ (= 14.13\%). \quad (3.27)$$

The bond's true sovereign yield ($Y^R = 14.13\%$) – as *used* by the market to discount the risky component of cash flow – is dramatically higher than the blended yield (Y = 9.90%) – as *quoted* by the market for daily business. Likewise, the bond's true sovereign spread (870 basis points) – as *used* by the market – is dramatically higher than the blended spread (466 basis points) that might be *quoted* by market participants. The sovereign spread, s^R, can be thought of as a special "stripped-of-recovery-value" spread which is comparable in nature to the stripped-of-collateral spread for a Brady bond.

3.5 The positive Eurobond versus Brady bond spread gap: no anomaly

One interpretation in the literature for the substantial spread gap between (high spread) Brady bonds and (low spread) Eurobonds has been one of a sustained valuation anomaly. The analysis above shows that this not the case at all. Indeed, the stripped sovereign spread on an emerging market Brady bond *must* be higher than the quoted spread on the same issuer's Eurobond in an efficiently priced market if a positive Eurobond default recovery value is assumed. The quoted spread on a Eurobond is based upon a "blended" yield derived as a single internal rate of return computed for a mix of a default risk-free cash flow (the assumed recovery value) and other risky cash flows (coupons and principal in excess of the assumed recovery value). In the framework used above, the "blend" in the quoted Eurobond spread occurs because the market uses the true (high spread) sovereign yield to discount the risky cash flows and the (zero spread) risk-free yield to discount the bond's assumed recovery value. A more accurate study of potential Eurobond and Brady bond yield spread misalignment would compare "stripped-of-recovery-value" Eurobond yield spreads with stripped sovereign spreads on Brady issues.

3.6 Risk-aversion and *adjusted* risk-neutral payment probabilities

If investors are risk-neutral, the risk-free rates used in the examples above are appropriate for expected bond cash flow discounting. However, most market observers would maintain that emerging market investors are risk-averse. In fact, many hold that shifts in market risk aversion were key factors in explaining observed emerging market price volatility and contagion effects. One way to handle risk aversion in discounted expected cash flow valuation is to substitute risk-adjusted discount rates for the risk-free rates used above. This substitution would require specifying a particular form of the appropriate risk premium.

An alternative approach would retain the use of risk-free rates and finesse the discounting problem posed by risk-averse investors by reinterpreting the nature of the payment probability distribution. In particular, this approach reinterprets the per period payment probability p used above as reflecting an *adjusted* risk-neutral probability distribution as in Harrison and Kreps (1979). This adjusted distribution is sometimes referred to as the *equivalent martingale measure*.[24] Alternatively stated, the adjusted distribution is that distribution that would result in the same market value (V) as the objective distribution in a risk-neutral world.

For current purposes, consider two alternative representations of the 2-period bond. Let p *now* denote the *adjusted* risk-neutral payment probability. When paired with the risk-free discount rate y to value a 1-period bond subject to default, the relevant discounted expected cash flow value is

[24] See Sundaram (1997) for an introduction to equivalent martingale measures and risk-neutral pricing.

$$V = \frac{p\,(C + 100)}{1 + y} + \frac{(1 - p)\,R}{1 + y} \qquad (3.32)$$

Let the *objective* (true) payment probability equal q and let the appropriate *risk-adjusted* discount rate equal λ. The corresponding discounted expected cash flow valuation equation would be

$$V = \frac{q\,(C + 100)}{1 + \lambda} + \frac{(1 - q)\,R}{1 + \lambda} \qquad (3.33)$$

Finally, denote the appropriate risk premium of the required expected return on the emerging market bond relative to the risk-free bond as $\pi = (1 + \lambda)/(1+y) - 1$. Then, clearly, the adjusted risk-neutral payment probability p is a derived "mongrel" parameter determined by both the objective payment probability and the appropriate risk premium:

$$p = q/(1+ \pi). \qquad (3.34)$$

If risk premiums do exist (i.e., $\pi > 0$), the implied risk-neutral payment probabilities estimated from observed bond price data would be smaller than the true payment probabilities. Thus, any default probabilities estimated from market data will need to be interpreted with care. In particular, evidence of contagion based upon correlations of implied payment probabilities (i.e., p) between two emerging markets might reflect common movements in risk premiums (i.e., π) rather than objective payment probabilities (i.e., q).[25] However, casting the model in terms of adjusted risk-neutral probabilities permits simple, unbiased, preference-free estimation of the key recovery value parameter even in a risk-averse world.

[25] See www.worldbank.org/contagion for links to papers and other resources related to the emerging markets contagion literature.

4. Emerging market bond valuation: the case of Argentina

This section applies expected discounted cash flow model to value Republic of Argentina Eurobonds during the midst of the market collapse prior to Argentina's default in December 2001. The analysis works backwards from available market Argentine Eurobond bond prices to extract measures of the market's implied recovery value and payment probabilities. Implementation requires decisions about both the appropriate recovery value assumption and the exact functional form for payment probabilities at alternative horizons.

4.1 Implied recovery values

The examples of Section 3 above treated the investor's expected recovery value as a known quantity. But how would a policymaker or any other market observer know what recovery value investors are using to value any particular issuer's bonds? As noted in Section 2, previous estimates of the average recovery rate on US corporate debt defaults – based upon actual post-bankruptcy emergence bond market value – range between 40% to 50% of face value. However, unlike the US domestic corporate debt markets, no rich default experience histories exist for the sovereign foreign currency bond markets. Merrick (2001) addressed this issue in the context of both Russian Federation and Republic of Argentina Eurobond prices during the Russian GKO-default credit crisis of 1998. That framework valued the available cross-section of bonds as a function of risk-free discount factors derived from the term structure of Treasury bond yields, a parsimonious function describing the term structure of bond cash flow payment probabilities, and the implied recovery value. In particular, the market's implied recovery value was *jointly* estimated on a daily basis along with the parameters of the payment probability distribution. For the August to December 1998 period, estimated recovery values derived from Argentina's Eurobond prices were quite close to a standard 50% US corporate debt assumption.

4.2 Joint examination of payment distribution and recovery value parameters

The discounted expected cash flow model has four components. The first is the bond's 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 recovery value, R, paid to the bondholder immediately upon the event of default.[26] 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 set of discount factors. Here, let f_t denote the present value discount factor for a time t cash flow as generated from the risk-free rate of interest for a cash flow with horizon t. Here, the discount factor for each futures horizon date will be interpolated from observed prices of US Treasury zero-coupon bonds (i.e., Treasury coupon strips). These risk-free present value discount factors can also be represented as a function of $y_{0,t}$, the set of initial date 0 risk-free zero-coupon bond yields applicable to any date t discounting horizon:

$$f_t = 1/\,(1+ y_{0,t})^t. \tag{4.1}$$

The final valuation component is the payments probability distribution.[27] To handle the possibility that per period payment probabilities (and therefore default rates) are not constant, the earlier notation of Section 3 must be altered. Let d_t denote the probability of *default* during the specific date t-1 to date t period. Next, denote the 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. Thus, P_t can be expressed as

$$P_t = 1 - \sum_{j=1}^{t} d_j \;. \tag{4.2}$$

[26] This specific form for R differs from that utilized in Section 3 above. Here, regardless of when default occurs, the investor immediately recovers a cash flow of R. In Section 3, the recovery payment was delayed until bond maturity. The common immediate payment assumption of the current section makes more sense in a context examining multiple bonds of different maturities but equal seniority from the same issuer.

[27] As discussed in Section 3.4, when discounting at risk-free interest rates, this distribution may be interpreted either as the *objective* distribution if investors are risk-neutral or as an *adjusted risk-neutral* distribution if investors are truly risk-averse.

Given these payment probabilities, d_t can also be written as the *difference* in the *joint* probabilities of no default occurring through dates t-1 and t:[28]

$$d_t = (P_{t-1} - P_t). \tag{4.3}$$

Hence, the probability of receiving the recovery value R on any particular date t equals d_t, the probability of default during the specific date t-1 to date t period, and the cash flow effect of recovery value spreads out across the event tree.

Equation (4.4) expresses the bond's current value, V_0, as the expected discounted cash flow relation:

$$V_0 = \sum_{t=1}^{N} P_t f_t C_t + P_N f_N F_N + \sum_{t=1}^{N} d_t f_t R. \tag{4.4}$$

As in Jonkhart (1979), Fons (1987), Hurley and Johnson (1996), Leland and Toft (1996) and Merrick (2001), equation (4.4) views the bond's current value as a probability-weighted sum of three components: coupon flows, principal repayment and recovery value.[29] 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 when none of its own coupon payments is scheduled. Careful treatment of recovery value as a separate flow component involves analyzing the specific institutional cross-default framework.

4.3 The term structure of per period payment and default rates

Some valuation models for US corporate bonds (e.g., Fons, 1987) and emerging market Brady bonds (e.g., Bhanot, 1998) apply the assumption of constant per period

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[28] By construction, $P_{t-1} \geq P_t$.

[29] Again, the specific form of the valuation equation need not correspond to (4.3). 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. However, such a form would be hard to motivate in the current application. The Republic of Argentina's Eurobonds contain cross-default provisions and maintain equal standing in default regardless of coupon or remaining term to maturity.

payment and default rates over the promised cash flow life of the specific issues studied. However, there are good reasons to question such an assumption. Both Eichengreen and Mody (1998) and Kamin and von Kleist (1999) report significant maturity effects on offering yield spreads (upward sloping spread curves) for their samples of emerging market issues. Since yield spreads are determined at least in part by default rates, this evidence suggests that per period default rates themselves may exhibit a positively sloped structure. That is, perceived default probabilities for deferred periods may be higher than those for near-term periods. On the other hand, in the midst of a crisis, default rates for deferred periods – which apply to per period 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.

It is useful to apply well-known bond market term structure formulations to the term structure of default rates. Denote the date 0 continuously-compounded *term* default probability *rate* for a date t cash payment as δ_t. Define the probability of timely payment of a future date t cash flow following from this term rate as:[30]

$$P_t = \exp(-\delta_t\, t) \tag{4.5}$$

For any t-period horizon, assume that the term default rate curve takes the following functional form: [31]

$$\delta_t = \alpha_0 + \alpha_1[1 - \exp(-t)]/t. \tag{4.6}$$

[30] Thus, suppose t = 3 and $\delta_3 = .10$. Then, $P_t = \exp(-\delta_t\, t) = \exp(-[.10][\cdot 3]) = .741$. The probability that a default would have occurred by the end of period 3 = $1 - P_3 = 1 - .741 = .259 = d_1 + d_2 + d_3$.

[31] Equation (4.6) is a special case of the functional form proposed by Nelson and Siegel (1987) for the term structure of default-free discount rates. Here, for any t-period horizon, Nelson and Siegel's expanded model would introduce two additional parameters, α_2 and α_3, and take the form:

$$\delta_t = \alpha_0 + (\alpha_1 + \alpha_2)[1 - \exp(-\alpha_3 t)]/(\alpha_3 t) - \alpha_2[\exp(-\alpha_3 t)].$$

Equation (4.3) above is the special case of Nelson and Siegel's model where $\alpha_2 = 0$ and $\alpha_3 = 1$. This restricted version is used because the more general form fits the data "too well." In its attempt to explain what most likely are bond-specific value factors, the general form's parameters produce an oscillating forward default rate curve that takes on negative values. See Duffie, Pedersen and Singleton (2002) for an example of the impact of bond-specific factors in the Russian debt market.

In equation (4.6), α_0 is the asymptotic value of the instantaneous forward interest rate reflecting the "long run" component of the default rate curve and α_1 is the current deviation of the instantaneous interest rate from its long-run value reflecting short-run component of the default rate curve. A "flat" default rate term structure ($\alpha_1 = 0$; $\delta_t = \alpha_0$) would imply identical forward default rates for all periods. A positive value for α_1, the short-run component, might be expected in the midst of a crisis. In that case, equation (4.6) would generate an inverted term structure of default rates. The associated term structure of forward default rates would also be inverted, but would show a gradual decay back to a long-run level. Equations (4.5) and (4.6) close the model.

4.4 Estimation of model parameters

In sum, the framework incorporates three unknown parameters: R, α_0 and α_1. The risk-free discount factors and the bond's notional cash flows are known. Since $d_t = (P_{t-1} - P_t)$, equation (4.7) embodies an estimable form of the bond valuation expression:

$$V_0 = \sum_{t=1}^{N} \exp\{-(\alpha_0 + \alpha_1[1 - \exp(-t)]/t)t\}\ f_t C_t] \ + \ \exp\{-(\alpha_0 + \alpha_1[1 - \exp(-N)]/N)N\} f_N F_N$$

$$+ \sum_{t=1}^{N} [\exp\{-(\alpha_0 + \alpha_1[1 - \exp(-[t-1])]/[t-1])[t-1]\} - \exp\{-(\alpha_0 + \alpha_1[1 - \exp(-t)]/t)t\}]\ f_t R. \qquad (4.7)$$

Estimates of the three implied model parameters for *any day* (date 0) can be derived by choosing the values for R, α_0 and α_1 that minimize the sum of squared residuals for the daily cross-section of individual bond values while simultaneously constraining the average cross-sectional bond pricing residual to equal zero. For each issue in the cross-section, the residual is constructed as the difference between the bond's observed market value and the value generated by equation (4.7) at the selected R, α_0 and α_1 parameter values.[32]

4.5 Application to Argentine Eurobond pricing: October 3, 2001

Figure 3 reveals the depth of the Argentine bond market's sell-off in the second half of 2001 through a plot of the weekly price history (source: Bloomberg) of the Republic of Argentina Eurobond 9.75% 9/19/2027 (Argentina '27s). The Argentina '27s began the year priced about \$85 per \$100 of par value. However, the price deteriorated throughout the year as Argentina's prolonged economic recession continued unabated, violent demonstrations took place in the streets of Buenos Aires and other locales, and the country's political situation grew increasingly unstable. At year-end, Argentina defaulted on \$141 billion of its public debt. On December 28th, the last plotted point in Figure 3, the Argentina '27s were marked at \$27.50 per \$100 of par value.

<insert Figure 3 about here>

The recovery value-enhanced model developed above can be applied and estimated to value the Argentine US Dollar Eurobond market on any chosen day. We study the market at the close of trading on October 3, 2001, when the Argentina '27s were marked at \$50.50 per \$100 of par value. This particular day occurs during the midst of the bond market's price collapse prior to the Argentine government's default.

Table 2 lists the Argentine US Dollar Eurobond market's fifteen outstanding issues marked as of the close of trading on October 3, 2001.[33] Twelve of the fifteen issues are standard semiannual-pay, level coupon issues maturing at par. Three bonds – those issue in June 2001 as part of a voluntary debt exchange restructuring plan – have a more complex structure. The 7% 12/19/2008 (Argentina '08s) has a coupon rate of 7% until 2004 when the coupon rate "steps up" to 15.5%. This issue also has a sinking fund structure. Both the 12.25% 6/19/2018 (Argentina '18s) and 12% 6/19/2031 (Argentina

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

[33] These market closes on these bonds were obtained from a large investment bank. Part of the expansion in the number of outstanding issues in the Argentine Eurobond market (from only five in 1998) can be traced to a restructuring program that retired existing Brady bond debt in exchange for new Eurobond issues. See the discussion at the end of Section 2 above as well as IMF (1997).

‘31s) capitalize interest payments until December 2006. The Argentina ‘18s also employ a sinking fund structure.[34]

<insert Table 2 about here>

To implement the model, the individual issue cash flow streams were generated and valuation equations of the form of equation (4.7) were developed for each bond. Closing quotes from the US Treasury coupon strips market for October 3rd were interpolated to generate the risk-free US dollar discount factors (source: Lehman Brothers). Estimates of the three parameters – R, α_0 and α_1 – for this day’s observations were selected to minimize the standard deviation of the zero-mean residuals (market value less model value) for the cross-section of fifteen bonds. Table 3 presents the empirical results. These include estimates of the model’s three parameters as well as the fitted model total value (price plus accrued interest) for each issue. The “Difference” column is the residual value for each bond constructed as the difference between the market and fitted model values for each bond in this fifteen-issue cross-section.[35]

The implied recovery value is $34.3 per $100 of par value. This day’s estimate is lower than the $50 per $100 reported by Merrick (2001) as the sample average implied recovery value for this market over the August-December 1998 period. The estimates of the two parameters of the default rate curve imply an instantaneous short rate of $\alpha_0 + \alpha_1 = 0.3108 + 0.3097 = .6205$ (62%) that decays to its estimated long-run forward rate level of .3108 (31%). These estimated parameters generate the entire payment probability schedule that supports the model bond values of Table 3.

<insert Table 3 about here>

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[34] In developing the individual issue cash flow stream, the two bonds with sinking fund provisions were assumed to sink at par.

[35] As in Merrick (2001) and Duffie, Pederson and Singleton (2001), valuation models for emerging market debt tend to result in large residuals for individual issues. The interpretation of issue-specific value effects (perhaps due to repo market effects or market segmentation) is not pursued here.

The estimated term default rate curve is the empirical version of equation (4.6) and is presented below as equation (4.8).

$$\delta_t = 0.3108 + 0.3097\ [1 - \exp(-t)]/t. \qquad (4.8)$$

This equation generates the market's implicit term default rate and expected payment probability for cash flows (via equation [4.5]) due at each horizon date. For example, a cash flow due in one year would have an estimated payment probability of 60%, calculated by applying a term default rate of 50.7% for the t = 1 year term:

$$\delta_1 = 0.3108 + 0.3097\ [1 - \exp(-1)]/1 = .507 \qquad (4.9)$$

and

$$P_1 = \exp(-\delta_1\ 1) = \exp[(-.507)(1)] = .603. \qquad (4.10)$$

Alternatively, a cash flow due in 2 years would have an estimated payment probability of 41%, calculated by applying a term default rate of 44.5% for the t = 2 year term:

$$\delta_2 = 0.3108 + 0.3097\ [1 - \exp(-2)]/2 = .445 \qquad (4.11)$$

and

$$P_2 = \exp(-\delta_2\ 2) = \exp[(-.445)(2)] = .411. \qquad (4.12)$$

Note that the default rate for the 2-year horizon is lower than that for the 1-year horizon. Figure 4 plots the entire estimated term default rate curve. Initially, the term default rate curve slopes downward quite steeply and then flattens out. Indeed, the initial instantaneous (t = 0) default rate is about double its long-run value.

<insert Figure 4 about here>

Standard term structure analysis differentiates between *term* rates and *forward* rates. Forward rates are the elements of the specific path of short-term rates that, if rolled over, would just match the return of a single zero-coupon investment out to longer-dated horizons. Here, the 1-year *forward* default rate priced on October 3, 2001 to apply to the 1-year period from October 3, 2002 to October 3, 2003 is 38.3%. This result can be verified by showing the product of the two 1-period discount factors (from δ_1, the initial 1-year rate, and $\boldsymbol{\delta_{1,1}}$, the 1-year *forward* rate beginning 1 year from now) equals the initial 2-year discount factor:

$$\exp(-\delta_1 \, 1) \exp(-\boldsymbol{\delta_{1,1}} \, 1) = P_2 = \exp(-\delta_2 \, 2)$$

$$\exp[(-.507)(1)] \exp[(\mathbf{-.383})(1)] = .411 = \exp[(-.445)(2)].$$

The 1-year-ahead, 1-year forward rate appears in bold and is easily solved for as the calculated rate that equates the returns of the "rollover" and "term investment" strategies.[36] Similar break-even rate calculations would produce the entire path of 1-year forward default rates from the initial term default rates.[37]

The forward default rate of 38.3% calculated above applies to the 1-year period beginning one year in the future. It is significantly lower than the initial 1-year default rate of 50.7%. Within a crisis environment, such an inverted default rate structure makes perfect sense. The market imputes a lower future default rate for this forward period since actually surviving to this specific time interval is conditional on Argentina's ability to successfully avoid an earlier default. Escaping default through to October 3, 2002 (the start of the forward period) would most probably mean some "good news" improving future payment prospects appeared along the way. Figure 4 plots the entire curve of sequential 1-year forward default rates generated by the parameter estimates for this day's closing prices.

Figure 5 plots the estimated payment probability curve as a function of the cash flow payment date. For example, as of October 3rd, market prices imply a 24% chance that Argentina would default on its obligations within six months (from the graph: P[t =

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[36] $\boldsymbol{\delta_{1,1}} = -\ln[\exp(-\delta_2 \, 2)/\exp(-\delta_1 \, 1)] = -\ln[\exp(-[.445][2])/\exp(-[.507][1])] = .383$.

[37] For example, compare the discount factors on 2- and 3-year horizons to compute the 1-year forward default rate beginning in 2 years: $\boldsymbol{\delta_{2,3}} = -\ln[\exp(-\delta_3 \, 3)/\exp(-\delta_2 \, 2)] = -\ln[\exp(-[.409][3])/\exp(-[.445][2])] =$ .337 or 33.7%.

0.5] = .76). The implied default probability for a 1-year horizon is 40% (from the graph: P[t = 1.0] = .60 as previously solved for algebraically).

<insert Figure 5 about here>

For comparative purposes, Figure 5 also plots a *companion* default probability curve derived assuming 0% recovery using the sovereign spreads reported in Table 2.[38] Note that this 0% recovery approach severely underestimates the market's true probability of default. For instance, at the 2.5-year horizon, the 0% recovery approach generates a default probability of 42.5% (given the payment probability of 57.5%). However, using the recovery value-enhanced model, the implied default probability is 65% (payment probability at the 2.5-year horizon is just 35%). At the 10-year horizon, the implied default probability for the recovery value-enhanced model is 97%. For the same horizon, the 0% recovery value approach implies a default probability of just 85.2%.

5. Summary

The explosive growth of sovereign emerging market foreign currency debt issuance in the 1990s has generated substantial interest in the underpinnings of security valuation in these markets. Academic research has expanded rapidly into the emerging markets, especially those for foreign currency debt. For policymakers, the results of this work have been both enlightening and disappointing. In particular, shifts in standard macroeconomic variables – the "fundamentals" – explain very little of the short-run variation in emerging market yield spreads. Shifts in "market sentiment" are seen to account for an outsized component of the emerging market yield spread movements. These findings lead policymakers to focus more attention toward acquiring a clear understanding of the information that bond yield spreads may contain about issuer default prospects.

[38] The spread-based curve of Figure 5 was generated as follows: (1) the sovereign spreads were converted to an annualized basis; (2) a quadratic function in years to maturity was fit via regression; (3) the parameters of the regression were used to generate a smooth set of fitted sovereign spreads for the plotted cash flow horizons; and (4) for each horizon, a payment rate was reverse engineered from equation 3.8 and utilized to calculate a payment probability.

Yield spreads on risky emerging market debt produce important signals regarding the market's consensus of prospective issuer default probabilities. However, these market-based signals are sometimes confusing and need to be interpreted with care. This paper has developed a step-by-step analytical framework to decompose and relate alternative yield spread concepts to the underlying crucial determinants of risky emerging market bond value. The analysis highlights the importance of assumptions regarding default-state recovery value on attempts to interpret yield spreads as signals of issuer default probability. One byproduct of the analysis is an explanation of why stripped sovereign spreads from Brady issues should be larger than the calculated sovereign spreads from the same issuer's Eurobonds (even though both spreads reflect identical default probabilities). The resolution of the apparent puzzle requires the definition of a special "stripped-of-recovery-value" spread.

The importance of default-state recovery value assumptions is stressed in the paper's formal emerging market bond valuation model. This discounted expected cash flow model values the cross-section of fifteen outstanding US dollar-denominated Republic of Argentina Eurobond bonds in the midst of that country's 2001 debt market crisis. Estimates of the market's implied recovery value along with implicit term and forward default rate curves are presented. The results are contrasted with the default probability signals from a standard yield-based sovereign spread analysis. The latter tends to be overly optimistic with regard to implied issuer prospects of avoiding default.

Yield spreads are traditional measures used by policymakers to assess emerging bond market conditions. This paper has highlighted the importance of understanding how the signals provided by yield spreads concerning default probability depend crucially on assumptions about default-state recovery value. In general, the relationships among yield spreads, default probability, and recovery value are quite complex. Bond valuation frameworks such as those examined here offer insight into the nature of these relationships, but, alas, no cures for crises. Nevertheless, policymakers need to understand the lessons of such models in order to accurately read the messages of the market.

Table 1

Recovery value assumption effects on bond values and yields in "normal" and "crisis" periods.

"Normal" market conditions: per period payment probability p = .92

Bond Maturity	R = 0 Value	R = 0 Yield	R=50 Value	R=50 Yield	R= 100: "Brady-type" Value	R= 100: "Brady-type" Yield	Payment Probability Factors p = .92	Risk-free Discount Factors y = 5%
1	96.38	14.13%	100.19	9.79%	104.00	5.77%	0.920	0.952
2	93.21	14.13%	100.18	9.90%	107.14	6.09%	0.846	0.907
3	90.43	14.13%	99.99	10.00%	109.55	6.40%	0.779	0.864
4	88.00	14.13%	99.66	10.11%	111.33	6.68%	0.716	0.823
5	85.86	14.13%	99.22	10.21%	112.58	6.94%	0.659	0.784
6	84.00	14.13%	98.68	10.30%	113.37	7.18%	0.606	0.746
7	82.36	14.13%	98.07	10.40%	113.78	7.40%	0.558	0.711
8	80.92	14.13%	97.40	10.50%	113.87	7.62%	0.513	0.677
9	79.67	14.13%	96.68	10.59%	113.69	7.82%	0.472	0.645
10	78.56	14.13%	95.93	10.68%	113.29	8.02%	0.434	0.614

"Crisis" market conditions: per period payment probability p = .60

Bond Maturity	R = 0 Value	R = 0 Yield	R=50 Value	R=50 Yield	R= 100: "Brady-type" Value	R= 100: "Brady-type" Yield	Payment Probability Factors p = .60	Risk-free Discount Factors y = 5%
1	62.86	75.00%	81.90	34.30%	100.95	8.96%	0.600	0.952
2	41.63	75.00%	70.66	32.08%	99.68	10.18%	0.360	0.907
3	29.50	75.00%	63.37	30.25%	97.23	11.14%	0.216	0.864
4	22.57	75.00%	58.38	28.85%	94.18	11.91%	0.130	0.823
5	18.61	75.00%	54.74	27.81%	90.87	12.57%	0.078	0.784
6	16.35	75.00%	51.92	27.08%	87.49	13.14%	0.047	0.746
7	15.06	75.00%	49.60	26.59%	84.14	13.66%	0.028	0.711
8	14.32	75.00%	47.59	26.30%	80.87	14.15%	0.017	0.677
9	13.90	75.00%	45.80	26.19%	77.71	14.61%	0.010	0.645
10	13.66	75.00%	44.17	26.22%	74.68	15.06%	0.006	0.614

Notes: Computations based on a flat 5% benchmark risk-free yield curve. R assumed paid at bond's original maturity. Payment probability and discount factors reported for individual annual cash flow dates.

Table 2

Republic of Argentina US Dollar Eurobonds

Price date: October 3, 2001 **Settlement date: October 9, 2001**

	Coupon Rate	Maturity Date	Market Price	Accrued Interest	Total Value	Yield	Sovereign Spread
	8.375	12/20/2003	69.50	2.54	72.04	27.80%	2,491
	11.000	12/04/2005	64.50	3.82	68.32	25.26%	2,178
	11.000	10/09/2006	62.50	0.00	62.50	24.38%	2,071
*,#	7.000	12/19/2008	55.63	2.14	57.76	24.96%	2,118
	11.750	04/07/2009	55.50	0.07	55.57	25.26%	2,138
	11.375	03/15/2010	52.75	0.76	53.51	25.09%	2,112
	12.375	02/21/2012	55.25	1.65	56.90	24.37%	2,030
	11.750	06/15/2015	54.00	3.72	57.72	22.79%	1,865
	11.375	01/30/2017	54.00	2.18	56.18	21.85%	1,767
**,#	12.250	06/19/2018	49.00	1.83	50.83	19.57%	1,500
	12.125	02/25/2019	53.50	1.48	54.98	23.10%	1,894
	12.000	02/01/2020	53.50	2.27	55.77	22.79%	1,862
	9.750	09/19/2027	50.50	0.54	51.04	19.45%	1,513
	10.250	07/21/2030	50.50	2.22	52.72	20.35%	1,607
**	12.000	06/19/2031	50.75	1.86	52.61	18.17%	1,346

* Coupon steps up to 15.5% on 6/19/2004.
** Interest capitalizes until 12/19/2006.
\# Sinking fund provisions.

Source: major Wall Street investment bank.

Table 3

Republic of Argentina Eurobonds: market vs. model values

Price date: October 3, 2001 **Settlement date: October 9, 2001**

Coupon Rate	Maturity Date	Market Value	Model Value	Difference
8.375	12/20/2003	72.04	68.82	3.22
11.000	12/04/2005	68.32	65.19	3.13
11.000	10/09/2006	62.50	59.55	2.95
7.000	12/19/2008	57.76	58.37	-0.61
11.750	04/07/2009	55.57	57.65	-2.09
11.375	03/15/2010	53.51	56.89	-3.38
12.375	02/21/2012	56.90	58.87	-1.97
11.750	06/15/2015	57.72	59.11	-1.39
11.375	01/30/2017	56.18	56.75	-0.57
12.250	06/19/2018	50.83	48.09	2.74
12.125	02/25/2019	54.98	57.54	-2.56
12.000	02/01/2020	55.77	57.99	-2.22
9.750	09/19/2027	51.04	51.81	-0.77
10.250	07/21/2030	52.72	54.37	-1.65
12.000	06/19/2031	52.61	47.45	5.17
		Average Difference:		0.00
		Standard Deviation:		2.67

Model parameter estimates:

R	34.33	Implied recovery ratio
α_0	0.3108	Long-run forward rate
α_1	0.3097	Short-run forward rate deviation

Figure 1: EMBI stripped sovereign spreads
(December 1990 - December 2001)

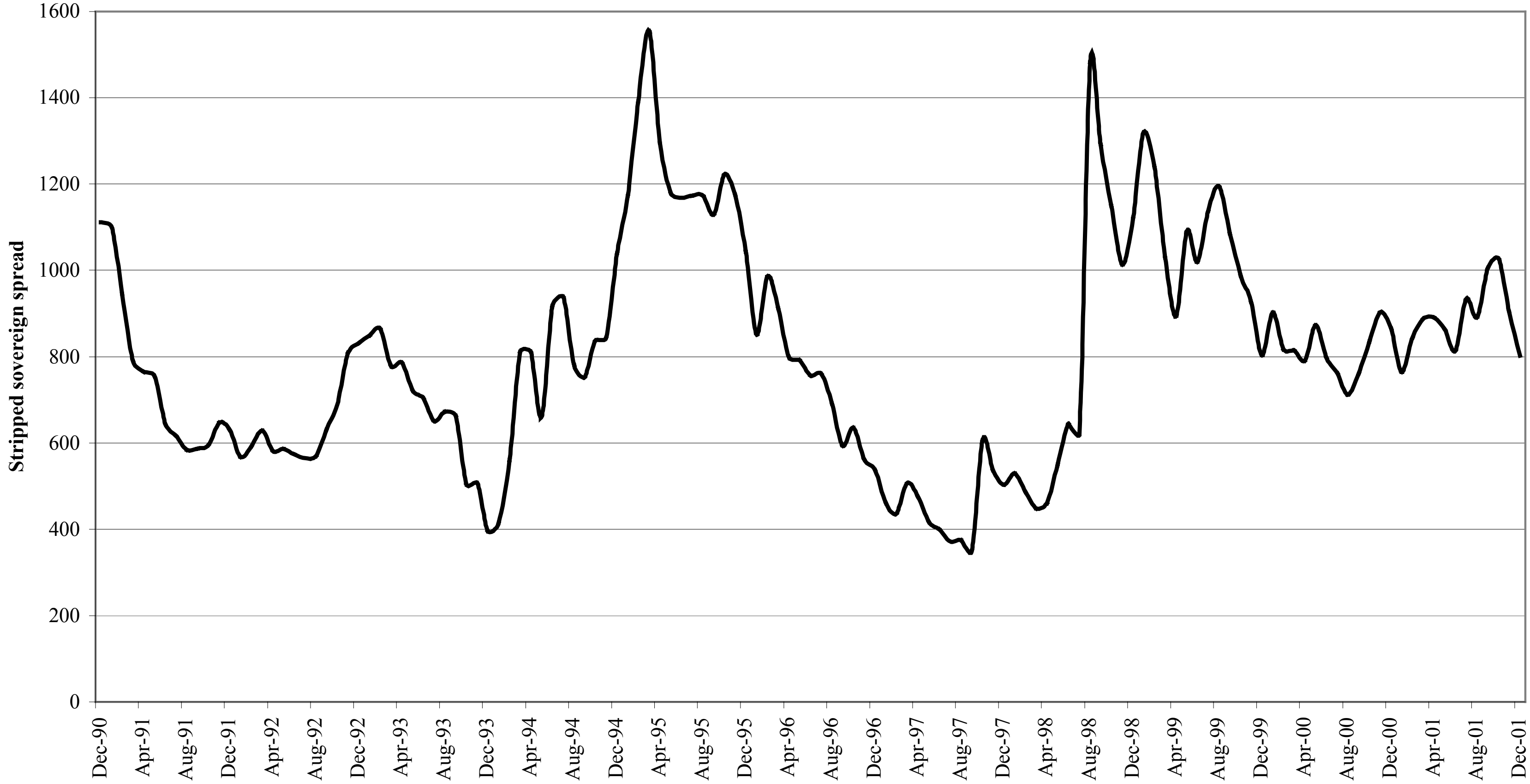


Figure 2: EMBI stripped spreads vs. US Treasury bill yields
(Scatter chart: December 1990 - December 2001)

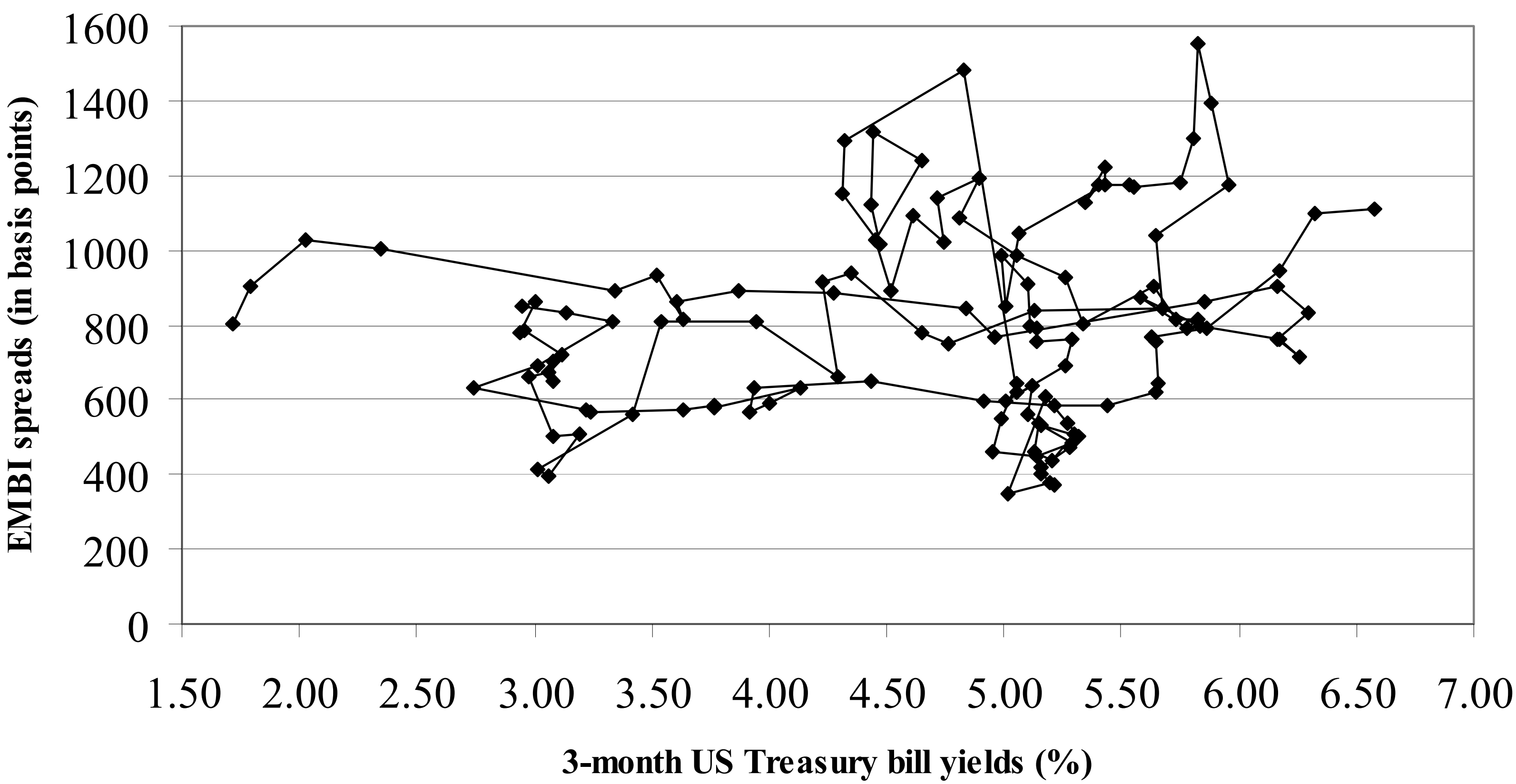


Figure 3: Price History of Argentina '27s (9.75% 9/19/2027)

Figure 4: Implied term and forward default rates on Argentine Eurobond cash flows
Estimated from recovery value-enhanced model
Price date: October 3, 2001

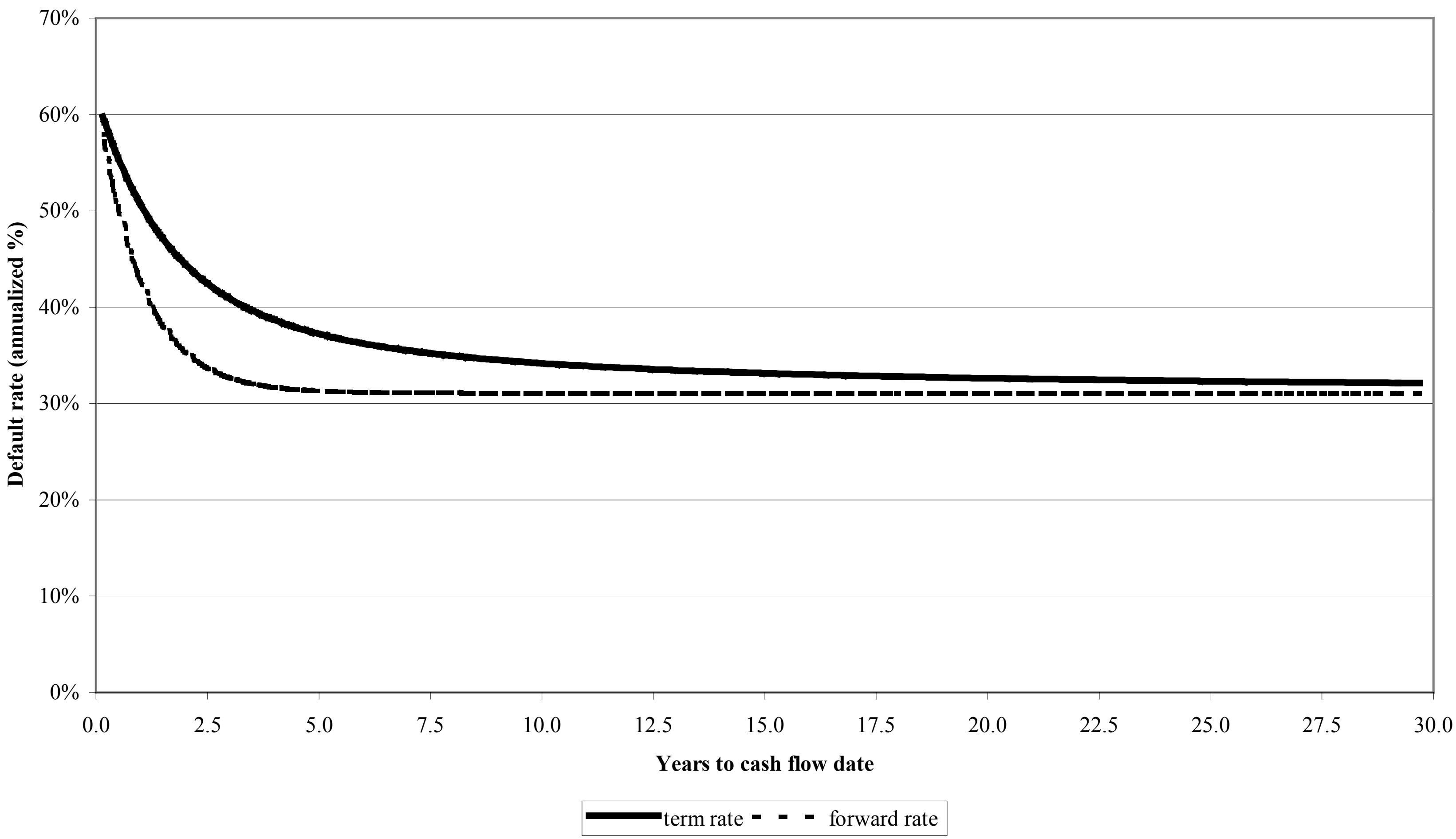
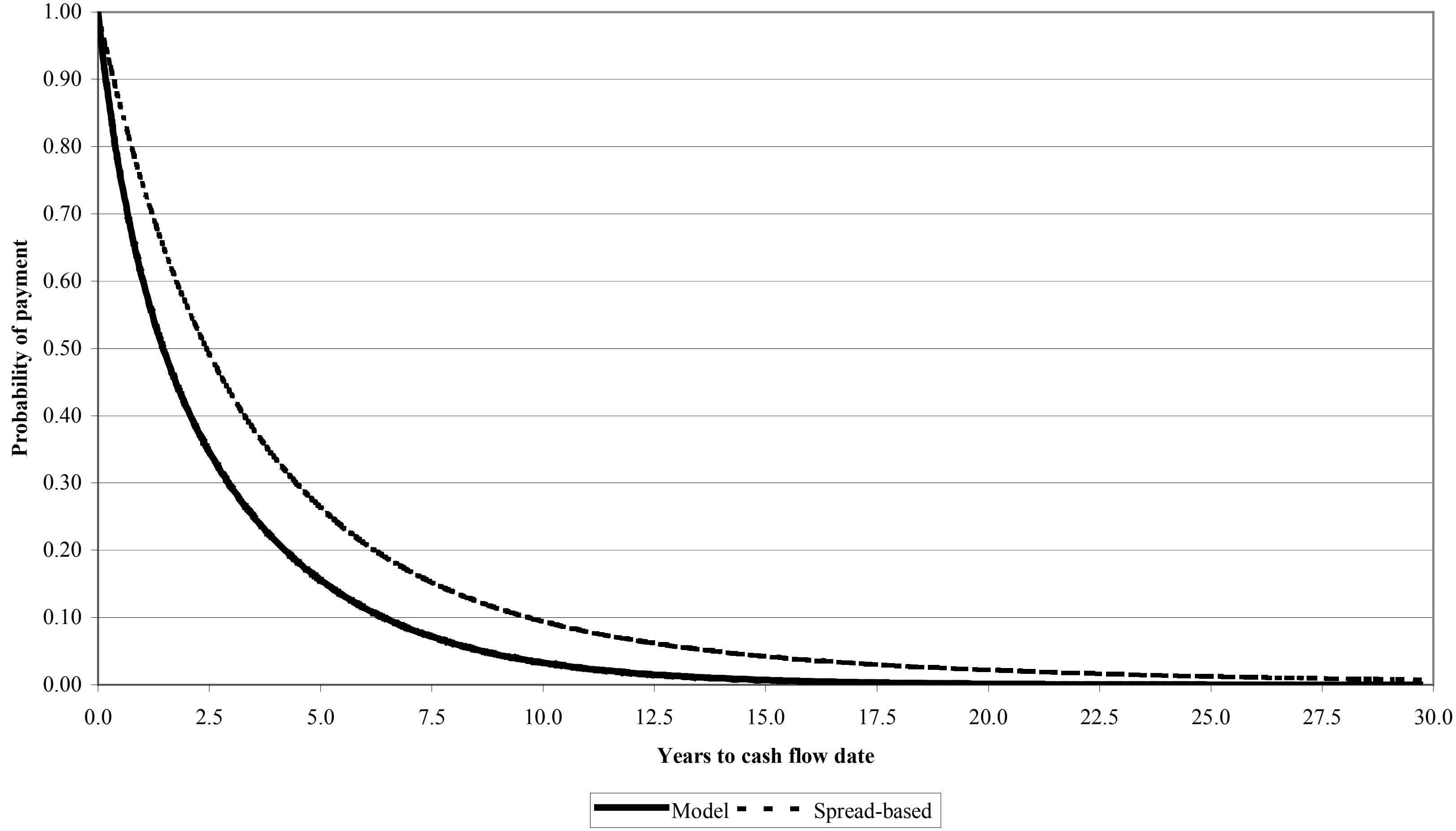


Figure 5: Argentine Eurobond implied cash flow payment probabilities:
Recovery value-enhanced model vs. yield spread-based approach
Price date: October 3, 2001



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Glossary

A bond's *yield-to-maturity* is the investor's internal rate of return computed from the bond's current market value using its promised future cash flows.

A *yield spread* measures the difference in quoted yields on two bonds. The spread can be used in either arithmetic: $s = Y - y$ or multiplicative form: $1+s = [1+Y]/[1+y]$).

The bond's *initial offering spread* or *issuance spread* reflects its yield spread at the time of issue.

The bond's *secondary market spread* reflects its yield spread as it trades in the market any time after being issued.

Brady bonds were created in the 1990s as part of the debt restructurings of defaulted emerging market sovereign loans. A key component of the Brady bond structure was that each issue is partially collateralized by zero-coupon US Treasury bonds. Typically, the zero-coupon Treasury collateral covers the entire principal amount and a rolling portion of the remaining coupon interest.

A Brady bond's *stripped sovereign spread* is the yield spread on the uncollateralized component of the issue's cash flow stream (computed after subtracting out the value of the collateralized payments).

A *bond indenture* is the legal agreement explaining the specific obligations of the issuer and the rights of the bondholder.

Collective action clauses enable a qualified majority of bondholders to modify key financial terms of the bond indenture and to impose such decisions on all other holders.

Recovery value is the percentage of bond face value that an investor recoups after a issuer's default. A 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 recovery value is the ratio of the involuntarily exchanged new security's market value relative to the face value of the original debt.

Implied recovery value is the parameter from a specific discounted cash flow model estimated for a daily cross-section of an issuer's bonds that measures the recovery value investors are using to price the market.

Risk-neutral valuation implies that the term structure of risk-free interest rates were used to discount the expected value of a bond's future cash flows.

A bond's *blended yield* is the internal rate of return on the bond using cash flows with different default exposures.

A *blended spread* is a yield spread based upon a blended yield.

The *stripped-of-recovery-value* spread is the yield spread on the default-exposed component of the issue's cash flow stream (computed after subtracting out the present value of the assumed recovery value).

The *equivalent martingale measure* is the adjusted probability distribution that, in a risk-neutral world, results in the same discounted expected cash flow value as the true objective probability distribution.

A *cross-default* provision in an indenture places the bond in default if its issuer defaults on another linked issue.

The *default rate* expresses the default probability on a bond's cash flow t-periods in the future as a per period percentage rate.

A *forward default rate* expresses the default probability on a bond's cash flow during a specific future time interval as a per period percentage rate.

A *sinking fund agreement* is the bond indenture mandates that the issuer retire the debt issue in scheduled stages prior to the actual maturity date.

The coupon rate on a *step-up bond* is scheduled to increase from an initial ("low") rate to a new higher level after a set number of periods.

A bond with *interest capitalization* pays no coupons for a set number of initial periods but instead increases the bond's par value by an amount equivalent to the interest otherwise earned.