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Abstract

While there is significant interest in investing in Brady bonds, the source of attraction is often the exposure to sovereign risk (and its yield compensation), while the exposure to U.S. interest rate risk is a "necessary evil". This paper addresses the problem of determining the interest rate sensitivity of Brady debt. We show that the most relevant state variables in determining the duration of a Brady bond are U.S. interest rates and the bond's strip spread. Motivated by the difficulty of using structural models to price and hedge Brady debt, we provide a model-free approach to estimating the hedge ratio. Using our approach to hedge the Argentinian Par and Discount Brady bonds, we find that only a small fraction (15% or so) of the total risk is hedgeable, but our hedged portfolio exhibits little covariation with U.S. interest rates.

1 Introduction

Brady bonds are sovereign debt issued to replace commercial bank loans made to developing countries over the past two decades.[1] This emerging market debt, which includes debt of Argentina, Brazil, and Mexico, among many others, has several unique features. First, some of the bonds are highly liquid, giving investors the opportunity to invest in sovereign credit. Second, the majority of the Brady bonds are denominated in U.S. dollars, and, credit risk aside, are therefore closely related to fixed and floating rate U.S. government debt. Third, most of the Brady Bonds include some type of credit enhancement, usually in the form of the entire principal and some interest payments being collateralized by zero coupon U.S. Treasury securities.

To the extent that there are ample opportunities to invest in U.S. government debt, the primary reason for the success of the Brady bond market is the opportunity to invest in the sovereign debt of emerging markets. Thus, isolating the sovereign component of Brady bonds by hedging out the U.S. interest rate risk of these bonds is especially important to market participants (see Telljohann (1994)). Informal evidence for the appetite investors have for securities which afford liquid sovereign risk without the U.S. interest rate risk can be found in (i) the common practice of "stripping off" Brady bonds (i.e., shorting the guaranteed component), and (ii) the enthusiasm which met the recent plan by the Mexican government for swapping Brady bonds for purely sovereign debt. This lack of appetite for U.S. interest rate risk is not surprising since most financial institutions and pension funds consider this risk systematic, while the sovereign risk is often considered non-systematic. Hence, there is a significant interest in understanding, quantifying and hedging the interest rate risk of Brady bonds.

In the case of a fixed-rate Brady bond, estimating the bond's interest rate sensitivity involves knowledge of both the bond's characteristics (e.g., maturity, coupon and any embedded options) and the level of interest rates. It is important to note, however, that even if interest rates are independent of the Brady bond's default rate, hedging the *interest rate* risk of the Brady bond requires additional information regarding default probabilities. This result is true even in the simple world of a flat term structure and an equal probability of default each period. In fact, it is possible to show that, under these assumptions, the

[1]Since 1990, a substantial number of Brady bonds have been issued, with billions of dollars in principal currently outstanding. Brady bonds get their name from the then Secretary of the Treasury Nicholas Brady, who emphasized a market-based approach in providing a plan for reducing emerging market debt.

Macaulay duration of the bond not only changes as the default probability increases, but that this change may be positive or negative, depending on the coupon, the interest rate level, and the default probability.

In order to understand the intuition, consider separating the Brady bond into a guaranteed component (collateralized with the appropriate zero coupon U.S. Treasury securities) and a non-guaranteed component. Suppose, for simplicity, that there is no upfront coupon guarantee (i.e., only the terminal face amount is guaranteed to be paid at maturity, independent of a default event occurring). As the probability of default increases, the non-guaranteed component's duration decreases as earlier coupons start to dominate later ones. At the same time, the share of the defaultable part in the whole declines. In contrast, the guaranteed component's share increases as more weight is given to the collateralized piece of the bond. The overall effect on duration is ambiguous and results in a complex relation between the Brady bond's price and its time-varying determinants, i.e., interest rates and default probabilities.

Given the current values of these determinants, one could dynamically adjust a hedged position by duration matching using, say, T-note futures — thus, completely isolating the Brady bond from *instantaneous* interest rate risk. The problem with this approach is that the assumptions underlying these theoretical duration measures are generally poor (see Cumby and Evans (1995) and Nadler, Tsoucas and Wierzynski (1996)). The goal of this paper is to develop a different approach for hedging Brady bonds using interest-rate instruments, such as T-note futures. The idea is to estimate a conditional hedge ratio between returns on a Brady bond and returns on T-note futures. The hedge ratio is conditional in the sense that we account for relevant current information. This is important for Brady bonds because, as interest rates and default rates change, the interest rate sensitivity of Brady bonds will change in a highly nonlinear fashion. In order to estimate this conditional hedge ratio, a structural model is usually required (as with most fixed-income valuation approaches). Unfortunately, this requirement involves making a number of assumptions on the underlying processes which may or may not be reasonable.

In this paper we take an empirical approach to estimating a conditional hedge ratio for Brady bonds using T-note futures. We take a stand only on what the relevant state variables are, namely, the level of interest rates and the strip spread, but not on the precise functional form of their relation to duration. We first record in sample results which show that the conditional hedge ratios of both fixed and floating Brady debt exhibit state-sensitivity. However, the empirical form of sensitivity we uncover is difficult to interpret given our priors. We then implement an out-of-sample experiment, in which we reestimate the hedge ratio

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using a moving window of past data, and compare various methods. We show that there is some, albeit limited advantage, to the use of conditioning information, relative to a simpler procedure of reestimating the hedge ratio repeatedly, but without any conditioning on state variables. We interpret these results as a reasonable outcome of the fact that our conditioning state variables are highly persistent. Overall, we find that only a small fraction of the volatility of Brady bonds can be hedged away, and most of the volatility (practically all, for the case of the Brady floater) is asset-specific.

The paper proceeds as follows. In Section 2 we provide a simple theoretical model which gives us the basic intuition as to how a Brady bond's duration will depend on the relevant state variables, namely, the level of U.S. interest rates and the probability of default. We also outline the hedging methodology, and how we go about estimating empirical conditional hedge ratios. In Section 3 we provide a description of the data and results. Section 4 concludes.

2 The Hedging Methodology

2.1 Theoretical Background

How sensitive are Brady Bond returns to interest rate changes?

To gain some intuition, consider a simple economy in which there is a flat term structure with interest rate r and a constant probability of default p (with no recovery). A fixed-rate bond paying a coupon C with underlying principal F has a present value equal to

$$V = \sum_{t=1}^{T} \frac{C(1-p)^t}{(1+r)^t} + \frac{F(1-p)^T}{(1+r)^T}. \tag{1}$$

The Macaulay duration of the bond is given by the usual formula, i.e.,

$$D_{mac} \equiv -\frac{\partial V/V}{\partial r/1+r} = \sum_{t=1}^{T} \frac{\mathrm{PV}_t(C)}{V}\, t \; + \; \frac{\mathrm{PV}_T(F)}{V} T, \tag{2}$$

where $\mathrm{PV}_t(\cdot)$ equals the present value of the cash flow in period t, adjusted for the probability of default. Thus, the Macaulay duration is simply a value-weighted sum of the maturities of the bond's cash flows. Both high interest rates and a high probability of default tend to substantially lower the present value of payoffs further in the future, thus reducing the duration of the bond. In fact, changes in the probability of default have much the same effect as interest rate changes, so that the standard convexity results follow.

Although Brady bonds face default, part of their cash flows are generally collateralized by U.S. Treasuries. For example, it is standard to guarantee the principal, and sometimes the more immediate coupon payments (usually 12-18 months worth), using U.S. Treasury strips. As an illustration, consider a fixed-rate bond with guaranteed principal. The valuation equation analogous to equation (1) is

$$V = \sum_{t=1}^{T} \frac{C(1-p)^t}{(1+r)^t} + \frac{F}{(1+r)^T}. \tag{3}$$

Note that the present value of the principal payment no longer depends on the default probability. Consequently, as the probability of default changes, the Macaulay duration of the bond changes in an indeterminate manner. Specifically, taking the derivative of the duration with respect to p, and rearranging some terms, we find that

$$\frac{\partial D_{mac}}{\partial p} = \frac{1}{1-p} \sum_{t=1}^{T} (tD_{mac} - t^2) \times \frac{\mathrm{PV}_t(C)}{V}. \tag{4}$$

A few comments are in order. Because the principal component in this example is guaranteed, it drops out of equation (4). Thus, unlike a non-guaranteed bond, the Macaulay duration of the bond may increase or decrease as the default probability changes. For example, as the default probability increases, the bond's earlier coupon payments tend to take on a greater proportion of the bond's present value relative to the later coupon payments, and duration falls. On the other hand, the guaranteed principal component also becomes more important, thus increasing the bond's duration. Of course, in the extreme case of default being close to a probability one event, the Macaulay duration is just the maturity of the principal. Equation (4) shows that the sensitivity of duration to increases in the default rate is high and positive in this case. These fairly complex relations between a Brady bond's price and Macaulay duration and both the level of interest rates and default probability are graphed in Figures 1 and 2. In contrast to the convexity of straight fixed-rate bonds, the duration of a Brady bond varies substantially over default rates (see Figure 1A). The interaction between default probabilities and interest rate levels suggests that the shape of a Brady bond's convexity (i.e., its duration sensitivity to interest rates) depends on the probability of default (Figure 1B).

The above discussion considers a fixed rate Brady bond. However, a number of existing bonds offer floating rates. It is well known that floating rate bonds are relatively insensitive to interest rate changes, as long as the probability of default is not correlated with interest rates. Here, the guaranteed component of Brady bonds dramatically changes this result. As the probability of default increases, only the duration of the guaranteed component matters; thus, in the above example, the Macaulay duration is the maturity of the bond's principal. Therefore, in contrast to the fixed rate bond, the duration of the floating rate note can vary from six months to thirty years, depending on the likelihood of a default. Consequently, hedging floating rate Brady bonds may require substantial positions in the bond market, a vastly different result than one would normally find.

2.2 Methodology

Since the interest rate sensitivity of Brady bonds changes with both the term structure of interest rates and the term structure of default probabilities, it is crucial to take these into account when forming the hedged position. The problem of implementing this hedged position is substantial. Specifically, the assumptions of a flat term structure and constant default probability are clearly inconsistent with the data. While models have been developed which generalize this base case (see, for example, Cumby and Evans (1995)), these models involve strong parametric assumptions. Thus, the results can be difficult to interpret to the extent that these models are *forced* to fit the current interest rate and default probability environment.

An alternative method is to allow the model to have more flexibility and to take an empirical approach to estimating the hedge ratio. The difficulty is that, as we have seen, this hedge ratio varies substantially with important economic variables, such as interest rate levels and default probabilities. Thus, standard regression-based hedges will not be sufficient. Here, we take a different approach towards estimating the conditional hedge ratio. Using estimates of conditional comovements between Brady returns and the hedging instrument, we estimate the conditional hedge ratio directly. That is, we estimate the conditional relation between the rate of return on a Brady and the return on, say, a T-note futures, conditional on relevant information available at any point in time. Suppose we are given T observations, $\mathbf{z}_1, \mathbf{z}_2, ..., \mathbf{z}_T$, where each $\mathbf{z}_t$ is an m-dimensional vector. Specifically, let $\mathbf{z}_t \equiv (R^B_{t,t+j}, R^{TN}_{t,t+j}, \mathbf{x}_t)$, where $R^B_{t,t+j}$ and $R^{TN}_{t,t+j}$ are the j-day returns on the Brady bond and T-note futures, respectively, and $\mathbf{x}_t$ is an $(m-2)$-dimensional vector of relevant factors known at time t. Given the discussion in Section 2.1, two prime candidates for the $(m-2)$-dimensional set of variables are the current level of interest rates and some measure of the probability of default (such as the strip spread between the Brady bond's yield on the non-guaranteed portion and U.S. Treasury rates).

There are a variety of methods for calculating the conditional relation between Brady bond returns and the hedging instrument. In particular, we want to estimate the conditional mean, $\mathrm{E}[R^B_{t,t+1}|R^{TN}_{t,t+1},\mathbf{x}_t]$, i.e., the expected Brady return given movements in the T-note return, conditional on the current economic state as described by $\mathbf{x}_t$. While there are a number of parametric and nonparametric techniques for estimating conditional means, consider one in particular based on standard regression methods:

$$R^B_{t,t+1} = \alpha + \beta_t R^{TN}_{t,t+1} + \epsilon_{t,t+1}. \tag{5}$$

One way of estimating β_t is through a Taylor series expansion, that is, $\beta_t = g(i_t, s_t, \tau)$ where i_t is the current interest rate level, s_t is the strip spread, and τ is time-to-maturity. Equation (5) can then be estimated using multivariate linear regression methods.

The interpretation of equation (5) is simple and intuitive. To see this, first consider an empirical duration method in which the Brady bond return is regressed on the T-note futures returns — thus, the hedge ratio is the resulting state independent β coefficient. That is, the hedge ratio is constructed by taking pairs of past Brady and T-note returns, and then equally weighting these pairs' comovements (in this case, by the variability of the T-note futures return). The problem with this approach is that all observations get equal weight. Thus, in estimating the hedge ratio today, comovements between Brady and T-note returns in high interest rate or high default probability environments get the same weight as in low interest rate or low default probability environments. A static hedge ratio, of course, is not appropriate for hedging Brady bonds.

The dynamic hedging strategy outlined above also has a clear interpretation. The state-dependent hedge ratio, β_t, is estimated by taking past pairs of Brady and T-note futures returns, and then differentially weighting these pairs' comovements depending on the co-relations between $R^B_{t-i,t+j-i}$, $R^{TN}_{t-i,t+j-i}$ and economic information $\mathbf{x}_{t-i}$. Equation (5) is similar in spirit to a regression hedge, except that the weights are no longer constant, but instead depend on current information. The idea behind this estimation is that these weights are not estimated in an ad hoc manner, but instead depend on the true (albeit estimated) relation between the relevant variables. Our approach has a clear advantage over the regression hedge. The hedge ratio in equation (5) explicitly takes into account the current economic state. For example, if interest rates are currently high, but the default probability is low, then more weight will be given to past comovements between Brady and T-note futures returns in those states. Thus, the hedge ratio adjusts to current economic conditions.

Note that equation (5) provides a formula for the hedge ratio between an investor's Brady position and T-note futures. For example, if $\beta_t \equiv \frac{\partial \mathrm{E}[R^B_{t,t+j}|R^{TN}_{t,t+j},\mathbf{x}_t]}{\partial R^{TN}_{t,t+j}}$ equals 0.5, then for every $1 of a Brady bond held, the investor should short $0.50 worth of T-note futures. This hedge ratio will change dynamically, depending on the current economic state described by $\mathbf{x}_t$. In our specific example, the hedge ratio should change in response to changes in the interest rate level and the probability of default.

3 Empirical Analysis

3.1 Data Description

In this paper, we employ several data sources over the period July 1992 to March 1996: (i) Brady bond prices of the Argentinian Par bonds (fixed rate) and the Argentinian Discount bonds (floating rate) from a major investment bank in the emerging markets area, cross-checked with prices from Datastream,[2] (ii) strip spreads for both of these bonds from the same investment bank, and (iii) 10-year T-note futures prices and various term structure information, including the 3-month, 1-year, 5-year and 10-year yields from Datastream.

With respect to the Brady bond data, we collected daily data on two Argentinian bonds: (i) the dollar denominated, $12.7 billion 30-year Par bond, with fixed rates building up to 6%, and principal and 12 months coupon interest guaranteed by U.S. Treasury strips, and (ii) the dollar denominated, $4.3 billion 30-year Discount bond, with an floating rate of LIBOR plus 0.8125%, and principal and 12 months coupon interest (at 8%) guaranteed by U.S. Treasuries. Both bonds mature on March 31, 2023. (For more information please see *The Emerging Market Handbook* by Chase (1995).)

U.S. interest rates and futures returns are taken from Datastream. Specifically, the one-year and ten-year rates are daily fixed-maturity series, compiled by the Federal Reserve Board of Governors. The ten-year T-note futures return series is a series of nearest to maturity futures, spliced at the last day of the month prior to the expiration month to avoid liquidity-related effects. The maturity effect in the futures contracts (which are issued in a three month cycle) may cause a seasonal pattern in the data, although this effect is secondary.[3]

[2]We chose Argentinian bonds for illustration and for their relatively high liquidity. Results for other bonds and other sovereigns are available.

[3]A simple way to see this is by considering the corresponding forward contract, which is, essentially, a long position in a long bond financed by a short position in a short bond (for a long futures position). The first order effect on changes in this forward/futures price will be due to changes in the long rate due to its

While the Brady market is extremely liquid, data concerns related to nonsynchronous quotes across the markets can be somewhat alleviated by using a longer measurement period. Throughout the paper we analyze weekly returns, which strike a reasonable compromise between measurement issues and the relatively small size of our data sample. We use overlapping data in order to use all available information, and where necessary, we adjust for the overlap.

Table 1 provides basic summary statistics for our dataset. During the sample period (October 15, 1992 to February 22, 1996), there was an average weekly gain in both the Par and the Discount bonds of 0.23% and 0.12%, respectively. Some of this return can be attributed to the decline in U.S. interest rates, and the rest to an improvement in the perceived credit worthiness of Argentina's debt.

The standard deviations of returns on both bonds are approximately 3.4% per week, about four times larger than the volatility of the corresponding T-note futures contract (with a return standard deviation of 0.84% per week). These standard deviations give us a preview of the results to follow, namely, that most of the variation in Brady bond prices will not be explained by variation in U.S. Government bond returns or related derivatives. To see this, we simply need to recognize that the typical asset underlying a T-note futures contract is a par coupon-bearing U.S. government bond, with cash flows which are fairly similar to the *promised* cash flows of the Argentinian Par bond. However, this Brady bond is much more volatile, and its correlation with the T-note futures contract is only 0.46. At the same time, the Argentinian Par bond is as volatile as the Argentinian Discount bond, and the correlation between the two Brady bonds is 0.83. This immediately indicates that sovereign risk is causing most of the variation, not dollar interest rate risk.

The volatility of Brady bond returns over our sample period can be largely attributed to the events that took place at the end of 1994. The collapse of the Mexican Peso, and with it the decline in the perceived credit worthiness of Mexican sovereign and Brady debt, had large spillover effects throughout South America. Specifically, during the half year surrounding the collapse of the Mexican Peso (most of which occurred during last weeks of 1994 and January 1995), the credibility of the Argentinian Peso's peg to the dollar became doubtful. The resultant impact on Argentinian Brady bonds was due to a perceived increase in the default probability. This is apparent in Figure 3, which depicts the path of the strip spreads of the Argentinian Par and Discount bonds.[4] The strip spread rose from about 6% prior

much higher duration.

[4]The strip spread is obtained in the following manner. Using a zero curve imputed from prices of U.S.

to the event, to an average level of over 12%, with strip spreads as high as 20% or more at times.

3.2 Empirical Findings

As noted in Section 2.1, there should be a link between the duration of a Brady bond and the default probability of that bond. The results in Section 2.1 were developed in a simple model with flat term structures of default probabilities and interest rates. Reality, however, presents a much richer environment. The approach taken in this paper allows for nonlinear patterns, as described in Section 2.2 above.

The premise of the paper is that in estimating the duration of Bradys we may confine our attention to a limited set of state variables, namely, default probabilities and U.S. interest rates. We further assume that these state variables can be proxied for by two factors: the ten-year U.S. government par yield, and the strip spread.

To get some intuition for the extent to which these *a priori* chosen factors play a role in determining Brady bonds' duration, and in what way, we start by estimating nonparametrically the *realized duration* of the Argentinian Par and Discount bonds within our sample. Specifically, for each bond we divide the sample into four subsamples, depending jointly on whether the ten-year U.S. interest rate was above or below its realized mean, and whether the strip-spread was above or below its mean (the state variables and the low/high states appear in Figure 3). We then estimate the state-dependent conditional variances of Brady bond returns and the percentage change in the ten-year U.S. rate, and their conditional covariance. This set of estimates allows us to obtain an empirical estimate of the Macaulay duration, conditional on the joint state.

Tables 2A and 2B provide the results for the conditional duration calculations for the Argentinian Par and Discount Brady bonds, respectively. The tables also contain information regarding the probability of each of the states occurring, and the conditional return correlation in these states. We find extreme state-sensitivity of the bonds' duration to the state variables. This is especially vivid in the case of the Discount bond (the floater). Specifically,

government bonds, the guaranteed payments of a given Brady bond are stripped off. The strip spread is then the difference between the default-free yield on the promised payments, and the defaultable yield given the value of the stripped bond. Some subtle issues arise with respect to the proper calculation given the rolling guarantee, which gives rise to some differences in strip spread calculations across methods. Irrespective of the method of calculation, however, the strip spread is the single best summary statistic for the market-perceived average default probability throughout the remaining life of the Brady bond.

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the duration varies from 13.86 in the high interest rate and high spread state, to 0.87 in the low interest rate and high spread state.

These results are extremely puzzling. Recall that our intuitive prediction was particularly strong with respect to the floater. At low spreads (and hence low default probability states), we expect the floater to be a low duration asset, just like a default-free floater should be. On the other hand, at high spreads (high default probability states) we expect the guaranteed part to dominate and cause an extension of the duration to, at the limit of actual default, a duration which is the maturity of the floater.[5] Interestingly, the results are unstable across two even-length subperiods (available upon request). While in the first subperiod the reversal is even more pronounced, in the latter subperiod, extending from July 1994 to February 1996, we obtain results which are consistent with our priors. Specifically, at high spreads the duration is 12.3, while at low spreads it is 5.5. On the one hand these are encouraging results because the second subperiod is one where the spread exhibited significant variation, and default probabilities could be thought of as high. On the other hand we have a very limited sample size, with highly correlated state variables. Also, the second subperiod results do not explain the failure to obtain meaningful results for the entire sample. Similarly puzzling results appear in the case of the Par bond, where for low interest rates, for example, we would expect a duration extension going from low to high spreads within the relevant ranges of data we have in our sample (see Figure 1A and 1B).

Given these puzzling results, we are only encouraged by the fact that our state variables were able to uncover state-dependence of the Bradys' duration, and hence may serve as useful conditioning state variables in determining the conditional hedge ratio. One possible interpretation of the results is the presence of a missing state variable, which is proxied for

[5]This "back of the envelope" calculation ignores the rolling upfront guarantee. We can get an idea of the relative effect of this upfront guarantee in a simple numerical example. Suppose the current term structure is flat with an interest rate of 6%. The present value of the $100 guarantee in thirty years is $\$100/(1.06^{30}) = \$17.41$. The rolling guarantee in the case of the Argentinian Brady Discount bond provides rolling collateral for two semi-annual coupon payments at an interest rate of 8%. Its present value is approximately $7.66. The duration would then be

$$\frac{17.41}{17.41+7.66} * 30 + \frac{7.66}{17.41+7.66} * .75 = 20.8 + 0.2 = 21.$$

Generally, at very high default probabilities the duration should be inversely related to the interest rate level. The prediction of a duration extension of Brady floaters in the event of default (and hence in the high default probability state) is, however, robust to the interest rate environment and the number of upfront guaranteed coupons within any reasonable range.

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by our state variables, and which has the opposite effect to our theoretical predictions.

3.3 Out-of-Sample Hedging

In this section we provide the results from a rolling out-of-sample hedging experiment, as outlined in Section 2.2 above. Specifically, for every date in our sample starting from the 251st date onward, we use the previous 250 observations (approximately one year of trading data) on Brady returns and T-note futures returns in order to determine the appropriate hedge ratio based on the covariance and variances of the variables. We also determine a state-dependent hedge ratio, which depends on the strip spread, the yield of the ten-year U.S. government par bond, and the Brady's time to maturity. We do so repeatedly using the 250-day window until the last day in our sample.

We experiment with a number of specifications for the functional form and the relevant conditioning variables in estimating the conditional hedge ratio, β_t. Our benchmark is a state independent (although not time invariant) hedge ratio, which is estimated repeatedly but without any conditioning on the relevant state variables. We then assume that the function $\beta_t = g(i_t, s_t, \tau)$ is a linear function of these variables, and consider hedging first using i_t only, then adding s_t to the set of conditioning information, and last, the time to maturity τ. We also allow for nonlinearities by considering a second order Taylor expansion on the most interesting set of conditioning information, namely i_t and s_t. This expansion involves the addition of squared and interaction term of these variables (three additional variables in total) to the original set of two conditioning variables.

Tables 3A and 3B document results for the Par and Discount Brady bonds respectively. For each of the hedging procedures considered we provide two summary statistics. First we document the volatility of the returns on a hedged portfolio which involves a long position in the relevant Brady bond, hedged by the appropriate short position in ten-year T-note futures. The goal is to minimize the volatility of hedged returns. The second statistic is the correlation coefficient between hedged returns and the contemporaneous change in the ten-year rate. Since our experiment is conducted as an out-of-sample experiment, we are not guaranteed orthogonality between the hedging errors and interest rate changes. As pointed out in the introduction, one might consider the ability to hedge a *specific* source of risk, interest rate risk in our case, important.

With respect to hedging the Par bond, the total unhedged standard deviation of returns is 3.68% per week, and the correlation between returns and interest rate changes is -0.56.

These numbers correspond closely, although not exactly, to the numbers in Table 1, due to the "missing" 250 days upfront in the results of this section. The standard error using the state independent hedging method is reduced to 3.09%, and the correlation is reduced to -0.10. With respect to the state-dependent hedge ratio results, the results overall can be considered disappointing. Using the ten-year rate as a single conditioning variable yields a standard deviation of 3.14% and the correlation of hedging errors with interest rate changes is -0.01. On the positive side, conditioning on the level of interest rates reduces whatever correlation with interest rate changes was left over from the unconditional hedge. This comes at the cost of increasing the variability of hedged returns.

Adding the spread to the set of conditioning information should, according to our theory, help to pin down the appropriate duration/hedge ratio. Indeed this bivariate hedge does yield the lowest return volatility (3.087%), but the improvement is hardly significant from an economic perspective. A Taylor expansion of the two-variable conditioning set provides no benefit, and, in fact, increases the return volatility (3.28%). This latter result is simply an artifact of estimation error, exacerbated by the highly volatile spread.

The results for the Discount bond are worse. There is very little, if any, reduction in the return volatility, and the only reduction is in the correlation coefficient between hedged returns and interest rate changes. This outcome would not be too surprising if the default probability was very low, since a default-free floater should exhibit very little volatility. However, the magnitude and variation of the strip spread suggest that conditioning on this variable should produce a viable hedge. Consequently, the empirical results are disappointing.

The results for both the Par and the Discount bonds are qualitatively robust to (i) the length of conditioning period, (ii) the hedging horizon, (iii) the specific subperiods, and (iv) the addition of the one-year U.S. interest rate to the set of conditioning variables. We also experimented with smoothing methods, which allow the state-dependent hedge ratio to vary more "sluggishly". Specifically, we considered an exponentially smoothed hedge ratio, with various smoothing parameters. Another refinement which we considered was the use of Stein Estimators.[6] The results were not remarkably different for either of these attempted improvements.

[6]Stein Estimators are also known as "shrinkage" estimators. They adjust for the signal to noise ratio by appropriately shrinking the hedge ratio. Stein estimators are often used by practitioners in the context of fixed income securities hedging and portfolio analysis (for a technical discussion see Judge et al (1985)).

4 Conclusion

The empirical results in the last section, and their weak link to the theory, illustrate the difficulty in hedging Brady bonds. From an asset pricing perspective the results pose a challenge, and perhaps an opportunity. They call for a further investigation of the appropriate missing variables and/or trading opportunities.

From a practical standpoint, the results in this paper provide one way to interpret the seemingly myopic hedging approach common to practitioners. It is quite common for investors to simply strip off the Brady bond's guaranteed component by taking a short position in a set of zeros corresponding to the set of guaranteed payments. Given our results, such a myopically hedged position would come close to being a pure "sovereign play".

The results in this paper also have interesting implications from a risk management perspective. They demonstrate the weak link which some dollar denominated bonds may have to the returns on U.S. government bonds. (The high yield debt area may provide similar results.) We show that only 20-40% of the variation in Brady prices can be attributed to changes in dollar discount rates. Such low explanatory power has meaningful implications for the appropriate *Value at Risk* numbers of trading groups and some financial institutions with high stakes in any one specific market.

Table 1
Summary Statistics

Table 1 provides summary statistics regarding the Argentinian Par and Discount Brady bonds, and relevant state variables. Return data are for weekly changes, overlapping daily. The sample period is 10/15/1992 to 2/22/1996. The variables are: $Di^l_{t,t+5}$ the weekly change in the ten-year U.S. par yield, $R^f_{t,t+5}$ the return on ten-year T-note futures, i^s_t the one-year U.S. par yield, i^l_t the ten year U.S. par yield, $R^{par}_{t,t+5}$ the return on the Brady Par bond, s^{par}_t the Brady Par bond strip spread, $R^{dis}_{t,t+5}$ the return on the Brady Discount bond, s^{dis}_t the Brady Discount bond strip spread.

	$Di^l_{t,t+5}$	$R^f_{t,t+5}$	i^s_t	i^l_t	$R^{par}_{t,t+5}$	s^{par}_t	$R^{dis}_{t,t+5}$	s^{dis}_t
Mean	-0.004	0.033	4.824	6.495	0.227	8.780	0.122	8.733
Std. Dev.	0.126	0.842	1.230	0.740	3.386	3.103	3.430	3.207
$Di^l_{t,t+5}$	1.000	-0.943	-0.094	-0.082	-0.493	-0.240	-0.235	-0.238
$R^f_{t,t+5}$	-0.943	1.000	0.093	0.082	0.461	0.225	0.222	0.225
i^s_t	-0.094	0.093	1.000	0.705	-0.051	0.523	-0.081	0.603
i^l_t	-0.082	0.082	0.705	1.000	-0.100	0.238	-0.127	0.276
$R^{par}_{t,t+5}$	-0.493	0.461	-0.051	-0.100	1.000	0.210	0.830	0.198
s^{par}_t	-0.240	0.225	0.523	0.238	0.210	1.000	0.121	0.983
$R^{dis}_{t,t+5}$	-0.235	0.222	-0.081	-0.127	0.830	0.121	1.000	0.147
s^{dis}_t	-0.238	0.225	0.603	0.276	0.198	0.983	0.147	1.000

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Table 2
Conditional Duration

Tables 2A and 2B provide the realized conditional Macaulay duration, for high and low strip spreads and interest rates, for the Argentinian Par and Discount Bradys, respectively. The tables also contain information regarding the probability of each of the states occurring, and the conditional correlation between Brady returns and interest rate changes in these states.

Table 2A
The Argentinian Par Bond

Probability			
	s_t Low	s_t High	Uncond'l
i_t Low	30.884	23.881	54.765
i_t High	22.044	23.192	45.235
Uncond'l	52.928	47.072	100.000

Duration			
	s_t Low	s_t High	Uncond'l
i_t Low	15.537	11.572	13.750
i_t High	11.973	13.755	12.964
Uncond'l	13.941	12.241	13.293

Correlation			
	s_t Low	s_t High	Uncond'l
i_t Low	-0.640	-0.546	-0.602
i_t High	-0.555	-0.326	-0.422
Uncond'l	-0.601	-0.385	-0.493

Table 2B

The Argentinian Discount Bond

Probability			
	s_t Low	s_t High	Uncond'l
i_t Low	32.032	22.732	54.765
i_t High	27.669	17.566	45.235
Uncond'l	59.701	40.299	100.000
Duration			
	s_t Low	s_t High	Uncond'l
i_t Low	9.441	0.874	5.581
i_t High	4.524	13.865	7.472
Uncond'l	6.928	5.520	6.405
Correlation			
	s_t Low	s_t High	Uncond'l
i_t Low	-0.457	-0.039	-0.263
i_t High	-0.253	-0.255	-0.230
Uncond'l	-0.355	-0.147	-0.235

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Table 3
Hedging

Tables 3A and 3B document hedging results for the Par and Discount Brady bonds respectively, using ten-year T-note futures contracts. Out-of-sample hedging errors are analyzed for the hedge regression

$$R^B_{t,t+5} = \alpha + \beta_t R^{TN}_{t,t+5} + \epsilon_{t,t+5}.$$

At any given date starting the 251st date, the previous 250 daily observations are used for estimation. The hedge ratio β_t is allowed to depend linearly or nonlinearly on conditioning information. Two summary statistics are recorded: (i) hedged return volatility, and (ii) ex post correlation of the hedging error with changes in the ten-year par yield.

Table 3A
The Argentinian Par Bond

	Unhedged	Conditioning Information				
		None	i^l_t Linear	i^l_t, s_t Linear	i^l_t, s_t Taylor	i^l_t, s_t, τ Linear
$\sigma(\epsilon_{t,t+5})$	3.676	3.092	3.136	3.087	3.275	3.094
$\rho(\epsilon_{t,t+5}, Di^l_{t,t+5})$	-0.556	-0.104	-0.010	0.096	0.096	0.018

Table 3B
The Argentinian Discount Bond

	Unhedged	Conditioning Information				
		—	i^l_t Linear	i^l_t, s_t Linear	i^l_t, s_t Taylor	i^l_t, s_t, τ Linear
$\sigma(\epsilon_{t,t+5})$	3.797	3.659	3.714	3.626	3.823	3.617
$\rho(\epsilon_{t,t+5}, Di^l_{t,t+5})$	-0.296	-0.045	-0.010	0.155	0.101	0.079

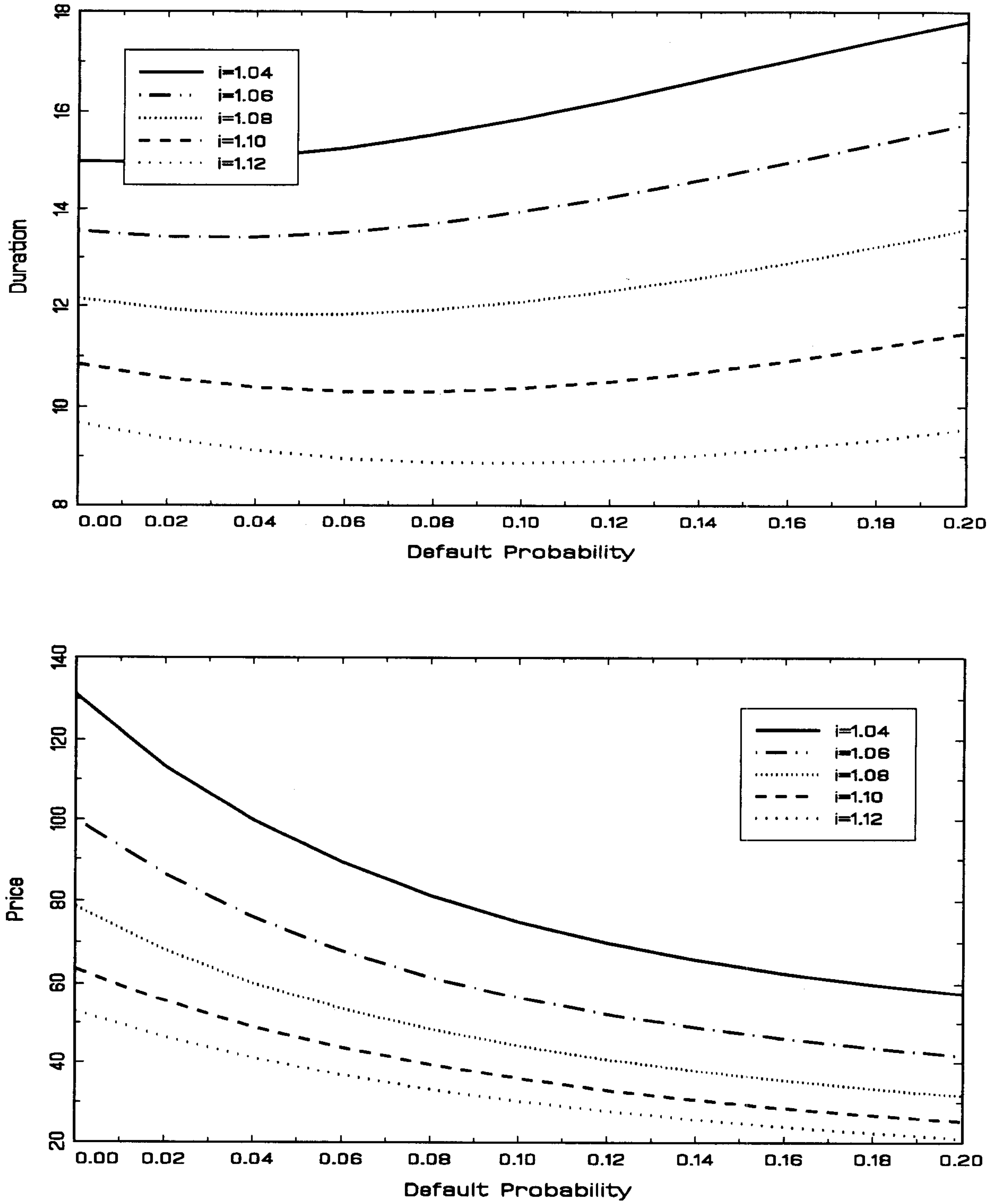

Figure 1: The prices and durations of a 6% Brady with annual coupon payments, thirty years to maturity, and a face amount only guarantee. Both the term structures of interest rates and default probabilities are assumed to be flat.

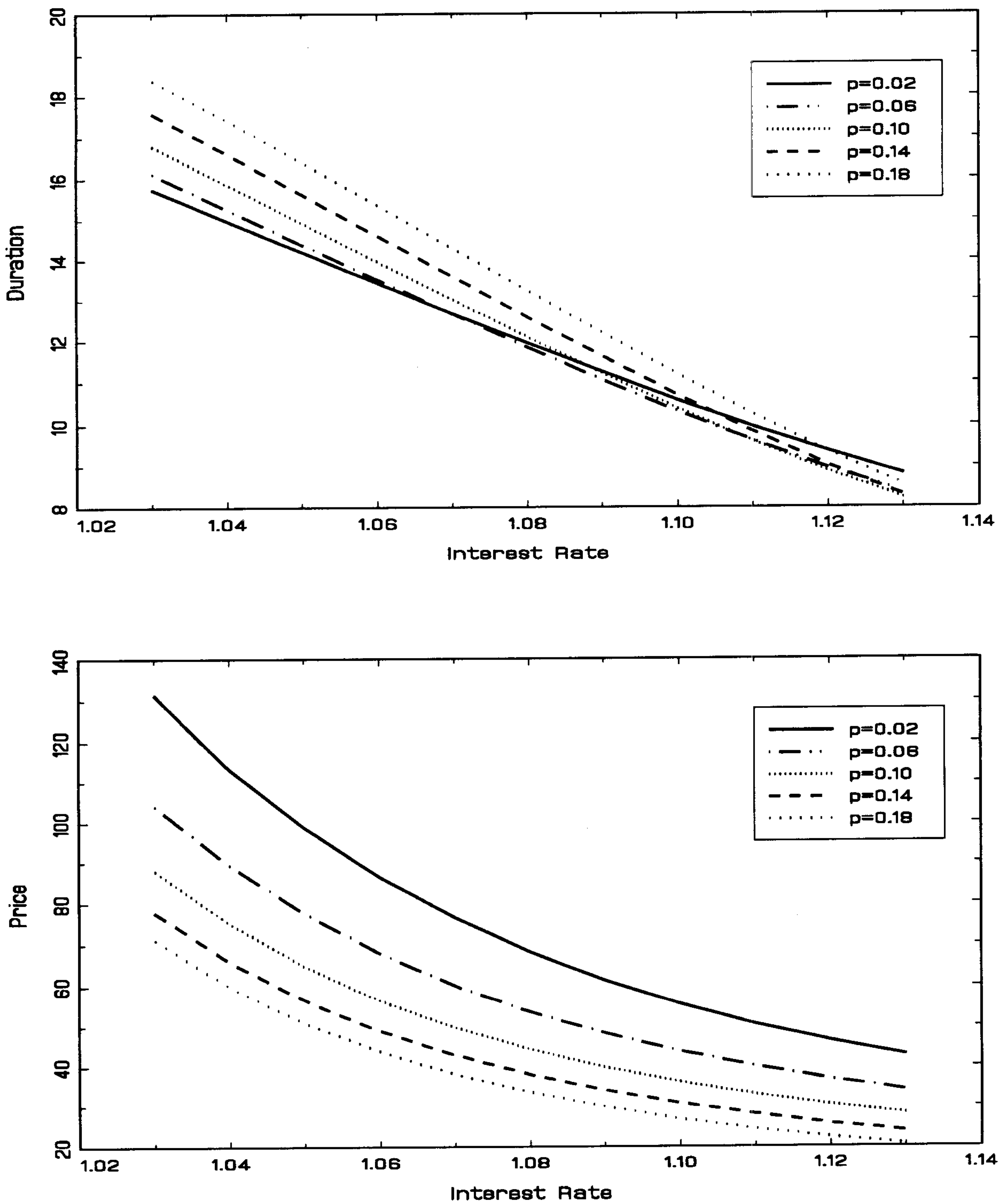

Figure 2: The prices and durations of a 6% Brady with annual coupon payments, thirty years to maturity, and a face amount only guarantee. Both the term structures of interest rates and default probabilities are assumed to be flat.

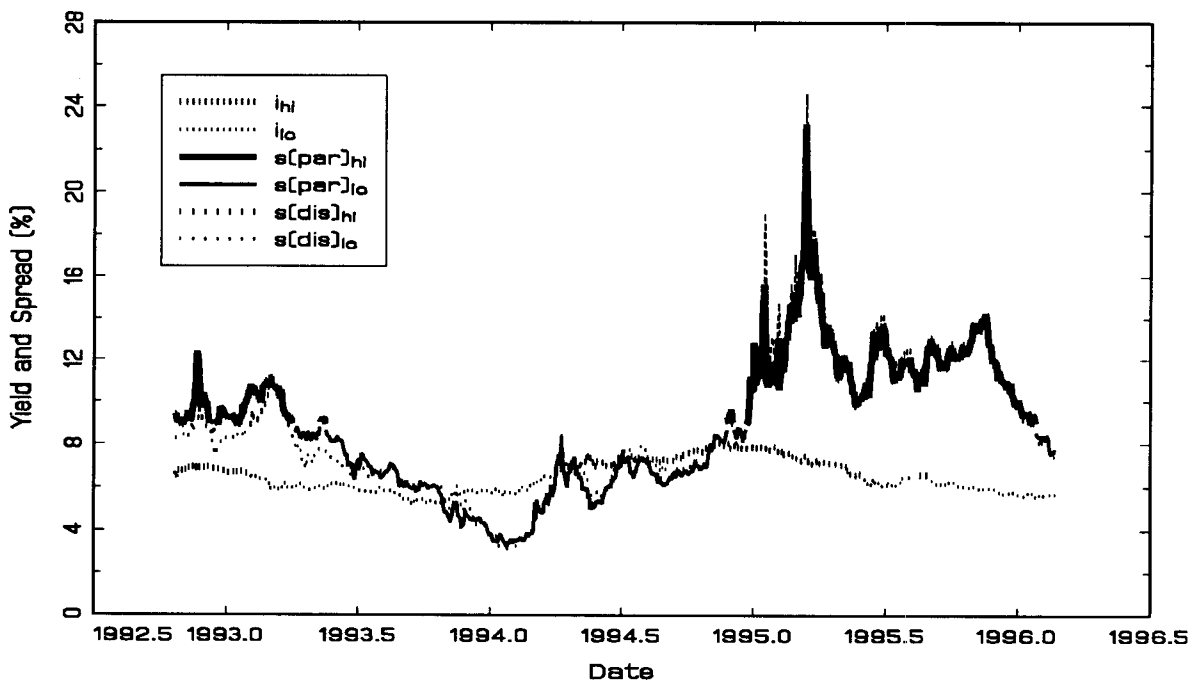

Figure 3: The strip spreads on Argentinian Par and Discount Brady bonds and the ten-year U.S. Government par yield. The thick lines denote that the series is above its sample mean.

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